

**Plenary I: Friedlander Lecture**

**Nanocarbon in Flames: From Unwanted Particulate Emissions to Useful Materials.** HAI WANG, *Stanford University*

Formation of particulate carbon is ubiquitous in many combustion and flame phenomena. Particulate carbon formed in flames or emitted from combustion sources is usually in the form of an aerosol. As a byproduct of combustion, particulate carbon or soot is a major source of air pollutants. Its emission is responsible for a wide range of human health problems. Soot emission is also a major cause of uncertainties in modeling global climate change. On the other hand, particulate carbon has a very long history as a useful material. It found its use prehistorically in cave paintings and provided the black pigment for India ink as early as the Neolithic age. Today, the same versatile material finds myriad uses, from rechargeable batteries as a chemically resistant electrical conductor to fuel cells as a cathode catalyst or catalyst support. This talk aims to provide an overview of the relationship between the properties of carbon particles and conditions of flames in which they are generated. It will provide an in-depth discussion about the reaction mechanism and kinetics of carbon formation in flames.

**Plenary II**

**Optical Characterization of Atmospheric Aerosols: From Fundamental Electromagnetism to Satellite Missions.** MICHAEL I MISHCHENKO, *NASA Goddard Institute for Space Studies*

The strong influence of tropospheric and stratospheric aerosols on the environment, as well as on the global and regional climates, is well recognized. This explains the utmost scientific and societal importance of detailed and accurate knowledge of physical and chemical properties of these particles. More often than not it is impracticable to collect actual aerosol samples and subject them to a laboratory test. Therefore, in most cases one has to rely on theoretical analyses of in situ and/or remote-sensing measurements of light scattered by aerosol particles. Fortunately, certain scattering properties of small particles can exhibit a strong dependence on the particle microphysics and composition. This factor makes measurements and analysis of electromagnetic scattering an extremely useful and often the only practicable means of physical and chemical particle characterization. Addressing growing ecological and climate-change concerns requires the development and application of remote-sensing instrumentation and data analysis methodologies enabling accurate characterization of key components of the exceedingly complex atmospheric environment. The accumulated body of evidence shows that addressing this challenging task requires the following: (1) The development of measurement concepts that provide adequate sensitivity to specific macro- and microphysical parameters of atmospheric particulates and their composition. These concepts must be based on modern physics of light-matter interactions; the broadest possible spectral range extending from near-UV to near-IR wavelengths; the use of all four Stokes parameters of the detected radiation rather than just the first one (intensity); and active as well as passive observation strategies. (2) The development of advanced physically-based retrieval algorithms fully accounting for the extreme morphological complexity of the vast majority of aerosol and cloud particles. (3) Synergistic use of ground-based, aircraft, and satellite instrumentation and data.

**Plenary III****Electronic Cigarettes: Evidence, Uncertainty and Policy.**  
JONATHAN SAMET, *University of Southern California*

Over a five-year span, use of electronic cigarettes (e-cigarettes), which deliver an aerosol generated by a battery-powered vaporizer, has rapidly increased, particularly among adolescents and young adults. Because e-cigarettes can deliver nicotine without the combustion-generated carcinogens and toxins of tobacco smoke, they have been proposed as potentially useful for harm reduction, if substituted for conventional cigarettes. However, the potential for harm reduction needs to be balanced against the potential for e-cigarettes to increase nicotine addiction among adolescents and young adults, to reduce cessation among cigarette smokers, and to “renormalize” use of tobacco products. With the Food and Drug Administration poised to take regulatory authority over e-cigarettes under the Family Smoking Prevention and Tobacco Control Act, the public health impact standard of the Act becomes relevant—that is, what is the overall public health impact of availability of e-cigarettes? This presentation addresses the evidence needed to gauge the public health impact of e-cigarettes and the use of models to estimate the balance between potential harms and benefits. Research to generate the needed evidence is challenged by the highly dynamic pattern of use of tobacco products subsequent to the addition of e-cigarettes to the marketplace. Models must project future scenarios of use that are quite uncertain. Nonetheless, policies are being developed at local, state, and national levels that draw on the limited evidence available and the application of principles of risk management. Research targeted at key uncertainties and careful surveillance are requisite in order to maintain the evidence base needed to minimize public health impact.

**Plenary IV: AEESP Lecture****Fire Aerosols: Exceptionally Common.** CHRISTINE  
WIEDINMYER, *National Center for Atmospheric Research*

Fire emissions and the downwind chemistry in and out of biomass burning plumes degrade air quality, impact regional climate, and contribute to negative human health outcomes. Fires, and specifically the burning of biomass, produce aerosols from incomplete combustion processes and contribute substantially to the global atmospheric burden of carbonaceous aerosol in terms of both mass and number. These fire aerosols are ubiquitous in the atmosphere and have been identified at all scales from the indoor environment to the stratosphere. Despite great advances in the ability to identify and quantify emissions from biomass burning, the techniques used to predict emissions and understand their fate and transport in the atmosphere are uncertain, and the subsequent estimates of the impacts are difficult to assess. Global change driven by climate, policy, and social behaviors alter fire activity and its impacts. Quantification of the feedbacks and interactions between fire activity and global change remain critical open questions. This presentation will detail efforts to identify and quantify biomass burning emissions across scales, and highlight their importance and confounding factors in air quality, health, and climate impact assessments.

**1AC.1**

**Linking the Formation of Dimeric Compounds and Organic Peroxides in the  $\alpha$ -pinene Ozonolysis System.** RAN ZHAO, Yuanlong Huang, Christopher Kenseth, Kelvin Bates, Rebecca Schwantes, Paul Wennberg, John Seinfeld, *California Institute of Technology*

The identity and formation mechanism of high molecular weight organic compounds (e.g. dimers) and organic peroxides (ROOHs) in secondary organic aerosol (SOA) arising from  $\alpha$ -pinene ozonolysis remain missing aspects to complete our understanding of the  $\alpha$ -pinene ozonolysis reaction system. Formation of dimers and ROOH have each received much attention separately, but little is known about the links between the two. Certain types of dimers and organic peroxides (e.g. peroxyhemiacetals, diacylperoxides) can be overlapping compounds arising from common formation mechanisms. In this study, we investigate the formation of dimers and ROOHs arising from  $\alpha$ -pinene ozonolysis using a laminar flow tube reactor, the Caltech Photo-Oxidation Tube (CPOT), as well as the 24 cubic meter Caltech chamber. The CPOT maintains a strict laminar flow and well-controlled temperature/RH conditions, facilitating a systematic investigation of the yields of dimers and ROOHs under a variety of experimental conditions. The chamber experiments represent more ambient-like conditions and provide temporal profiles of dimers and ROOHs. Offline samples are collected from the CPOT and the chamber via filter collection and particle-into-liquid sampling (PILS), respectively. Dimeric compounds in the offline samples are analysed by Ultra Performance Liquid Chromatography Electrospray Ionization Time-of-flight Mass Spectrometry (UPLC/ESI-Q-TOFMS). ROOH concentrations are analyzed by potassium iodide (KI) assay and a high performance liquid chromatography (HPLC) – fluorescence technique. The KI assay determines the total organic peroxides, and the HPLC-fluorescence technique separates and quantifies  $H_2O_2$ , with the difference of the two techniques representing the ROOH concentrations. The correlations between dimers and ROOHs are evaluated for the first time, and possible formation mechanisms of dimers and ROOHs are discussed based on the observed trends.

**1AC.2**

**Influence of Seed Aerosol Surface Area and Oxidation Rate on Vapor-Wall Deposition and SOA Mass Yields: A case study with  $\alpha$ -pinene Ozonolysis.** THEODORA NAH, Renee McVay, Xuan Zhang, Christopher Boyd, John Seinfeld, Nga Lee Ng, *Georgia Institute of Technology*

Laboratory chambers, invaluable in atmospheric chemistry and aerosol formation studies, are subject to particle and vapor wall deposition, processes that need to be accounted for in order to accurately determine secondary organic aerosol (SOA) mass yields. We studied the influence of seed aerosol surface area and oxidation rate on SOA formation in  $\alpha$ -pinene ozonolysis. The observations are analyzed using a coupled vapor-particle dynamics model to interpret the roles of gas-particle partitioning (quasi-equilibrium vs. kinetically-limited SOA growth) and  $\alpha$ -pinene oxidation rate in influencing vapor wall deposition. SOA growth rate and mass yields are found to be independent of seed surface area within the range of seed surface area concentrations used in this study. This behavior arises when the condensation of SOA-forming vapors is dominated by quasi-equilibrium growth. Faster  $\alpha$ -pinene oxidation rates and higher SOA mass yields are observed at increasing  $O_3$  concentrations for the same initial  $\alpha$ -pinene concentration. When the  $\alpha$ -pinene oxidation rate increases relative to vapor wall deposition, rapidly produced SOA-forming oxidation products condense more readily onto seed aerosol particles, resulting in higher SOA mass yields. These results indicate that the extent to which vapor wall deposition affects SOA mass yields depends on the particular VOC system, and can be mitigated through the use of excess oxidant concentrations.

**1AC.3****Chemical Characterization of Secondary Organic Aerosol from Oxidation of Isoprene Hydroxyhydroperoxides.**

Matthieu Riva, Sri Hapsari Budisulistiorini, Yuzhi Chen, Zhenfa Zhang, Avram Gold, Joel A. Thornton, Manjula Canagaratna, JASON SURRETT, *University of North Carolina at Chapel Hill*

Atmospheric oxidation of isoprene under low-NO<sub>x</sub> conditions leads to the formation of isoprene hydroxyhydroperoxides (ISOPOOH). Subsequent oxidation of ISOPOOH produces largely isoprene epoxydiols (IEPOX), which are known secondary organic aerosol (SOA) precursors. Although SOA from IEPOX has been previously investigated, systematic studies of SOA formation through a non-IEPOX route from ISOPOOH oxidation are lacking.

In the present work, SOA formation from the oxidation of authentic 1,2-ISOPOOH under low-NO<sub>x</sub> conditions was systematically examined with varying seed aerosol compositions and relative humidity in an indoor smog chamber. Chemical characterization of SOA was investigated using ultra performance liquid chromatography coupled to electrospray ionization high-resolution quadrupole time-of-flight mass spectrometry (UPLC/ESI-HR-QTOFMS) and gas chromatography interfaced with electron ionization mass spectrometry (GC/EI-MS) with prior trimethylsilylation. High yields of highly oxidized compounds, including multifunctional organosulfates (OSs) and hydroperoxides, were chemically characterized in both laboratory-generated SOA and fine aerosol samples collected from the southeastern U.S. IEPOX-derived SOA constituents were observed in all experiments, but their concentrations were only enhanced in the presence of acidified sulfate aerosol, consistent with prior work. High-resolution aerosol mass spectrometry (HR-AMS) reveals that 1,2-ISOPOOH-derived SOA formed through non-IEPOX routes exhibits a unique mass spectrum with a characteristic fragment ion at  $m/z$  91. This laboratory-generated mass spectrum is strongly correlated with the 91Fac recently resolved by positive matrix factorization (PMF) of Aerosol Chemical Speciation Monitor (ACSM) data collected in areas dominated by isoprene emissions, suggesting that ISOPOOH oxidation could contribute to ambient SOA measured in the southeastern United States.

**1AC.4****Thermal Decomposition of Organic Species from Biogenic Secondary Organic Aerosol in Thermal Desorption**

**Instruments.** HARALD STARK, Laxmi Narasimha Yatavelli, Samantha Thompson, Jordan Krechmer, Joel Kimmel, Brett Palm, Weiwei Hu, Patrick Hayes, Douglas Day, Pedro Campuzano-Jost, Manjula Canagaratna, John Jayne, Douglas Worsnop, Jose-Luis Jimenez, *CIRES, University of Colorado*

The chemical composition of secondary organic aerosol (SOA) is crucial to the understanding of the formation and processing of this important particle class. Between 1,000 and 10,000 different molecules can be found in a typical aerosol sample from biogenic origin. Identification of these molecules and estimation of their volatilities is important to quantify the total amount of SOA produced.

We will present results from a high-resolution chemical ionization time-of-flight mass spectrometer (HRTof-CIMS), operated with two different thermal desorption inlets designed to characterize the aerosol as well as the gas phase chemical composition. We used a micro-orifice volatilization impactor (MOVI) and a filter inlet for gases and aerosols (FIGAERO). The data were collected during two field campaigns, BEACHON-RoMBAS in a Ponderosa pine forest in Colorado in the summer of 2011 and SOAS in a mixed forest in Alabama in the summer of 2013.

Volatility distributions derived from the signal vs. temperature profiles (thermograms) show much lower volatilities than those estimated from a functional group contribution method (SIMPOL) based on the detected molecular formulas. We interpret those differences as being due to large fractions of the compounds present in aerosols undergoing thermal decomposition upon heating in the instruments. The estimated impacts on volatility of different possible decomposition processes such as decarboxylation, dehydration or fragmentation are examined. We show that the results from the thermogram method are consistent with those obtained using thermal denuders combined with high-resolution aerosol mass spectrometer (AMS) data. Our findings indicate that many commonly used thermal desorption methods might lead to inaccurate results in terms of the identification of molecules present in SOA. Further, the onset of thermal decomposition at moderate temperatures might have implications for the thermal stability of the aerosols and could also give insights into the chemical processes occurring inside the particles.

**1AC.5****Highly Oxidized Multifunctional Compounds in Oxidation of Aromatics; a Step Forward in Understanding Urban SOA.**

OLGA GARMASH, Matti Rissanen, Oskari Kausiala, Iida Pullinen, Sebastian Schmitt, Thomas F Mentel, Astrid Kiendler-Scharr, Jürgen Wildt, Einhard Kleist, Mikko Sipilä, Markku Kulmala, Mikael Ehn, *University of Helsinki*

Aromatic compounds are thought to be one of the main precursors of secondary organic aerosol (SOA) in urban areas. In previous studies, discrepancies in SOA yields from oxidation of aromatic compounds have been observed. The aim of this study was to connect the gas-phase chemistry to the formation of SOA from aromatics by measuring the selected oxidation products; more specifically, highly oxidized multifunctional compounds (HOM). Measurements were conducted at the Jülich Plant Atmosphere Chamber (JPAC) where benzene oxidation was studied and in the flow-tube at the University of Helsinki where the formation of HOM in the oxidation of several aromatics (benzene, toluene and naphthalene) was investigated. The gas-phase HOM were detected using a Chemical Ionisation Atmospheric Pressure interface Time-of-Flight mass spectrometer (CI-API-TOF, Tofwerk AG). In JPAC, aerosol seed experiments were performed where 100nm monodisperse ammonium sulphate (AS) aerosol was added to the chamber. The chemical composition of the particles was measured by a High-Resolution Time-of-Flight Aerosol Mass Spectrometer (HR-TOF-AMS, Aerodyne Inc.). We have identified over 100 different HOM monomers and dimers with more than six oxygen atoms from oxidation of aromatics. The identified HOM were observed for the first time and are not represented by existing chemical oxidation pathways. We determined the HOM molar yield from the benzene-OH reaction to be on the order of 4%, which is similar to that found for alpha-pinene oxidation by ozone. The slight deviation in HOM molar yield as a function of oxidation conditions may explain the SOA yield discrepancies observed in previous studies. In presence of seed particles, rapid decrease of most gas-phase HOM was observed, though some HOM with five oxygen atoms stayed constant, which is indicative of different volatilities of the products.

**1AC.6****Enhancements in Secondary Organic Aerosol Formation in the Presence of Ambient or Directly Emitted Organic Particles.**

JIANHUAI YE, Paul Van Rooy, Cullen Adam H., David R. Cocker III, Arthur Chan, *University of Toronto*

Secondary organic aerosol (SOA) produced from atmospheric oxidation of organic vapors, comprises a large fraction of ambient particulate matter. Currently, SOA modeling typically assumes that all organic species form a well-mixed phase. Oxidation products are assumed to partition into primary organic aerosol (POA) similarly as into SOA; and it follows that SOA yields (mass of SOA formed per mass of hydrocarbon reacted) must be enhanced in the presence of preexisting organic aerosol. Recently, our study showed that yield enhancements of alpha-pinene SOA were only observed with selected organic aerosol surrogates, such as hexadecanol and tetraethylene glycol. The miscibility of organic species is not ideal, but can be predicted by measures of intermolecular forces, such as Hansen Solubility Parameters.

In this work, the validity of “single phase” assumption is further examined with representative ambient organic aerosol. The enhancements of SOA yields from alpha-pinene ozonolysis are investigated in the presence of organic aerosol collected from emission sources, such as meat cooking, biomass burning and vehicle exhaust, and ambient urban organic aerosol. Hansen Solubility Parameters are used to predict organic miscibility and SOA yield enhancements. Contribution of SOA enhancements from different POA sources will also be discussed. In conclusion, there is a strict mixing criterion for organic aerosol in the atmosphere. Our results will help to provide a better understanding of aerosol mixing and better parameterize SOA formation yields in the atmosphere.

**1AC.7**

**Reaction Pathways, Kinetics, and Equilibria of Multifunctional Hydroperoxides in Secondary Organic Aerosol.** DEMETRIOS PAGONIS, Paul Ziemann, *University of Colorado-Boulder*

Multifunctional hydroperoxides are a significant component of secondary organic aerosol produced in low-NO<sub>x</sub> environments. Products of autoxidation reactions and many proposed structures of extremely low volatility organic compounds (ELVOCs) are thought to be multifunctional hydroperoxides. While knowledge of the sources of multifunctional hydroperoxides has increased in recent years, the fate of these compounds in the atmosphere is still not well understood. Prior work in our lab has shown that particle phase intramolecular and oligomerization reactions are possible for these hydroperoxides, but kinetic and equilibrium data have not been available. In this work we present results of laboratory studies of the reaction pathways of alkoxy hydroperoxyaldehydes, along with measurements of equilibria and constraints for reaction kinetics. We produced these multifunctional hydroperoxides through solution synthesis as well as gas-phase reaction in an environmental chamber. The ability to synthesize these hydroperoxides with high yield allows for utilization of a wide array of analytical techniques, and reaction pathways have been established through thermal desorption particle beam mass spectrometry (TDPBMS), NMR, FTIR and offline iodometric determination of peroxide content. We find that the multifunctional hydroperoxides studied rapidly equilibrate to form peroxyhemiacetals and acetals through unimolecular and bimolecular reactions, and that the equilibria are sensitive to environmental conditions. We also present results on the effects of relative humidity and aerosol acidity on the reactions of multifunctional hydroperoxides to better understand the fates of these compounds in the atmosphere.

**1AP.1**

**Properties of Caesium Hydroxide Clusters from Molecular Dynamics Simulations.** JULIAN THOMPSON, Conor Galvin, Jonathan Barrett, Michael Rushton, Ian Ford, *University College London*

We investigate the nucleation of caesium hydroxide particulates from the vapour by calculating cluster free energies within molecular dynamics. We describe interactions between the caesium and hydroxide ions using screened Coulomb and short-range Buckingham potentials, and consider temperatures where clusters are solid-like and liquid-like. The free energy change associated with the 'mitosis' of a cluster of size  $N$  into two clusters of size  $N/2$  is determined from nonequilibrium molecular dynamics simulations using the Jarzynski equality, and a sequence of such operations enables us to compute the free energy of cluster formation from a given vapour phase [1]. The outcome is compared with the predictions of classical nucleation theory, and with an approximation based on the low temperature harmonic dynamics associated with a solid-like cluster.

[1] G.V. Lau, P.A. Hunt, E.A. Mueller, G. Jackson and I.J. Ford, Water droplet excess free energy determined by cluster mitosis using guided molecular dynamics, *J. Chem. Phys.* 143 (2015) 244709.

**1AP.2**

**A New Frontier of Ion Mobility Calculations; Coupling Molecular Dynamics to Kinetic Theory of Gases.** CARLOS LARRIBA-ANDALUZ, *IUPUI*

Ion Mobility Spectrometry separation is obtained through the different ways charged molecular structures react to being drifted through a medium by means of an electrical field. This reaction is invariably attached to the inference of the collision cross section (CCS,  $\Omega$ ), which in most instances is the value used to obtain mobility diameters for non globular particles. Due to the complexity of the CCS, -which depends strongly on the gas used, temperature, scattering and vibrations of molecular atoms -numerical methods often make use of experimental parameters to obtain simplified models that are in general not accurate for all conditions. The accommodation coefficient often used in the Stokes Millikan approximation is one of such parameters. Here we try to couple Molecular Dynamics to our homemade IMoS software to numerically define some of these parameters. IMoS software mimics the interactions between an all-atom structure and a gas environment. The gas environment is calculated as an undisturbed real gas where densities, concentrations and kinetic velocities, i.e. gas temperature, are taken into consideration. Fluxes of gas molecules then enter the domain of calculation and interact with the traveling molecule exchanging momentum and energy with it. Until now the atoms were kept fixed and a set of parameters, either an accommodation coefficient or gas dependent Lennard-Jones constants, were obtained experimentally. In this work we obtain positions and velocities of the atoms from a Molecular Dynamics (MD) forcefield previously implemented and are used in IMoS to study reemissions. Preliminary Data shows that reemission depends strongly on the interaction between atoms and gas molecules. For Diatomic Nitrogen; reemission direction and velocities depend on the masses and velocities of the colliding atoms and trajectories differ from specular elastic to a more effectively diffuse condition.

**1AP.3**

**Reduced Representation of the Aerosol Mixing State through the Quadrature Method of Moments.** LAURA FIERCE, Robert McGraw, *Brookhaven National Laboratory*

Sparse representations of atmospheric aerosols are needed for efficient regional- and global-scale chemical transport models. Here we demonstrate a new framework for simulation complex aerosol distributions, based on the quadrature method of moments. We show that key features of aerosol populations are captured using quadrature approximations of multivariate moments. Each quadrature consists of a collection of abscissas, or representative particles, and associated weights. Distributions with respect to key aerosol quantities, such as the critical supersaturation for CCN activation or optical cross sections, can be approximately reconstructed using constrained maximum entropy distributions. Unlike the commonly used sparse representations, such as modal and sectional schemes, the maximum-entropy moment-based approach is not constrained to pre-determined size bins or assumed distribution shapes. CCN activity and optical properties from the sparse aerosol simulations are benchmarked against the particle-resolved model PartMC-MOSAIC. This study is a first step toward a new aerosol simulation scheme for large-scale simulations that will track multivariate aerosol distributions with sufficient computational efficiency for large-scale simulations.

**1AP.4**

**Discontinuities in Hygroscopic Growth Below and Above Water Saturation for Laboratory Surrogates of Oligomers in Organic Atmospheric Aerosols.** NATASHA HODAS, Andreas Zuend, Katherine Schilling, Thomas Berkemeier, Manabu Shiraiwa, Richard Flagan, John Seinfeld, *California Institute of Technology*

Organic oligomers are potential sources of viscous atmospheric aerosol components, which may inhibit the mass transport of water and introduce kinetic limitations to hygroscopic growth, particularly at low relative humidity (RH). As water content increases, however, particle viscosity is expected to decrease due to the plasticizing effect of water. To investigate the influence of particle viscosity on water-uptake behavior across the range of RH conditions occurring in the atmosphere, measurements of hygroscopic growth under subsaturated RH conditions and of the CCN activity of laboratory surrogates for oligomers in atmospheric aerosols were conducted.

Experiments were conducted for particles comprised of polyethylene glycol (PEG) with average molecular masses ranging from 200 to 10,000 g/mol, as well as mixtures of PEG with ammonium sulfate (AS). Results were compared with calculations of hygroscopic growth at thermodynamic equilibrium, and the influence of kinetic limitations on observed water uptake was further explored through estimations of water diffusivity in the PEG oligomers. At RH < 100%, we observed little variability in hygroscopic growth across PEG systems; however, increases in CCN activity with increasing PEG molecular mass were observed. This was most pronounced for PEG-AS mixtures, and a modest enhancement in CCN activity was observed for the PEG10,000-AS mixture as compared to pure AS, as evidenced by an 8% reduction in critical activation diameter at a supersaturation of 0.6%. There was no evidence that kinetic limitations to water uptake due to the presence of viscous aerosol components inhibited water uptake at low RH. Discontinuities in hygroscopicity above and below water saturation are attributed to RH-dependent differences in the sensitivity of water uptake to non-ideal interactions between aerosol components and to surface tension effects. This work provides insight into the factors potentially contributing to discontinuities in aerosol water-uptake behavior below and above water saturation observed in the ambient atmosphere.

**1AP.5**

**Physical and Chemical Properties of 3-methyl-1,2,3-butanetricarboxylic Acid (MBTCA) Aerosol.** Evangelia Kostenidou, Eleni Karnezi, Rafal Szmigielski, SPYROS PANDIS, *Carnegie Mellon University, University of Patras*

3-methyl-1,2,3-butanetricarboxylic acid (MBTCA) has been proposed as the most relevant tracer compound for atmospheric terpene secondary organic aerosol (SOA) (Szmigielski et al., 2007). Recently was shown that MBTCA is produced from the oxidation of pinonic acid in the gas phase (Muller et al., 2012). However, the physical and chemical properties of MBTCA aerosol are limited. To our knowledge this is the first time that MBTCA aerosol is studied in an environmental chamber.

Aerosol MBTCA was generated through an atomizer and characterized in the Patras ICE-HT smog chamber. Atmospheric levels of OH radicals were produced by HONO photolysis under UV illumination. An Aerodyne High Resolution Aerosol Mass Spectrometer (HR-AMS) and a Scanning Mobility Particle Sizer (SMPS) measured the particle phase, while a thermodenuder was used for the volatility characterization. The gas phase was monitored by a Proton Transfer Reaction Mass Spectrometer (PTR-MS).

Some of the characteristic m/z's in the HR-AMS mass spectrum were 39, 41, 43, 44, 53, 55, 59, 67, 69, 96, 81, 83, 99, 100, 113, 114, and 141. Even after heating the particles to 120°C for 30 s the mass spectrum remained practically the same ( $\theta < 12^\circ$ ). The fresh MBTCA density was calculated  $1.8 \pm 0.1 \text{ g cm}^{-3}$ . The  $T_{50}$  was estimated around 87°C, while an integrated volatility characterization was performed according to Karnezi et al. (2014) approach. After exposure to OH radicals and UV illumination the aerosol O:C ratio decreased while the H:C ratio increased indicating fragmentation. Positive matrix factorization (PMF) applied to the chamber experiments revealed a second less oxygenated factor after OH addition.

## References:

- Karnezi, E. et al (2014) *Atmos. Meas. Tech.*, 7, 2953-2965, 2014.  
Müller, L. et al. (2012) *Atmos. Chem. Phys.*, 12, 1483-1496.  
Szmigielski, R. et al. (2007) *GRL*, 34, 6 pp., L24811.

**1AP.6**

**Investigating the Phase Transitions of Lower Alkanes - Pentane, Hexane, and Heptane - in a Supersonic Laval Nozzle.** KEHINDE OGUNRONBI, Barbara Wyslouzil, *The Ohio State University*

Probing the vapor-liquid phase transitions of hydrocarbons is important to improving their separation from raw natural gas before transportation in a pipeline. If they are not removed these materials can condense creating a two-phase flow, and thereby greatly increasing the pressure drop in the pipe. We have investigated the phase transitions that lead to the formation of pentane, hexane, and heptane nanodroplets, on the microsecond timescale in a supersonic Laval nozzle. We conducted position-resolved pressure trace measurements (PTM) for the three n-alkanes at stagnation pressure of 30.1kPa and stagnation temperatures of 293 K and 303 K. We evaluated the temperature, pressure, mass fraction of condensate, flow velocity, and area ratio of flow by PTM. For these relatively short alkanes, we observe condensation at temperatures below 180 K. To reach these conditions, the experiments use argon, rather than nitrogen as the carrier gas and a more rapidly expanding nozzle than our earlier work. In addition we have made FTIR measurements to follow the vapor-liquid-(solid) transitions of pentane, hexane and heptane, and found evidence for freezing in the latter two compounds.

**1AP.7**

**Effect of Wall Shear Stress on Aerodynamic Particle Resuspension.** Patrick Fillingham, KALYAN KOTTAPALLI, Xiaolin Zhan, Igor Novosselov, Harikrishna Murali, *University of Washington*

Particle resuspension from surfaces due to aerodynamic forces is of interest in various applications, including trace material detection, surface cleaning and the study of the fate of radioactive particles. Particle removal from surfaces depends on the balance of forces acting on the particle; in an aerodynamic resuspension scenario, the structure of the boundary layer is especially important. Wall shear stress can be used to define the boundary layer flow at the surface. We combine the use of particle removal data from a controlled flow cell experiment with Computational Fluid Dynamics (CFD) modeling to study the effect of wall shear stress on particle resuspension in the constant wall shear stress environment of the flow cell.

In addition, a computational model is developed for the wall shear stress from high-pressure impinging jets. An experimental setup using an oblique rectangular slit nozzle impinging jet is used for particle resuspension study. This experimental setup uses pressures ranging from 5 to 20 psig for the resuspension of silica glass microsphere particles on a glass substrate ranging in size from 8 to 50 microns. The test substrate is subjected to a range of wall shear stress from 10-500 pascals by varying the jet pressure and standoff distance. The experimental removal efficiency data together with the CFD models yields a correlation between wall shear stress and particle removal. This correlation allows for the prediction of particle resuspension in a variety of aerodynamic removal scenarios.

**1HR.1****Investigating the Links between Chemical Composition of Atmospheric Particulates and Adverse Health Effects.**

DOMINIQUE YOUNG, Sonya Collier, Xiaolin Sun, Haiying Wei, Kent Pinkerton, Keith Bein, Qi Zhang, *University of California, Davis*

The association between atmospheric particulate matter (PM) and adverse health effects, such as cardiopulmonary disease, has long been recognized, yet due to the enormous chemical complexity of PM connections between PM chemical properties and toxicological responses remain poorly understood. The goal of this project is to identify both sources and key chemical components of PM that are potentially responsible for adverse health effects through detailed analysis of PM samples. A secondary goal is to use analytical techniques that can identify markers for inflammation in a non-selective, top-down approach using a High-Resolution Time-of-Flight Aerosol Mass Spectrometer (AMS). PM<sub>2.5</sub> filter samples collected during winter from California and China were analyzed using the AMS to determine their chemical composition. There were notable compositional differences between the two samples including organic contribution to total PM mass, degree of oxidation of the organic compounds, as well as distinct tracer ions indicating different sources of the PM. Further, Inductively Coupled Plasma Mass Spectrometry analysis indicated differences in heavy metal content for the two samples, including higher copper abundance in the California PM. A mouse model used to investigate toxicological effects demonstrated significantly different inflammatory responses between China and California PM. The lavage fluids collected from mouse lungs after exposure were also analyzed using the AMS. Due to a large influence from background signals, the mass spectra of the lavage samples were deconvolved using Positive Matrix Factorization. There are indications that the samples from mice exposed to PM had differences in their compositions compared to the control group. Some differences between samples for mice exposed to California and China PM were also discerned. Ultimately this work will inform regulatory policy and provide much needed information for risk assessment of air quality as well as identify markers for disease outcomes with the aim of improving human health.

**1HR.2****Oxidative Potential and Chemical Characteristics of Water-soluble PM<sub>2.5</sub> Collected from Various Sites in South Korea.**

LUCILLE JOANNA BORLAZA, Minhan Park, KwangYul Lee, HungSoo Joo, Tsatsral Batmunkh, Kihong Park, *Gwangju Institute of Science and Technology*

Substantial research has confirmed that health effects of fine particulate matter (PM<sub>2.5</sub>) can be attributed to several other factors other than just PM<sub>2.5</sub> mass levels. A large number of these studies have pointed to redox active compounds of PM<sub>2.5</sub> as a culprit, hence the growing interest on oxidative potential (OP) of PM<sub>2.5</sub> as a more suitable health-based measure. The OP analysis can assess the capability of PM<sub>2.5</sub> to produce reactive oxygen species (ROS) which is suggested that at exceeding normal range have considerable implications. This study looked into OP and its association with chemical composition of ambient PM<sub>2.5</sub> collected from various sites in South Korea. Ambient PM<sub>2.5</sub> was collected on zeflour and quartz filters using URG cyclones at several sites (urban, industrial, road side, and rural sites). Chemical analysis for inorganic ions, metals, organic carbon (OC) and elemental carbon (EC) were done. Two chemical assays were used to characterize OP of water-soluble PM<sub>2.5</sub>: dithiothreitol (DTT) and electron spin resonance (ESR) assay. OP-DTT was carried out through assessment of the capability of redox active compounds in PM<sub>2.5</sub> to transfer electrons from DTT to oxygen thereby generating superoxides. The consumption of DTT over specific time intervals (5, 15, 25, 35 and 45 mins) was interpreted as a measure of the capability of ambient PM<sub>2.5</sub> to produce ROS. On the other hand, OP-ESR was performed using ESR with a spin trap (5,5 – dimethylpyrroline – N – oxide or DMPO) which measures the capability of PM<sub>2.5</sub> to generate hydroxyl radicals ( $\bullet$ OH) though Fenton type reactions with the presence of hydrogen peroxide. Results for all chemical and OP analyses will be presented in this study.

**1HR.3**

**Relationship between Organic Aerosol Composition, In Vitro Oxidative Potential and In Vivo Airway Hypersensitivity.** Jianhuai Ye, Sepehr Salehi, Michelle North, Anjelica Portelli, Chung-Wai Chow, ARTHUR CHAN, *University of Toronto*

Epidemiological studies have shown that particulate matter (PM) is associated with the incidence, morbidity and mortality of cardiopulmonary diseases. Secondary organic aerosol (SOA) is a major component of ambient PM. Here we measure the in vitro oxidative potential of SOA using dithiothreitol assay and study the in vivo pulmonary effects on mice exposed to lab-generated SOA. SOA from oxidation of naphthalene (N-SOA) was found to exhibit high levels of oxidative potential compared to other SOA types. The contribution of individual compound groups (quinones, peroxides) to overall oxidative potential is investigated. Healthy 8-10 weeks old female mice were exposed for 1 hr/day for 3 consecutive days to N-SOA, maintained at levels similar to street-level concentrations during exposures. Pulmonary function and methacholine-responsiveness were assessed 24 hours after the final exposure. Daily exposures to N-SOA increased total respiratory resistance to methacholine when compared to control filtered-air mice, and in a dose-dependent manner. However, the total and differential leukocyte counts in the broncho-alveolar lavage fluid were similar in all experimental groups, and histological staining showed no signs of cell recruitment, suggesting that increase in airway responsiveness was not associated with airway inflammation. Further studies will investigate non-inflammatory pathways causing airway hypersensitivity and the relationship between N-SOA composition, in vitro oxidative potential and airway hypersensitivity.

**1HR.4**

**Ambient Size Distributions of Particulate Matter Oxidative Potential and Estimated Deposition in the Human Respiratory System.** TING FANG, Linghan Zeng, Vishal Verma, Rodney J. Weber, *Georgia Institute of Technology*

Oxidative potential (OP), referred as to the capability of aerosols to generate reactive oxygen species, has been proposed as a better health relevant indicator than particulate matter (PM) mass. Particle size is an important factor in the health effects of OP since it controls deposition efficiency, thus influences where each inhaled particle is likely to deposit in the human respiratory system. Particle size distributions also provide evidence on sources and processes that affect ambient concentrations. Size-segregated ambient PM samples were collected from an urban background site and a road-side site in Atlanta, GA. Samples were measured for OP, elemental organic carbon, and sulfate. Water extracts of samples were measured using the dithiothreitol (DTT) and ascorbic acid (AA) assays. Total DTT activity, which includes both water-soluble and water-insoluble fractions, was also measured with the DTT method. Results show that OP size distributions do not have the typical minimum at PM<sub>2.5</sub>. Instead, water-soluble OP shows a mono-modal distribution which peaks at 0.8-2.5  $\mu\text{m}$ . Water-soluble AA activity has a much narrower distribution and peaks at a larger size than that for water-soluble DTT activity at both sites. Water-soluble DTT distribution is quite spatially uniform while total DTT activity at the road-side site has a significant contribution from larger size particles. Our results suggest the contribution from both organic species and metals to the OP in Atlanta from both primary emissions and secondary processes. The estimated deposition of oxidative potential in the human respiratory tract suggests that although ultrafine particles are considerably more oxidatively active per mass, given that the mass of ultrafine particles in ambient air is rather small, fine and coarse fractions are more significant in terms of OP deposition throughout the respiratory system and so potentially more health-relevant.

**1HR.5**

**Generation of Reactive Oxygen Species Catalyzed by Mixtures of Atmospheric Humic Substances and Copper/Manganese: Evidence for the Importance of Metal-organic Interactions.** MANFEI LIN, Jian Zhen Yu, *Hong Kong University of Science & Technology*

Excessive generation of reactive oxygen species (ROS) and the corresponding oxidative stress has been recognized as one important cause for the adverse health effects associated with exposure to ambient particulate matter (PM). Transition metals (TMs) and humic-like substances (HULIS) in PM have been separately demonstrated to produce ROS, however, the impact of their interactions on their oxidative potentials has not been investigated and little understood. HULIS is an abundant fraction of water-soluble organic material in PM, sharing similarity in functional group composition with terrestrial and aquatic humic substances. In this study, we used a cell-free dithiothreitol (DTT) assay to assess the effects of interactions between TMs and HULIS and between two representative TMs, copper (Cu) and manganese (Mn). HULIS were found to suppress the DTT consumption from Cu by up to 10~20%, possibly due to the organic ligands in HULIS binding Cu and thereby reducing the redox reactivity of Cu. On the contrary, significant enhancement effects on DTT loss rate were observed both in the mixtures of HULIS and Mn and in the mixtures of Cu and Mn. Our work demonstrates the importance of quantifying interactions between components when we evaluate the contribution of individual species to the total oxidative strength. Difficulties encountered in attributing mixture effects to underlying interactions suggest that further work in metal-PM organics interactions should be done using techniques capable of more specific oxidant measurements in order to acquire a deeper mechanistic insight into the interactions.

**1HR.6**

**Dose-dependent Intracellular Reactive Oxygen and Nitrogen Species Production from Particulate Matter Exposure: Comparison to Oxidative Potential and Chemical Composition.** WING-YIN TUET, Shierly Fok, Vishal Verma, Marlen Tagle Rodriguez, Anna Grosberg, Julie Champion, Nga Lee Ng, *Georgia Institute of Technology*

Health effects of particulate matter (PM) exposure have received considerable attention wherein epidemiological studies have associated elevated PM concentrations with increases in the incidence of cardiopulmonary diseases. Toxicology studies have suggested that PM-induced oxidant production, including reactive oxygen and nitrogen species (ROS/RNS), may induce inflammatory cascades, which may in turn lead to further oxidative stress, cellular damage, and chronic inflammation. Here we present ROS/RNS measurements from 104 ambient PM samples collected from urban and rural sites during multiple seasons in the southeastern US as part of the Southeastern Center for Air Pollution and Epidemiology (SCAPE) study. Murine alveolar macrophages and neonatal rat ventricular myocytes were used to measure intracellular PM-induced ROS/RNS production using a fluorescent probe, carboxy-H<sub>2</sub>DCFDA. For each filter sample, a dose-response curve was obtained over ten dilutions, and the Hill equation was applied to obtain response parameters (maximum response, EC<sub>50</sub>, Hill slope, threshold, and area under the dose-response curve, AUC). These parameters were then compared with results from a common chemical assay (dithiothreitol, DTT assay) to determine whether chemical assays represent cellular ROS/RNS response, and with water-soluble PM components to elucidate species associated with PM-induced ROS/RNS production. We found that ROS/RNS production was highly dose-dependent, non-linear, and could not be represented by a single concentration measurement. Furthermore, we demonstrate that no simple correlation exists between DTT activity/PM composition and cellular ROS/RNS responses. For summer samples, we found that DTT activity, water-soluble organic carbon, and brown carbon were significantly correlated with cellular ROS/RNS production as measured by AUC, which highlights the importance of understanding the contribution of summertime secondary organic aerosols (SOA) to PM-induced ROS/RNS production.

**1HR.7**

**Methods for Quantifying the Total Oxidative Potential of Ambient Particles.** DONG GAO, Ting Fang, Vishal Verma, Rodney J. Weber, *Georgia Institute of Technology*

Both water-soluble and water-insoluble components of ambient particulate matter (PM) have been shown to contribute to the oxidative potential (OP) of PM. In this study, we develop and compare methods for quantifying the total oxidative potential (OP<sub>Total</sub>) of ambient particles using the dithiothreitol (DTT) assay. The approach involved analysis of fine PM extracted from high-volume filters (23h integrated samples). Three methods for measuring OP<sub>Total</sub> were compared: 1) sonicating filter punches in a vial with water and then performing the DTT assay in this vial containing the filter, 2) extracting punches in methanol, evaporating an aliquot of the methanol extract to near dryness, reconstituting with water and measuring DTT activity and 3) the sum of a standard water extraction with DTT analysis of the filtered liquid extract, followed by methanol extraction (method 2) performed in series on the same filter punches. Based on the results obtained from these three methods, for filters collected at a roadside and at a representative urban site, OP<sub>Total</sub> from method 1 (OP<sub>Total\_1</sub>) was generally the highest, indicating, of these three methods, the first method is the most efficient way to measure OP<sub>Total</sub>. It is also the method most easily automated. By subtracting OP of water-soluble components (OP<sub>WS</sub>) from OP<sub>Total</sub>, the relative contribution of water-soluble and water-insoluble compounds to the OP of ambient fine aerosols can be further determined. At the representative urban site, 60-75 percent of the OP<sub>Total</sub> was associated with water-soluble species. Whereas at the roadside site, roughly 50 percent of the OP<sub>Total</sub> was water-soluble, indicating a large contribution of water-insoluble compounds, such as DTT-active compounds associated with black carbon or insoluble road dust associated with traffic emissions. The application of this method can help to more comprehensively identify sources of PM toxicity and an automated analytical system applied to large population health studies.

**1IM.1**

**ARISense - Enabling Air Pollution Measurements with Low(er)-cost AQ Sensor Technologies.** EBEN CROSS, Gregory Magoon, Timothy Onasch, David Hagan, Jesse Kroll, Leah Williams, Gary Adamkiewicz, Ann Backus, Douglas Worsnop, John Jayne, *Aerodyne Research, Inc.*

The environments in which we live, work, breathe, and play are subject to enormous variability in air pollutant concentrations. To adequately capture and characterize one's air quality, measurements must be fast (real-time), scalable (ubiquitous), and reliable (with known accuracy, precision, and stability over time). Low-cost AQ sensor technologies offer new opportunities for fast and distributed measurements, but a persistent characterization gap remains when it comes to evaluating sensor performance. This limits our ability to inform stakeholders about pollution sources and inspire policy makers to act. ARISense is an ongoing research endeavor focused on evaluation and development of low-cost AQ sensor technologies. In this presentation, we will describe results from laboratory and field measurements obtained with low-cost sensor systems comprised of electrolytic and optical sensors for measurement of criteria gas phase (NO, NO<sub>2</sub>, CO, O<sub>3</sub>, CO<sub>2</sub>) and particulate pollution. Results from the Dorchester Air Quality Sensor System (DAQSS) in the south Boston community of Dorchester will be discussed. DAQSS provides an opportunity to assess sensor-derived pollutant concentrations, characterize the long-term (12-18 mo.) stability of the sensors, and improve our understanding of the interference resulting from relative humidity, temperature, and other gas phase pollutant species. The importance of developing mathematical descriptions of the sensor interference surface (obtained from real-world co-location datasets) will be demonstrated.

**11M.2**

**Aerosol Elemental Analysis Using Atmospheric Glow Discharge Spectroscopy.** LINA ZHENG, Pramod Kulkarni, *Centers for Disease Control and Prevention, NIOSH*

A new low-cost method has been developed for semi-continuous elemental analysis of aerosols using radio frequency glow discharge optical emission spectroscopy. The method involves microconcentration of aerosols on an electrode tip, followed by atomization and excitation of the particulate matter using atmospheric glow discharge initiated in the inter-electrode gap in an argon bath. The resulting atomic emissions are recorded using a spectrometer for elemental identification and quantification. The glow discharge plasma was characterized by measuring spatially resolved gas temperature (500 – 1500 K) and electron density ( $2 - 5 \times 10^{14} \text{ cm}^{-3}$ ). Spatial analysis of the spectral feature shows that the collision and excitation of the collected particles occurs in the region near the collection electrode. The signal intensity from the analyte decreases with time during the glow discharge. Sucrose particulate mass of 193 ng could be ablated in approximately 2 s using the continuous glow discharge. The system was calibrated using 100 nm particles containing C, Cd, Mn, and Na. The method provides limits of detection in the range of 0.055 – 1.0 ng in terms of absolute elemental mass, and a measurement reproducibility of 5 – 28%. The study demonstrates that the atmospheric glow discharge can be an excellent low-cost excitation source for development of portable aerosol elemental spectrometers.

**11M.3**

**Assessing the Accuracy and Reliability of Low-cost Particle Counters for Determining PM<sub>2.5</sub> Loadings.** DAVID HAGAN, Jesse Kroll, *MIT*

The past several years have seen the emergence of a number of low-cost commercial devices for measuring particulate matter (PM) for the monitoring of both indoor and outdoor air quality. Although these devices are beginning to see widespread use, very little is known about the accuracy and reliability of their data. In particular, most such monitors measure particle number concentration only, and thus the extent to which they can be used to estimate particle mass concentration, the quantity on which most health-based assessments and PM regulations are based, is unclear. Low-cost PM counters are typically based on light scattering, presenting major challenges for estimating mass loadings of accumulation mode aerosols (0.1 – 2.5 microns). Here we describe a computational framework for the exploration of the ability of low-cost PM-counters to accurately and precisely infer PM<sub>2.5</sub> mass (as well as the particle size distribution) based on key instrument parameters (bin width, size-dependent counting efficiency, etc.). The expected performance of various commercially-available counters is assessed using this approach, and results are compared to laboratory experiments using research-grade monitors across a range of aerosol types and distributions.

**IIM.4**

**Calibration of Portable and Personal PM<sub>2.5</sub> Sensors.** DI LIU, Da-Ren Chen, *Virginia Commonwealth University*

The recent development of portable and personal PM sensors for the PM<sub>2.5</sub> monitoring is very active. It is primarily stemmed from the high PM<sub>2.5</sub> level encountered and the increasing public awareness of PM health consequence in foreign countries, such as China and India. As a result various PM sensors in small packages and at the price much lower than scientific instruments are now available in market. The performance of these portable and personal PM sensors however requires to be calibrated in order to properly monitoring the PM concentration in the ambient. In our study we had performed a series of experiments to calibrate these small PM sensors and investigated the effects that may influence the reading of these sensors.

Four optical sensors, i.e., Sharp, Shinyei, Samyoung and Oneair, one Personal Dust Monitor (PDM) from Thermal Scientific and Dusttrak from TSI were included in this study. A classic TEOM, which was calibrated using the filter method prior to this study, was used as the reference PM instrument. Test particles with the size distributions in different mean sizes, standard deviations and materials were either generated from nebulizing solutions of NaCl, Florescence slat and Methylene blue via various nebulizers or airborne via dispersing dry powders of fine and ultrafine dusts, and ASHRAI dusts. The performance of sensors under different flow conditions, including calm air, was studied. The detail results obtained in this study will be shared in this talk.

**IIM.5**

**Distributed Low-cost Wireless Particle Sensors: Optical Characterization.** JIAYU LI, Pratim Biswas, *Washington University in St Louis*

Compact low-cost sensors for measuring particulate matter (PM) concentrations are receiving significant attention as they can be used in larger numbers and in a distributed manner (Wang et al, 2015). A configuration for use of these networked sensors in a distributed manner is presented in this work wherein data collection is done using wireless technology. To ensure accurate and reliable representation of PM mass concentrations, the performance characteristics of such sensors need to be better understood. Computational and experimental approaches were used to establish the relationship of mass concentration to the optical signal obtained from the device. The dependence on material properties and size distribution of the particles was established. Theoretical calculations were based on the Mie regime scattering expressions. Experiments were based on aerosolized sodium chloride particles produced by a constant output atomizer and an ultrasonic nebulizer. The calculated light scattering intensity correlated well with the signal from the sensor (Sharp GP2Y1010AU0F) signal in both the small and large particle size ranges. The results illustrated that the calibration factor is different for these two regimes. A semi-empirical equation for the calibration factor as a function of the refractive index and size distribution parameters (total number concentration, the geometric standard deviation, and the geometric mean diameter) is presented. The well characterized wireless sensor system with fifteen calibrated sensors was used in several indoor and outdoor environments: such as a laser cutter workshop, woodshop, and high traffic outdoor area. These sensors were used to monitor the hotspots and generate 3D maps of particle concentrations. In field measurements, sensors showed instant and accurate responses, which demonstrates high-quality performance at both sampling and networking capability.

Wang, Yang, et al. *Aerosol Sci. Technol.* 49.11 (2015): 1063-1077.

**IIM.6**

**A Compact Electrical Particle Sizer for Wireless Sensor Network to Monitor Fine and Ultrafine Particles.** Qiaoling Liu, DA-REN CHEN, *Virginia Commonwealth University*

Wireless sensor network based on particle sensors are in high demand for emerging applications such as continuous monitoring of spatial/surface distribution of fine and ultrafine particles (UFPs) in local communities, air quality and traffic monitoring in smart cities, early fire detection in buildings and hospitals, worker protection in the nanomaterial facility, vertical UFP profiling, and many others. Cost-effective and light-weighted particle sensors in a compact package are required to realize the above applications under the consideration of budget limit. A miniature electric ultrafine particle sizer (mini-eUPS) was thus developed to meet the above fine and ultrafine monitoring task.

A prototype mini-eUPS primarily consists of a mini-plate aerosol charger for electrically charging sampled particles, a mini-plate DMA for particle sizing based on particle electrical mobility and a mini Faraday cage with sensitive pre-amp for measuring electrical charges carried by charged particles. The mini-plate aerosol charger, mini-plate DMA and mini-Faraday cage were individually calibrated prior to the assembly. A data-reduction scheme was developed to quickly recover the size distribution of particles from the measured raw data. Together with all flow control units and circuits to properly operate aerosol charger, DMA and electrometer and an embedded computer, the overall package size and weight of mini-eUPS are 5" (L) × 5" (W) × 6" (H) and 3 lb, respectively. In addition to the measurement of particle size distribution, each mini-eUPS further equips with the capability of recording temperature, relative humidity, pressure, timing, GPS and altitude of the samples. The prototype mini-eUPS can be used either as a single-alone sensor or a node in wireless sensor network. Laboratory and field experiments are being conducted to evaluate the performance of mini-eUPSs. The detail of this study will be present in this talk.

**IIM.7**

**Opto-Dielectrometric Sensors for Automated Control of Total Incombustible Content in Underground Coal Mines.** OMID MAHDAVIPOUR, John Sabino, Timothy Mueller-Sim, Michael R. Shahan, Clara E. Seaman, Paul A. Solomon, Paul Wright, Richard White, Lara Gundel, Larry D. Patts, Igor Paprotny, *University of Illinois at Chicago*

Finely divided coal dust produced during underground coal-mining, i.e. float dust, which deposits throughout the coal mine can be a feedstock for coal dust explosions. To prevent such explosions, inert rock dust (limestone powder) is applied in underground areas of a coal mine. The ratio of total incombustible mass (rock dust + incombustible content of coal dust) to the total mass of the deposited dust is called total incombustible content (TIC) of the dust deposited within the mine. Regulations require that a certain minimum TIC ratio to be maintained for safe working conditions within active coal mines.

This paper presents a low-cost/low-power distributed sensing module that can continuously measure the TIC of the deposited dust. The sensing module uses continuous optical and dielectrometric methods to measure the TIC of the deposited float dust and rock dust. The main sensing components of this system are an optical reflective sensor and an interdigitated dielectrometric dust thickness/moisture monitor. The optical reflective sensor determines the TIC of the deposited dust based on optical reflection/transmission through the deposited dust stack. We present an extension of the Bouguer-Beer-Lambert Law to find the relation between the reflectivity from a layer of known thickness of a dust mixture to the ratio of each constituent. We also present the experimental results from testing the sensor prototypes in a realistic test bed where the sensors were exposed to a realistic coal/rock dust mixture. The sensor performance and stability at different humidity levels is evaluated and the accuracy of the results are compared to the currently established best practices for measuring TIC in underground coal mines.

**1NM.1**

**Aerosol Synthesis of Palladium Based Nanopowders and Nanoinks in a Flame-Driven High Temperature Reducing Jet Reactor.** SHAILESH KONDA, Mohammad Moein Mohammadi, Raymond Buchner, Mark Swihart, *University at Buffalo - SUNY*

Over the past few years, we have synthesized several types of multicomponent metal and semiconductor nanoparticles using a flame driven High Temperature Reducing Jet (HTRJ) reactor. In the HTRJ process, high speed combustion products pass through a converging-diverging nozzle. An aqueous precursor solution injected at the throat section of the nozzle evaporates and decomposes, initiating nucleation of particles in a reducing environment containing excess H<sub>2</sub>. This allows flame-based synthesis of nanoparticles of metals that can be reduced by H<sub>2</sub> in the presence of H<sub>2</sub>O. A key advantage of the HTRJ system over other flame-based aerosol synthesis methods is decoupling of the combustion and particle formation zones. In this contribution, we will focus on the synthesis of palladium-based nanopowders and nanoinks. We have prepared a range of binary and ternary alloys of palladium, copper, and silver of controlled composition. The targeted application of these palladium-based nanopowders is polymer nanocomposite membranes for H<sub>2</sub>/CO<sub>2</sub> separation, where the palladium alloy particles can provide highly selective pathways for H<sub>2</sub> transport through a membrane. Hence the nanopowders from the flame reactor are dispersed in a polymer-compatible solvent to form nanoinks, then cast into thin film membranes.

**1NM.2**

**Atomically-dispersed Pd on Nanostructured Titania for NO Removal by Solar Light.** Kakeru Fujiwara, SOTIRIS E. PRATSINIS, *ETH Zurich*

Aerosol technology is uniquely positioned for large scale synthesis of noble metal sub-nano clusters on ceramic supports that can lead to enhanced catalyst performance with minimal use of noble metals. So Pd clusters onto nanostructured TiO<sub>2</sub> particles are prepared in one step while controlling the Pd cluster size from a few nanometers down to that of single atoms. Under solar light irradiation, these materials remove NO<sub>x</sub> 3 or 7 times faster than commercial TiO<sub>2</sub> (P25, Evonik) with or without, respectively, photo-deposited Pd on it (ACS Catalysis, 2016, 6:1887-1893). Annealing such materials leads to solar photocatalytic NO<sub>x</sub> removal in a standard ISO reactor up to 10 times faster than that of commercial TiO<sub>2</sub>. Such superior performance can be attained by only 0.1 wt% Pd loading on TiO<sub>2</sub>. Annealing these flame-made powders decreases the amorphous TiO<sub>2</sub> fraction and increases its crystal and particle sizes while single Pd atoms and clusters are stable up to, at least, 600 C for 2 hours in air but at 800 C they grow into PdO nanoparticles whose fraction is comparable with the nominal Pd loading proving the presence of Pd atoms on the catalysts surface along with STEM analysis. Diffuse Reflectance Infrared Fourier Transform Spectroscopy reveals NO adsorption on single, double, 3- and 4-fold coordinated Pd atoms depending on their flame concentration and annealing conditions. The peak intensity of NO adsorption sites involving multiple Pd atoms is substantially lower in TiO<sub>2</sub> with 0.1 than 1 wt% Pd but that intensity from single Pd atoms is comparable. This indicates the dominance of isolated Pd atoms compared to their clusters in Pd/TiO<sub>2</sub> containing 0.1 wt% Pd that match or exceed the photocatalytic NO<sub>x</sub> removal at higher Pd contents proving the potential of flame-depositing of Pd atoms.

**1NM.3**

**Rapid Synthesis of Highly Porous Polymer Nanocrystals by Aerosol Routes.** Zhuoran Gan, Xiang He, WEI-NING WANG, *Virginia Commonwealth University*

Metal-organic frameworks (MOFs) are a class of porous polymer crystals, which find various applications, such as gas adsorption and separation, catalysis, and biomedical-related technologies. MOFs have been prepared traditionally by wet-chemistry methods. In this work, a single step aerosol method was used to successfully synthesize several example MOFs. Effects of precursor concentration, metal/linker ratio, solvent type, and synthesis temperature were investigated in detail. The as-synthesized nanocrystals were characterized systematically by SEM, TEM, XRD, UV-vis, FTIR and BET. The crystal formation mechanisms of MOFs in aerosol routes will be discussed.

**1NM.4**

**A Study of Hydrogen Assisted Spark Discharge for Generating Hydrogen Passivated Silicon Nanoparticles with High Crystallinity.** DONGJOON LEE, Kiwoong Lee, Dae Seong Kim, Jong-Kwon Lee, Sei Jin Park, Mansoo Choi, *Global Frontier Center for Multiscale Energy Systems*

The purity control over nanoparticles is significantly important in the particle generation process, and their crystallinity and surface chemistry play a crucial role for enhancing the performance in nanoparticle-embedded opto- and nano-electronic devices. In this study, we investigate the effect of the hydrogen gas on production of the silicon nanoparticles via spark discharge generation process. When we use argon as a carrier gas, a small amount of the oxygen gas causes the generation of silicon oxide particles, and the spark energy is insufficient to produce high-crystalline silicon nanoparticles. By introducing hydrogen gas, the inert atmosphere in the spark discharge generator is converted into a reducing atmosphere, which effectively eliminated the oxygen gas in the spark discharge generator. The purity of generated silicon nanoparticles gradually enhanced as the portion of hydrogen gas increased. In addition, hydrogen plasma generated from the spark discharge process improves the crystallinity of the silicon nanoparticles. Moreover, as highly reactive hydrogen plasma interacts with dangling bonds on the surface of silicon nanoparticles, the surface of the silicon nanoparticles is passivated with the hydrogen atom. Thus, the suggested technique herein produces the hydrogen-passivated silicon nanoparticles with high crystallinity, which is applicable for generating silicon quantum dots with size-selection.

**1NM.5**

**Synthesis and Photoelectrochemical Property of Monodisperse Hollow Metal Oxide Microspheres.** HANEOL LEE, Youngku Sohn, WeonGyu Shin, *Chungnam National University*

A novel method to synthesize monodisperse hollow TiO<sub>2</sub>, SnO<sub>2</sub> and ZnO microspheres was developed. Water droplets generated from an inkjet nozzle containing clusters of polystyrene latex (PSL) particles covered with metal oxide nanoparticles and were continuously dried up forming PSL clusters decorated with metal oxide nanoparticles. By heating the clusters up to 400 degrees of Celsius, the PSL particles are evaporated forming hollow spheres. Monodisperse hollow TiO<sub>2</sub>, SnO<sub>2</sub> and ZnO spheres in the size range of 5.1–8.6 micrometer were consequently generated with a narrow particle size distribution. And the hollow TiO<sub>2</sub>, SnO<sub>2</sub> and ZnO spheres have 41.0, 30.0 and 85.3 nanometer sized pores, respectively. The method enables us to have simpler and faster process to generate hollow TiO<sub>2</sub>, SnO<sub>2</sub> and ZnO spheres and to control the diameter of hollow spheres easily by adjusting waveform applied to a nozzle compared to other processes. A potential applicability to photoelectrochemical cells was demonstrated for the prepared hollow TiO<sub>2</sub> grown a Si substrate.

**1NM.6**

**Crumpling of Graphene-oxide by Evaporative Confinement in Nano-droplets using Electrospray.** SHALINEE KAVADIYA, Ramesh Raliya, Michael Schrock, Pratim Biswas, *Washington University in St. Louis*

Crumpled graphene oxide (CGO) has attracted significant attention recently due to its remarkable properties, including high surface area and dispersion as a single crumpled ball, unlike graphene oxide (GO) sheets, which tend to restack. CGO has been synthesized through the evaporative confinement of GO sheets in a droplet<sup>1</sup>. Furthermore, as the solvent evaporates from the droplet, a capillary force is induced on the GO sheets, resulting in their crumpling. Previously used techniques include spray drying, furnace aerosol reactor, and electrospray. However, these techniques were all demonstrated at elevated temperature environments for complete solvent evaporation or the addition of a crumple-inducing material. Such techniques also produce larger crumpled structures, and have not demonstrated the fabrication of nanometer sized particles.

In this study, an electrospray was used to produce CGO at sizes <100 nm under ambient conditions and without the use of any crumpling agent. Nanometer-sized crumpled particles are favorable in many applications due to their high surface area to volume ratio, high packing efficiency, and easy surface decoration. The effect of various process parameters such as substrate-to-nozzle distance, GO concentration and flow rate (droplet size) was investigated on the crumpling force and the crumpled particle size. Crumpled particles were characterized on-line using scanning mobility particle sizer (SMPS) and off-line using electron microscopy. Effects of these parameters were then linked to the characteristic times -- namely, time for the complete solvent evaporation ( $\tau_e$ ), residence time of the droplet ( $\tau_{res}$ ), and the time for the charge droplet to reach Rayleigh limit ( $\tau_{rav}$ ). The size distribution of the crumpled particles was observed to be bimodal mainly as a result of the charged droplet break-up. Furthermore, another interesting morphology of thread-like morphology of GO particles were produced under certain experimental conditions. Finally, the synthesis and deposition of CGO at ambient conditions provide flexibility in substrate selection and enables a variety of applications.

Reference:

1. Wang et. al., *J. Phys. Chem. Lett.*, 2012, 3, 3228–3233.

## 1NM.7

**Electrochemical Performance of Multi-Layer Graphene-Carbon Nanoflower Composite Synthesized by Aerosol Based Methods.** Mirella Miettinen, Anna Lähde, Tiina Torvela, Tommi Karhunen, Juho Välikangas, Ulla Lassi, JORMA JOKINIEMI, *University of Eastern Finland, Kuopio, Finland*

Different carbon nanomaterials have been synthesized eagerly during the past years because they may result in more efficient materials for energy applications, such as supercapacitors or lithium-ion batteries. The aerosol based synthesis of a multi-layer graphene-carbon nanoflower composite (MLG/CNF) is previously reported (Miettinen et al., 2014). The starting material was synthesized from hexamethyldisilane (HMDS) by the atmospheric pressure chemical vapor synthesis (APCVS). The resulting Si-C material was then annealed at high temperature induction furnace to obtain multi-layer graphene-carbon nanoflower composite. Here, structure and electrochemical performance of the composite was studied.

The structure of the MLG/CNF composite was studied with an aberration corrected high-resolution transmission electron microscope (TEM, JEOL JEM-2200FS). The analyses were performed at electron acceleration voltage of 80 kV. Selected area diffraction analysis (SAED) was performed from the MLG sheets. For the electrochemical testing, as prepared powder was sieved ( $> 45 \mu\text{m}$ ) to remove residual SiC crystals and electrodes were prepared using conventional method. Electrochemical performance of the MGL/CNF composite was tested in Li-ion button cells against graphite reference.

SAED analysis showed that graphene layers were rotated to each other. The most common rotation angle in the MLG sheets was  $30 \pm 2^\circ$ , but also other rotation angles were detected (Miettinen et al., 2015). Due to rotational faults the interlayer distance in the sheets was increased  $\sim 12\%$  compared with graphite. The CNFs contained nanosize cavities. The wrinkled network of the MLG sheets and the CNFs may increase, e.g., lithium-ion insertion capacity of the composite. The electrochemical performance of the MLG/CNF composite was better than graphite reference.

Miettinen, M., Hokkinen, J., Karhunen, T., et al. (2014) *J. Nanopart. Res.*, 16, 2168.

Miettinen, M., Torvela, T., Pfüller, C., et al. (2015) *Carbon*, 84, 214-224.

## 1UA.1

**Seasonal and Regional Differences in the Chemical Composition of Ambient Aerosol from Fresno and Fontana, California.** CHIA-LI CHEN, Lynn Russell, Jun Liu, Derek Price, Raghu Betha, Kevin Sanchez, Sijie Chen, Jackie First, Alex K. Y. Lee, Xiaolu Zhang, Christopher Cappa, *Scripps Institution of Oceanography*

Aerosol emissions from residential, agricultural, and wildfire burning activities are highly seasonal, episodic, and have adverse impacts on climate. This study (1) identified and characterized the chemical composition of  $\text{PM}_{10}$  and  $\text{PM}_{2.5}$  and (2) quantified the organic components from burning emissions and from atmospheric formation of secondary organic aerosol at two California locations, Fresno (December 2014) and Fontana (July 2015). Ambient aerosol was characterized by a suite of advanced instrumentation, including a high-resolution time-of-flight aerosol mass spectrometer (HR-ToF-AMS), a single-particle soot photometer (SP2), a scanning electrical mobility spectrometer (SEMS), an aerodynamic particle sizer (APS), an optical particle sizer (OPS), and Fourier Transform infrared spectroscopy (FTIR). Four aerosol components were identified with Positive Matrix Factorization (PMF) analysis in both Fresno and Fontana. The Fresno factors include a hydrocarbon-like organic aerosol (HOA), a biomass burning organic aerosol (BBOA), an oxygenated organic aerosol (OOA), and a fog-OOA component. The fog-OOA factor correlates with ammonium, nitrate and sulfate well ( $R^2 > 0.77$ ). Black carbon (BC), CO, and potassium (K) have higher correlation with the BBOA factor, indicating carbonaceous aerosols formed from residential or agricultural biomass burning activities. The Fontana factors include a less oxidized semi-volatile OOA (SVOOA), a highly oxidized low volatility OOA (LVOOA), a cooking emission OA (COA), and HOA. The LVOOA component dominates OA mass (66%) and correlates well with  $\text{O}_3$  formation, temperature and wind speed, suggesting aged aerosol formation from photochemical reaction regionally in Fontana. Bimodal particle size distributions were observed in the afternoon hours from Fontana measurements while most particles exhibit single mode size distributions in Fresno, indicating more nucleation and photochemical aging reactions occurred during the summer in Fontana compared to winter in Fresno. FTIR results from both Fresno and Fontana show that alkane groups were the major contributors to the total  $\text{PM}_{10}$  and  $\text{PM}_{2.5}$  organic mass, followed by alcohol, carboxylic acid, and amine groups.

**1UA.2****The Air Pollution at Rochester: Long-Term Trends.**

FERESHTEH EMAMI, Mauro Masiol, Afshin Ommi, Philip K. Hopke, *Clarkson University*

There have been a number of changes in the sources of air pollutant in the northeastern United States since 2001. Trend analyses of monthly averages were performed on PM<sub>2.5</sub>, ionic species, elemental carbon (EC), organic carbon (OC) and gaseous pollutants collected between 2001 and 2015 for NYS Department of Environmental Conservation sites in Rochester. Non-parametric (Mann-Kendall regression with Sen's slope) and parametric (weighted linear and non-linear regressions) approaches were applied to estimate the trends and seasonality. We fitted the different models to monthly averages of each species for each month over the 15 years of available data. Separating the data by month removes their seasonal dependence. The unequal number of attainable samples averaged to provide monthly asset value was accounted for by weighting each month proportional to its number of available daily concentration values. Sulfate and nitrate showed downward trends. For almost all of the species over the whole, the weighted linear parametric modeling yielded steeper slopes than the non-parametric Mann-Kendall approach. For sulfate, the slopes = -0.20 and -0.15  $\mu\text{g m}^{-3} \text{ year}^{-1}$ , respectively. These trends will be compared to changes in emissions in the upwind source domain.

**1UA.3****Spatial Variation of Organic Aerosol and Source Identification of Temperature-resolved Carbon Fractions.**

HUGH LI, Timothy Dallmann, Xiang Li, Peishi Gu, Albert A. Presto, *Carnegie Mellon University*

Long-term exposure to particulate matter (PM) is the major contributor to air pollution related death in 21st century. Organic aerosol is a major component of PM<sub>2.5</sub>, ranging from 20% to 90% in mass. A mobile sampling campaign was conducted in 2013 summer and winter in Pittsburgh, PA and to characterize spatial variations in organic aerosol mass and its components. 36 sites were chosen based on three stratification variables—traffic density, proximity to point source, and elevation. Filter samples were collected in three time sessions (morning, afternoon, and night) in each season, and we used Sunset OC/EC instrument to analyze organic carbon (OC) components of different volatility—OC1, OC2, OC3, OC4, and pyrolytic carbon (PC).

We compared OC concentrations in the ambient environment, a traffic tunnel, and dynamometer tests. We found that OC2 and OC3 showed a strong increasing trend with traffic intensity while OC4 and PC were more spatially homogenous. PC was not found on all quartz filters from dynamometer tests, and it suggested traffic (gasoline or diesel) was not a source for ambient PC. Land-use regressions (LUR) models were developed for these OC fractions, and models were good with an average R<sup>2</sup> of 0.62 (SD=0.08).

Finally, cumulative probability function of population weighted OC concentrations showed that OC2 and OC3 drove the human exposure patterns.

## 1UA.4

**Online Measurement of Atmospheric Organic Aerosol Using a Novel Extractive Electrospray Ionization Time-of-Flight Mass Spectrometer (EESI-TOF).** Felipe Lopez-Hilfiker, Veronika Pospisilova, Giulia Stefanelli, Yandong Tong, Athanasia Vlachou, Urs Baltensperger, Andre Prévôt, JAY SLOWIK, *Paul Scherrer Institute*

Atmospheric organic aerosol (OA) is a complex mixture consisting of thousands of compounds, many of which remain unknown, and is responsible for significant uncertainties in aerosol effects on climate and health. Online measurements have yielded major advances in the elucidation of OA sources and atmospheric transformations, however current techniques rely on thermal desorption and/or electron ionization. This results in substantial molecular decomposition and ion fragmentation, destroying key information for source apportionment and mechanistic studies. We present the first ambient measurements by a novel extractive electrospray ionization time-of-flight mass spectrometer (EESI-TOF), which utilizes an ambient temperature, soft ionization technique to provide highly time-resolved (~5 sec) measurements of OA composition without any fragmentation or thermal decomposition. EESI-TOF measurements of OA are linear with mass and, unlike conventional electrospray systems, essentially free of ion suppression or matrix effects.

The EESI-TOF was deployed for several weeks during spring/summer 2016 at the Zurich-Kaserne station of the NABEL monitoring network (Zurich, Switzerland). This deployment coincided with long-term measurements by a quadrupole aerosol chemical speciation monitor (Q-ACSM), which provided complementary information on major OA sources, as well as constraining OA mass and bulk composition. While previous studies at Zurich-Kaserne have identified primary OA from traffic, cooking, and wood burning, quantitative links between secondary organic aerosol (SOA) and specific emission sources remain elusive. Positive matrix factorization (PMF) analysis of the EESI-TOF mass spectral time series was used to assess the potential of this new instrument for SOA source apportionment. The retrieved factors are compared to the time series of marker ions and ancillary measurements, as well as chamber-generated mass spectra, to characterize and constrain ambient SOA sources.

## 1UA.5

**Characterising an Intense PM Pollution Episode in March 2015 in France from Multi-site Approach and Near Real Time Data: Climatology, Variabilities, Geographical Origins and Model Evaluation.** JEAN-EUDES PETIT, Olivier Favez, Tanguy Amodeo, Frederik Meleux, Bertrand Bessagnet, Laurent Menut, Didier Grenier, Yann Pellan, Alexandre Ockler, Benoit Rocq, Valérie Gros, Jean Sciare, Eva Léoz-Garziandia, *Air Lorraine*

The understanding of atmospheric particulate pollution still represents important issues, due various effects on climate and public health. These impacts are highlighted during pollution episode occurring in densely urbanized areas. In Northern Europe, and more particularly in France, most intense and persistent episodes usually occur during spring, and are characterized by a large-scale pattern, covering most of the territory. The presented work focuses on the investigation of the intense PM pollution episode that occurred in March 2015 in France from multi-site observations and near real time data. Aerosol Chemical Speciation Monitor and 7-wavelength aethalometer measurements were carried out in 4 sites across the country.

A climatology approach showed that this episode is associated at all sites with clear rain shortage compared to normal values. When looking back until 2007, unusually high PM concentrations are always associated to pronounced rain shortage. If this trend become confirmed, this could be an illustration of the regional impact of climate change, and its link with air quality issues.

Despite a clear dominance of secondary species, singularities from site to site are observed: While high amplitudes are observed in the Paris Basin, concentrations stayed fairly stable in Lyon and Metz, highlighting different transformation processes linked to different meteorology. Also, the increase of the PM<sub>1-2.5</sub> fraction emphasizes the need of a better characterization in terms of chemical composition and sources.

Also, a novel trajectory-based methodology allowed to distinguish advected from local/regional signal and showed that the sites are influenced by different long-range emission zones, and thus potentially different sources. This being of primarily importance to settle mitigation policies, coordinated over large geographical scales.

Finally, modelled PM<sub>1</sub> chemical composition by CHIMERE shows satisfying consistency for secondary pollutants, but exhibits high discrepancies for OM and BC, underlining the need of, among others, refined emission inventories and/or emission factors.

**1UA.6****Investigation of Primary and Secondary Processes in the Formation of Oxy-PAHs and Nitro- PAHs in Paris (France) by Conjoining On-line and Off-line Measurements.**

DEEPCHANDRA SRIVASTAVA, Olivier Favez, Nicolas Bonnaire, Emilie Perraudin, Valérie Gros, Eric Villenave, Alexandre Albinet, *INERIS/EPOC, Université Bordeaux, France*

The carbonaceous fraction of aerosols is composed of many compounds which constitute the organic carbon (OC) and elemental carbon (EC) components. Within the organic carbon component, Polycyclic Aromatic Hydrocarbons (PAHs) are the prevalent contributor to atmospheric pollution and emitted by incomplete combustion processes. Atmospheric oxidation of PAHs induces the formation of oxidized compounds such as oxygenated-PAHs (oxy-PAHs) and nitrated-PAHs (nitro-PAHs). The study of these PAH derivatives have become a prime concern as most are known to be carcinogenic and potentially more mutagenic than PAHs. These compounds may also instigate the formation of secondary organic aerosol (SOA), which may represent a large source of SOA in urban areas. The main objective of this study was to investigate the primary and secondary processes leading to the formation of oxy-PAHs and nitro-PAHs. This was accomplished by utilizing information obtained from intensive filter measurements along with online monitoring. To the best of our knowledge, this unique approach has not been explored yet. Measurements were conducted at SIRTAL-LSCE, which features, the suburban background conditions of Paris, France. Results highlight high concentrations of oxy-PAHs and nitro-PAHs during the period 14-21, March 2015, including specific secondary PAH derivatives as 6H-dibenz[b,d]pyran-6-one, acenaphthenequinone and 2-nitrofluoranthene. This suggests that such species could be generated through secondary processes related to high  $\text{NO}_3^-$  and  $\text{SO}_4^{2-}$  concentrations that can be explicitly observed considering ACSM results. Besides, the formation of 6H-dibenz[b,d]pyran-6-one seems to be highly influenced by the daytime chemistry while 2-nitrofluoranthene may be generated during nighttime (potentially involving  $\text{NO}_3$  radical chemistry). Interestingly, fossil-fuel-based Black Carbon ( $\text{BC}_{\text{ff}}$ ) and 1-nitropyrene (1-NP, a promising marker for diesel emissions) present similar temporal concentration profiles. Discussion will further accentuate diurnal variations, information about the day- and nighttime chemistry, and also usefulness of combining off-line and on-line measurements to ensure a comprehensive understanding of the prevalent atmospheric processes.

**1UA.7****Modeling of Gas Adsorption by Aerosol Plumes Emitted from Industrial Sources.** BORIS KRASOVITOV, Tov Elperin, Andrew Fominykh, Itzhak Katra, *Ben-Gurion University of the Negev, Israel*

Although it is commonly accepted that air pollution is dominated by local emissions many studies report that plumes of harmful pollutants can be transported by wind across oceans and continents and warn about the growing danger of air quality degradation. Adsorption of trace atmospheric gases such as  $\text{NO}_2$ ,  $\text{HNO}_3$  and Iodine-131 by aerosol particles contributes to the evolution of concentration distribution of the trace constituents and can affect chemical reactions in the atmosphere. In the present study we suggest a two dimensional model of adsorption of trace atmospheric constituents by aerosol particles in air pollution plume emitted from industrial source. The model is based on an application of theory of turbulent diffusion in atmospheric boundary layer in conjunction with plume dispersion model. The wind velocity profiles used in the simulations were fitted from data obtained in field measurements conducted in the Northern Negev (Israel) using the experimental wind mast. The developed model allows analyzing spatial and temporal evolution of adsorbate concentration in the gaseous phase as well as in the particulate matter. The calculations were conducted for the particulate matter  $\text{PM}_{2.5-10}$ , which is typical for industrial emissions. Analysis is performed for the different meteorological conditions and atmospheric stability classes. It is shown that concentration of the gases adsorbed by aerosol plume strongly depends on the level of atmospheric turbulence. The results of the present study can be useful in an analysis of different meteorology-chemistry models including gas adsorption by aerosol plumes emitted from industrial sources.

**2AC.1****Temperature-induced Variants in Secondary Organic Aerosol Formation from the Photo-oxidation of Fuel.**TERRY LATHAM, *Phillips 66*

Increasingly stringent environmental regulations on particulate matter are requiring a more advanced understanding of the emission, formation, and evolution of atmospheric particles. Industry and regulators require a more detailed understanding of these particle sources and particle formation pathways to ensure efficient and cost-effective regulatory compliance. This presentation will discuss the current challenges and uncertainties in quantifying and measuring secondary particulate matter from fuel sources, with an emphasis on variants in particle formation resulting from changes in ambient temperature. Secondary organic aerosol (SOA) formation resulting from the atmospheric photo-oxidation of gasoline and aromatics will be presented from experiments conducted at the Phillips 66 Research Center. The data set includes two years of outdoor chamber experiments conducted at temperatures ranging from -10 to 40C and comparison to similar experiments conducted in an indoor temperature-controlled chamber within the same temperature range. It will be shown that both fuel composition and temperature can have significant influences on SOA formation potential. The impact of temperature variations on both the kinetics and magnitude of SOA formation from fuels and aromatics will also be discussed.

**2AC.2****Modeling the Impact of Biomass-Burning Aerosol on Urban Areas.**CHANTELLE LONSDALE, Chris Brodowski, Matthew Alvarado, John Henderson, Jeffrey R. Pierce, John Lin, *AER*

Fresh biomass-burning aerosol evolve quickly, both physically and chemically, in the atmosphere due to coagulation, primary organic aerosol evaporation, and secondary organic aerosol formation. These aerosols are a complex mixture of organic species, black carbon, and inorganic salts. The size, number, and chemical composition of these particles depend on the type of vegetation that is burning, combustion efficiency, fire size and ambient conditions. Understanding and simulating this complex evolution is critical to understanding the impact of biomass-burning plumes on air quality and climate.

We present results from a new Lagrangian aerosol modeling tool, STILT-ASP, which is comprised of the Stochastic Time Inverted Lagrangian Transport (STILT) model with an integrated Aerosol Simulation Program (ASP). This tool allows for the identification of air parcels that were influenced by fire emissions during their transport to the model receptor (i.e. an urban monitoring site). The model then determines the contribution of primary emission (of PM<sub>2.5</sub>) and secondary chemical formation (both O<sub>3</sub> and PM<sub>2.5</sub>) from the fires to the pollutants in the parcel, and then sums these fire contributions across all parcels to determine the influence of the fire at the receptor. We present the results of two biomass-burning impact studies; 1) a fire in Bastrop, Texas in September 2011 influencing the Austin-Round Rock metropolitan area and 2) Pacific Northwest and Lower Mississippi River fires on the Houston metropolitan area in August 2011. We also discuss the preliminary integration of the System for Atmospheric Modeling (SAM) with ASP to model the evolution of plume scale biomass-burning aerosol number and size in order for this evolution to be better represented in aerosol microphysics and climate models.

**2AC.3**

**Refractive Index of Secondary Organic Aerosols from Oxidation of alpha-pinene and 1-methyl-nathalene.** JUSTIN DINGLE, Stephen Zimmerman, Justin Min, Roya Bahreini, *University of California Riverside*

Optical properties of secondary organic aerosols (SOA) formed in the atmosphere are still poorly characterized. In this study, we report on the complex refractive index (RI) of SOA formed from oxidation of alpha-pinene and 1-methyl-nathalene. Experiments will be conducted in a Teflon film chamber, under varying relative humidity and  $\text{NO}_x$  conditions, with the utilization of chlorine and hydroxyl radicals to initiate reactions of the precursor compounds. Optical extinction coefficient ( $\beta_{\text{ext}}$ ) at 632 nm will be measured using a Cavity Attenuated Phase Shift extinction monitor (CAPS- $\text{PM}_{\text{ex}}$ ), while absorption and scattering coefficients ( $\beta_{\text{scat}}$  and  $\beta_{\text{abs}}$  respectively) at 375 nm will be measured using a Photoacoustic Extinctionmeter (PAX-375). Additionally, aerosol size distributions will be measured with a Scanning Electron Mobility Sizer (SEMS). In order to determine SOA's RI, scattering (at 375 nm and 632 nm) and absorption coefficients (at 375 nm) of aerosols corresponding to the average measured size distributions will be calculated at 5 min intervals, using Mie Theory and initial guesses for the real (n) and imaginary (k) components of RI. In this calculation, it is assumed that SOA is non-absorbing at 632 nm. Values of RI will then be varied and calculations will be repeated until the comparison between the measured and calculated optical coefficients results in a minimum value for the modified Chi-square ( $\text{Chi}^2$ ) functions. Trends in the optimum values of n and k for different hydrocarbons and oxidation conditions will be investigated.

**2AC.5**

**Dinitrogen Pentoxide Reactive Uptake and Chlorine Activation on Authentic Biomass Burning Aerosol: Implications for Reactive Nitrogen and Halogen Budgets.** LEXIE GOLDBERGER, Adam Ahern, Lydia Jahl, Ryan Sullivan, Joel A. Thornton, *University of Washington, Seattle, WA*

Nitryl chloride ( $\text{ClNO}_2$ ), formed by the heterogeneous reaction of dinitrogen pentoxide ( $\text{N}_2\text{O}_5$ ) on chloride-containing particles, occurs in polluted marine environments elevating the oxidant budget<sup>1</sup>. Inland observations of  $\text{ClNO}_2$  in moderately polluted regions have motivated efforts to determine the source of particulate chloride, postulated as the limiting ingredient to  $\text{ClNO}_2$  formation<sup>2</sup>. Biomass burning is a major source of both particulate matter and reactive nitrogen oxide radicals, yet the rate and products of  $\text{N}_2\text{O}_5$  reactive uptake onto biomass burning aerosol have not been well studied. Using a smog reactor at Carnegie Mellon University coupled to a biomass combustion chamber with controlled particle and gas injection, we simulated the nocturnal evolution of  $\text{N}_2\text{O}_5$  in biomass burning plumes mixed with ozone. Smoke plumes were generated from a range of authentic fuel types including saw grass and white European birch, mixed into the 12 m<sup>3</sup> chamber, and exposed to 70-150 ppb of ozone and 0-60% relative humidity in the dark. Gaseous  $\text{N}_2\text{O}_5$ , nitric acid ( $\text{HNO}_3$ ),  $\text{ClNO}_2$ ,  $\text{Cl}_2$ , and HCl were monitored using a high resolution time of flight iodide adduct chemical ionization mass spectrometer. Particle size distributions and composition were monitored continuously with an SMPS and a Soot-Particle Aerosol Mass Spectrometer among other instruments.

We report on  $\text{N}_2\text{O}_5$  uptake coefficients as well as molar yields of  $\text{ClNO}_2$  and correlated changes in  $\text{Cl}_2$  and HCl. We assess the reactivity of  $\text{N}_2\text{O}_5$  on humidified soot particles relative to ammonium bisulfate probed in separate experiments. We report the halogen budget's dependences on RH and combustion fuel type as well as on the presence of radiation. These results suggest a potentially important impact of chlorine atom initiated oxidation in biomass burning plumes. The  $\gamma(\text{N}_2\text{O}_5)$  and yields of  $\text{ClNO}_2$ ,  $\text{Cl}_2$ , and HCl determined from this study will allow for more robust parameterizations of these compounds in atmospheric models.

1 Finlayson-Pitts, B. *Nature* 337,241-244(1989).

2 Thornton, J. *Nature* 464,271-274(2010).

**2AC.6**

**The Role of Morphology on the Rate and Products of Heterogeneous Oxidation of Organic Aerosol.** REBECCA SUGRUE, Christopher Lim, Martin Wolf, Daniel Cziczo, Jesse Kroll, *MIT*

Heterogeneous oxidation of organic aerosol (OA) by hydroxyl radicals can affect particle mass and composition over long atmospheric timescales (several days to weeks of atmospheric oxidation). However, previous studies on heterogeneous oxidation have for the most part used pure, organic particles, which may not be representative of ambient aerosols. In order to study the role of particle morphology on oxidation kinetics and mechanisms, we carried out a series of heterogeneous oxidation experiments on thin organic coatings. Ammonium sulfate particles were passed through a squalane reservoir to condense a thin (1-10 nm) layer of squalane (C<sub>30</sub>H<sub>62</sub>) on the seed particles then photochemically oxidized by exposure to hydroxyl radicals (OH) in a flow tube reactor. Oxidation kinetics and products were measured using an AMS and organic mass was measured using an SMPS and AMS PToF data; in addition, CCN activity of the oxidized particles was monitored. Coated aerosols underwent large changes in carbon oxidation state and CCN activity after relatively short atmospheric aging times (the equivalent of 1-3 days in the atmosphere), due to the high surface-area-to-volume ratios of the organic coatings. This work indicates that heterogeneous oxidation may change the chemical composition and properties of morphologically complex OA particles at a significantly faster rate than is currently assumed.

**2AC.7**

**How Do Atmospheric Mineral Dust Particles Promote the Formation of Sulfate?** JIYEON PARK, Myoseon Jang, *University of Florida*

Mineral dust particles are one of the largest contributors to aerosol mass loading in the atmosphere. The surfaces of mineral dust particles can act as sinks for criteria air pollutants, such as sulfur dioxide (SO<sub>2</sub>) and NO<sub>x</sub>. Mineral dust particles can heterogeneously catalyze the oxidation of SO<sub>2</sub> ramping to the formation of sulfate. However, there is little knowledge about the mechanisms of photocatalytic oxidation of SO<sub>2</sub> on the surface of mineral dust particles. In this study, we investigated the kinetics and mechanisms of SO<sub>2</sub> oxidation on the surface of Gobi desert dust (GDD) and Arizona test dust (ATD) particles using a 2-m<sup>3</sup> indoor photo-irradiation chamber. Metal oxides in mineral dust particles acts as a semiconductor to form an electron-hole pair, which can react with the water molecules adsorbed on the surface of dust particles and produce OH radicals. These OH radicals contribute to oxidation of the SO<sub>2</sub> or sulfite ions. In general, the catalytic ability of GDD is higher than that of ATD because the mineral oxide fraction of GDD particles is higher than that in ATD particles. The rate constant for heterogeneous oxidation of SO<sub>2</sub> is determined using the sulfate concentrations measured with a particle into liquid sampler coupled with ion chromatography (PILS-IC) over the course of chamber experiment. The rate constants of heterogeneous oxidation of GDD are measured under varying humidity, ozone and NO<sub>x</sub> and compared with those from ATD. The hygroscopic properties of fresh dust particles were compared to those of aged dust particles using a Fourier transform infrared spectroscopy (FTIR). To study the chemical reactions between sulfuric acid and alkaline carbonates on dust particles, aerosol acidity ([H<sup>+</sup>]C-RUV, mol L<sup>-1</sup> by aerosol volume) was measured using a colorimetry integrated with a reflectance UV-Visible spectrometer (C-RUV).

**2AC.8**

**Estimation of Polydispersed Aerosol Optical Properties during Smog and Asian Dust Events in Korea.** CHANG HOON JUNG, JiYi Lee, Yong Pyo Kim, *Kyungin Women's University*

This study investigates the optical properties of aerosol for different meteorological events, including smog and Asian dust. Sampling was performed in Seoul, a representative urban site in Korea. Organic carbon (OC) and inorganic species were measured, and the OC and Elemental Carbon (EC) in the sample filters were analyzed using the thermal/optical transmittance (TOT) method. During the sampling period, data from the smog and Asian dust events data was compared with that from normal days.

The calculated optical properties were compared with the Aerosol Optical Thickness (AOT) obtained from remote sensing data, and the results showed comparable trends.

The results show the comparison of the aerosol extinction efficiency and AOT (Aerosol Optical Thickness) during the sampling periods. The aerosol extinction efficiency of PM<sub>2.5</sub> is compared with those for AOT. The internal mixture and the fully external mixture are both considered, and we compared the AOT data from Seoul. A close relationship exists between AOT and the extinction coefficient. A comparison between internal mixture and fully external mixture does not show much of a discrepancy.

This study also shows a comparison of the aerosol extinction efficiency and the AOT (Aerosol Optical Depth) during the sampling periods when each composition has been excluded. The slope changes due to each aerosol, and the correlation coefficient shows different values that depend on the composition. A comparison with the correlation coefficient for the total aerosol, excluding the OC aerosol, shows a more relevant relation when compared to AOT, which means that the explanation of OC in AOT is not enough.

**2AC.9**

**Photooxidation Reactions of Polycyclic Aromatic Hydrocarbons in the Presence of Environmentally Relevant Metals.** JOHN HAYNES, Keith Miller, Brian Majestic, *University of Denver*

This study focuses on the interaction between polycyclic aromatic hydrocarbons (PAH) and soil-derived metals. PAH are introduced to the atmosphere through a variety of natural and anthropogenic sources. They are considered persistent pollutants and therefore undergo long range transport. Long term exposure to PAH have been implicated with pulmonary and cardiovascular diseases, with some considered carcinogenic. The extended atmospheric lifetimes of PAH lend themselves to longer exposure times to sunlight and oxidizing pollutants, potentially producing other branched and oxidized PAH (oxPAH) products such as benzo-e-pyrene and naphthol, which are more toxic than their parent compounds. Metals commonly found in atmospheric environments may serve as catalysts or direct oxidizing agents in the presence of sunlight to promote the production of oxPAH by donating electrons to surrounding molecules analogous to complexation reactions. Additionally, soluble metals may use ultraviolet radiation as a catalyst in an electron transfer interaction with water molecules to produce hydroxyl radicals, mimicking a Fenton-like reaction. Hydroxyl radicals are highly reactive oxidation agents and may initiate several oxidizing pathways, including proximal PAH resulting in the production of oxPAH.

The production of oxidized organic compounds due to metal assisted reactions is monitored by HPLC, while they are identified by LCMS. Reaction conditions use varying light exposure, metal concentration, and duration. Initial PAH data include many new HPLC peaks during and following light exposure periods, which indicate the production of several species of oxPAH. Increasing absorbances at specific retention times throughout the reaction demonstrate the evolution of explicit reaction pathways toward predictable products. Combining the formation of products from specific PAH species with photo-reactions conducted against individual major soil components including iron, aluminum and silica allows for the determination of specific reaction mechanisms. This will offer a comparison of each compound and its contribution to these genres of reactions.

**2AC.10**

**Lifetime Evaluation of Biomass Burning Markers in Low Temperature Conditions.** VIKRAM PRATAP, Shunsuke Nakao, *Clarkson University*

Specificity and stability of markers are essential in source apportionment studies. Although organic markers can provide rich information on specific sources, recent studies suggest significant reactivity of biomass burning markers, such as levoglucosan, under typical summertime conditions in the context of wildfires. We note, however, that no experimental study has focused on wood smoke marker stability in wintertime conditions that is most relevant in assessing the contribution of wood stove to regional air pollution. This study will perform chamber experiments to quantify lifetime of primary and secondary wood smoke markers in a wide temperature range, including winter conditions. An 8 m<sup>3</sup> Teflon outdoor chamber will be used to study photochemistry of markers in real wood smoke. The diluted smoke in the chamber will be analyzed for time evolution of markers and gaseous species. Finally, we will assess the applicability of various wood smoke markers for source apportionment studies by comparing experimental results and models. A preliminary model calculation shows that the lifetime of levoglucosan increases to nearly two weeks as the temperature goes below 0°C, suggesting that levoglucosan may be considered reasonably stable in wintertime source apportionment studies.

**2AC.11**

**Gas and Particle Phase Products of the Reactions of 1-Alkenes with OH Radicals in the Presence of NO.** JULIA BAKKER-ARKEMA, Paul Ziemann, *University of Colorado*

Controlled environmental chamber studies are important for determining atmospheric reaction mechanisms and gas and aerosol products formed in the oxidation of volatile organic compounds (VOCs). Such information is necessary for developing detailed chemical models for use in predicting the atmospheric fate of VOCs and also secondary organic aerosol (SOA) formation. In this work, we explored the reaction of 1-tetradecene [CH<sub>3</sub>(CH<sub>2</sub>)<sub>11</sub>CH=CH<sub>2</sub>] with OH radicals in the presence of NO as a model for the oxidation of alkenes, which are the dominant components of non-methane biogenic VOC emissions to the atmosphere. Particle-phase products were analyzed in real time with a thermal desorption particle beam mass spectrometer, and off-line by collection onto filters and subsequent analysis of functional groups by derivatization-spectrophotometric methods developed in our lab. Derivatized products were also separated by liquid chromatography for molecular quantitation by UV absorbance and identification using chemical ionization-ion trap mass spectrometry. Gas phase aldehydes were analyzed in real time with a proton transfer-reaction mass spectrometer and off-line by collection and derivatization on a 5-channel denuder and subsequent analysis by gas chromatography. Previous work in this lab has quantified the yields of beta-hydroxynitrates and dihydroxynitrates, and here we quantified the other two major expected products: tridecanal and dihydroxycarbonyls, which are formed by decomposition and isomerization of alkoxy radical intermediates. Tridecanal was also studied with regards to its potential role in particle-phase formation of hemiacetals, and a potential contribution to SOA from unexpected carboxylic acid products was investigated. Together, the gas and particle phase measurements provide a more comprehensive view of the mechanism of alkene oxidation and SOA formation.

**2AC.12**

**Solidification of Organic Aerosol Particles Caused by Glyoxal +OH Radical Reactions.** ALYSSA ANDRETTA, David De Haan, *University of San Diego*

The recent discovery that atmospheric organic aerosol particles are often semi-solid, rather than liquid, encourages the rethinking of how organic aerosol processes work. In bulk-phase aqueous studies performed at high concentrations, glyoxal + OH radical reactions have been reported as a source of oligomers. To determine whether this oligomer formation process can lead to rapid solidification of aerosol particles, a solution of glyoxal and hydrogen peroxide was mixed, photolyzed with a UV lamp at 366 nm, and aerosolized into a Teflon chamber via diffusion dryers. The resulting particles were exposed to increasing levels of humidity (from 25% to 50% RH) while their size distribution was measured. Control experiments were performed without UV light exposure or without HOOH. Unphotolyzed glyoxal + HOOH solutions yielded the largest aerosol particles, perhaps because they remained liquid. Photolyzed (glyoxal +  $\dot{Y}$ OH radicals) solutions generated significantly smaller aerosol particles in the chamber. Oxidation of glyoxal by OH radicals may have led to fragmentation reactions and loss of CO<sub>2</sub> to the gas phase. Alternatively, oligomers produced by glyoxal +  $\dot{Y}$ OH radical reactions may have solidified the droplet surface during drying, producing hollow, semi-solid aerosol which later “popped” to produce smaller fragments, as previously observed in Raman microscopy experiments. In humidification experiments, aerosol generated from solutions without  $\dot{Y}$ OH radicals increased the most in size, while solutions with  $\dot{Y}$ OH radicals increased the least. This suggests that oligomers produced by the glyoxal +  $\dot{Y}$ OH radical reaction are comparatively hydrophobic.

**2AC.13**

**Formation of Secondary Brown Carbon in the Multiphase Simulation Chamber (CESAM) through Aldehyde and Amine-Initiated Maillard Reactions.** HANNAH G. WELSH, Raunak Pednekar, Elyse Pennington, Jason Casar, Lelia Hawkins, David De Haan, Aki Pajunoja, Jean-François Doussin, Mathieu Cazaunau, Edouard Pangui, Aline Gratien, Paola Formenti, Lorenzo Caponi, *Harvey Mudd College*

Laboratory measurements support the notion that secondary organic compounds—with absorbance spectra characteristic of atmospheric humic like substances (HULIS)—can form in aerosol and cloud water. Atmospheric HULIS encompass a wide range of properties with notable features such as broad, wavelength-dependent absorbance tailing into the visible region, highly functionalized and high molecular weight character, and, in some cases, appreciable organic nitrogen. In this work, we simulate the formation and evaporation of clouds in the presence of aldehydes and amines using a multiphase chamber designed for this purpose (Multiphase Atmospheric Experimental Simulation Chamber at the University of Paris Est Creteil, France). Particle absorbance was determined with a Particle Into Liquid Sampler-Capillary Waveguide system and was normalized to integrated particle mass measured with a scanning mobility particle sizer. Measurements indicate that browning occurs prior to cloud formation in the presence of methylamine and methylglyoxal but that browning increases following cloud formation. Further, artificial sunlight appears to bleach the products reducing overall aerosol absorbance. A second round of experiments conducted in summer 2016 provide more chemical detail and reproducibility of preliminary measurements.

**2AC.14**

**Characterization of Aerodyne Potential Aerosol Mass Oxidative Flow Reactor.** CHIRANJIVI BHATTARAI, Vera Samburova, Hans Moosmuller, Andrey Khlystov, *Desert Research Institute*

Secondary organic aerosols (SOA) are formed in the atmosphere by oxidation of volatile organic compounds (VOCs). The atmospheric oxidation occurs on time scales ranging from minutes to days depending upon the concentration of oxidants and VOCs. It is not feasible to conduct experiments in a laboratory on such a long time scale. One way of studying the atmospheric oxidation process is to use a smog chamber, where VOCs, ozone, and UV irradiation are present to mimic atmospheric conditions. However, smog chambers are fairly large and are limited to measurements for only a few hours due to wall losses. A few years ago, a concept of Potential Aerosol Mass (PAM) reactor has been introduced and successfully applied in numerous laboratory and field studies. A PAM reactor is a cylindrical flow-through reactor with UV lamps installed inside to irradiate sample air. Due to a strong UV irradiation, high concentrations of hydroxyl radicals can be achieved. Thus, within a relatively short residence time in the PAM, oxidation equivalent to hours or days in the atmosphere can be achieved. Recently, Aerodyne Research Inc. has commercialized the PAM concept (Aerodyne PAM Oxidative Flow Reactor). In the present study, we will report laboratory characterization of an Aerodyne PAM, which includes residence time distribution of air inside the chamber, particle losses, hydroxyl radical production, and a comparison of aerosol yields of isoprene with those reported in the literature.

**2AC.15**

**Addition of an SVOC/IVOC Trap for the Thermal Desorption Aerosol Gas Chromatograph (TAG) and Its Application in Studying the Phase-Partitioning of Key Molecular Tracers in Lab-Generated Biomass Burning Organic Aerosol.** CLAIRE FORTENBERRY, Michael Walker, Yaping Zhang, Dhruv Mitroo, Christopher Oxford, William Brune, Brent Williams, *Washington University in St Louis*

Semivolatile organic compounds (SVOCs) and intermediately volatile organic compounds (IVOCs) are known to compose a significant fraction of biomass burning emissions. While key molecular tracers for biomass burning organic aerosol (BBOA) have been characterized in previous studies, the gas-to-particle phase partitioning of many of the SVOCs/IVOCs is expected to change with photochemical aging and therefore merits further study.

The Thermal desorption Aerosol Gas Chromatograph (TAG) is able to achieve in situ ambient collection and molecular level speciation with hourly time resolution. While the original design of the TAG is suitable for collecting and analyzing particle-phase emissions, it has limited SVOC/IVOC analysis capability due to its inertial impaction collection and thermal desorption (CTD) system. Subsequent versions of the TAG (i.e., the SV-TAG) have utilized a metal filter cell to additionally collect the gas fraction of SVOC/IVOCs and rotates sampling with and without a denuder to separate the gas and particle fraction. Here, an alternate approach to separately collect the gas fraction parallel to the particle fraction is applied. This approach is an add-on to the original TAG system and does not replace components. In this study, the collection capability of a newly developed SVOC/IVOC trap, consisting of a custom-built diffusion denuder (for gas-phase collection) installed in parallel with denuded sampling on the original CTD cell (for particle-phase collection), was characterized using lab-generated biomass burning emissions, which were aged using a Potential Aerosol Mass (PAM) flow reactor to simulate different levels of atmospheric aging. The phase-partitioning of key molecular tracers was determined using results from the SVOC/IVOC trap and the CTD cell in the TAG. Finally, positive matrix factorization (PMF) results for both gas- and particle-phase material will be presented.

**2AC.16**

**Effect of Functional Groups on Composition and Yields of SOA Formed from Reactions of VOCs with OH Radicals in the Presence of NO<sub>x</sub>.** LUCAS ALGRIM, Paul Ziemann, *University of Colorado*

In a series of environmental chamber experiments we have identified major products and measured the yields of secondary organic aerosol (SOA) formed from the reactions of C<sub>12</sub> ketone, C<sub>10</sub> alcohol, and C<sub>10</sub> nitrate position-isomers with OH radicals in the presence of NO<sub>x</sub>. Gas- and particle-phase products were analyzed using real-time and offline mass spectrometry as well as gas and liquid chromatography. Although particle composition was similar for different VOC isomers containing a particular functional group, SOA yields depended on functional group position on the carbon chain. The effect of functional groups on yields can be explained by differences in vapor pressures of parent VOCs and the fate of alkoxy radical intermediates. For example, in the case of ketones important observed differences from alkane chemistry were enhanced decomposition via alpha-cleavage from alpha-ketoalkoxy radicals, and the ability of the added keto group to allow particle-phase cyclic hemiacetal formation. Results also indicate that both 1,5- and 1,6-H shift isomerizations are significantly hindered when the keto group is part of the transition state ring. Effects of hydroxyl and nitrooxy groups have also been determined and will be discussed. These results will be used to help evaluate and improve VOC oxidation and SOA formation mechanisms and models used to predict SOA formation in the atmosphere.

**2AC.17**

**Characterization of the Aqueous Oxidation of Glyoxal and Methylglyoxal in the Presence of Salts Using a Quartz Crystal Microbalance.** Hannah Holst, Alvin Burrows, Maeve Ryan, CHRISTEN STROLLO, *CSBSJU*

The focus of this project is to determine the physical properties of products formed from the aqueous phase reactions of glyoxal with hydroxyl radicals. Glyoxal and methylglyoxal are the most abundant dicarbonyls in the atmosphere and contribute to the formation of secondary organic aerosol (SOA). A quartz crystal microbalance (QCM) equipped with a humidity controlled flow cell is used to measure the deliquescence of a variety of reaction solutions. Solutions are aspirated onto the quartz crystal and subsequently dried, then exposed to increasing humidity. Understanding SOA in aqueous aerosols has the potential to eliminate the gap between predicted and measured SOA formed from gas-partitioning. Here, we describe the specific characteristics of the aqueous reaction of dicarbonyls commonly present in the atmosphere as well as the effect of the presence of salts has on the deliquescence of the resultant solutions.

**2AC.18**

**Modeling the Secondary Organic Aerosol Formation of Mixed Biogenic Systems from Both Partitioning and Aerosol Phase Reactions.** ROSS BEARDSLEY, Myoseon Jang, *University of Florida*

Secondary organic aerosol (SOA) are produced by the photooxidation products of volatile organic compounds (VOC) via partitioning and aerosol phase reactions. Models have been developed to constrain atmospheric SOA formation, but none are able to comprehensively represent SOA formation under the wide range of conditions of the ambient atmosphere. VOC photooxidation produces a large number of reactive species that form SOA from partitioning, aqueous phase reactions, and oligomerization reactions in organic-only liquid phases. In order to fully constrain atmospheric SOA formation, a comprehensive model must be developed that is able to predict the SOA formation in all phases. In this study, the UNIPAR model was updated to simulate the SOA formation of mixed  $\alpha$ -pinene/isoprene SOA in the absence and presence of acidic inorganic aerosol. UNIPAR utilizes a near-explicit chemical mechanism to simulate photooxidation, and then lumps the secondary products as a function of aerosol phase reactivity and vapor pressure. SOA formation is predicted as function of aerosol phase composition and VOC/NO<sub>x</sub> within a module only requiring inputs currently available in regional models.

While isoprene SOA are polar and reactive in aqueous phase reactions,  $\alpha$ -pinene SOA are primarily non-polar and unreactive. Therefore, in the presence of a deliquesced inorganic seed, the mixed biogenic SOA undergo liquid-liquid phase separation forming an inorganic aqueous phase and a polar organic phase. In this system,  $\alpha$ -pinene products will partition predominantly into the non-polar organic phase, while the isoprene derived products will be split between both phases depending on the physicochemical properties of each compound. Since UNIPAR lumps products using thermodynamic properties, the model is able to handle the distribution and reaction of the lumped product in both phases. The model was evaluated using outdoor chamber data and the influence of liquid water content, aerosol acidity, and VOC/NO<sub>x</sub> ratio on the mixed biogenic SOA are discussed.

**2AC.19**

**Investigating Secondary Aerosol Formation from Agricultural Amines and Reduced Sulfur Compounds.** PAUL VAN ROOY, Kathleen Purvis-Roberts, Philip Silva, David R. Cocker III, *University of California, Riverside*

Gas phase amines and reduced sulfur compounds are often co-emitted from agricultural processes. Amines have been recently recognized as potentially major sources of agricultural aerosol formation, while the reduced sulfur compounds are largely ignored. There is a severe lack of knowledge and understanding regarding the interactions that take place between these co-emitted pollutants to form aerosol. As part of a collaboration between UC Riverside, Western Kentucky University, and Claremont colleges, environmental chamber experiments were conducted in order to investigate secondary organic aerosol formation and properties from these sources. Trimethylamine (TMA) was injected into the environmental chamber along with a reduced sulfur compound (dimethylsulfide, dimethyldisulfide, methanethiol, or hydrogen sulfide) and the hydroxyl radical for oxidation. The aerosol yields and characteristics from the oxidation of the combination of precursor were much different than aerosol from either the amine or sulfur compound alone. The amine and the sulfurs interacted quickly to form a substantial concentration of aerosol, much greater than the hydroxyl radical oxidation of the individual components. For example, dimethyldisulfide and TMA with the hydroxyl radical formed nearly 900 micrograms per cubic meter of aerosol after three hours, while separately they formed no more than 20 micrograms per cubic meter. In some cases (e.g. TMA and hydrogen sulfide) aerosol volatility remained constant during the experiment while in other cases (e.g. TMA and dimethyldisulfide) aerosol volatility changed with time. Bulk aerosol composition varied with reduced sulfur compound used. TMA with dimethyldisulfide showed large sulfate peaks. Other combinations (e.g. TMA and methanethiol) showed peaks at high mass-to-charge ratios, consistent with oligomer formation. This novel investigation provides important information on agricultural aerosol formation. Knowledge gained through this study may be useful in regional air quality models as well as particulate matter regulations, specifically for large agricultural operations.

**2AC.20**

**Exploring Potential Brown Carbon Chromophores with Mass Spectrometry and NMR.** PAIGE AIONA, Sergey Nizkorodov, Alexander Laskin, Julia Laskin, Peng Lin, *University of California, Irvine*

Atmospheric aerosols have the ability to scatter and absorb radiation, resulting in a strong influence on climate. One particular type of organic aerosol of increasing interest is "brown carbon" (BrC), which absorbs visible and near-ultraviolet light to varying degrees. Primary BrC is emitted directly from biomass and fossil fuel burning, but it can also be formed by secondary reactions in the atmosphere. It is unknown what types of compounds are responsible for the "brown" color of secondary BrC, but it is suggested by previous studies that nitrogen organic compounds (NOC) are often associated with BrC. This study will investigate the compound(s) in a variety of model BrC samples, such as products of reactions between atmospherically relevant carbonyl compounds and isotopically labelled ammonium nitrate and sulfate. We will determine the chemical form of nitrogen in BrC using nitrogen-15 nuclear magnetic resonance (NMR) spectroscopy. In addition, we will use high resolution mass spectrometry and optical absorption spectroscopy to identify BrC compounds, and fluorescence spectroscopy to further constrain its chemical properties.

**2AC.21**

**Epoxide Formation from Heterogeneous Oxidation of Polycyclic Aromatic Hydrocarbon with Gas-phase Ozone.** SHOUMING ZHOU, Leo Yeung, Scott Mabury, Jonathan Abbatt, *University of Toronto, Toronto, Canada*

Polycyclic aromatic hydrocarbons (PAHs) are a class of ubiquitous air pollutants generated as by-products from incomplete combustion processes. PAHs can also be formed in indoor environments by meat cooking, candle burning and tobacco smoke. Due to their toxic effects on humans, PAHs and their biological/chemical degradation have received extensive studies. While several mechanisms for metabolic activation of PAHs have been proposed, bay-region diol-epoxide formation is believed to play an essential role in the toxicity of PAHs. Toxicological studies also show that the mono epoxides from biotic degradation of PAHs are mutagenic and cytotoxic. Studies on the chemical degradation of PAHs, on the other hand, have shown the formation of a series of oxygenated products, including phenols, quinones, carbonyls and carboxylic acids. To date only one study reported the formation of mono epoxide from oxidation of benzo[a]pyrene (BaP) with ozone.

In this presentation, we will show the experimental evidence of epoxide formation from heterogeneous oxidation of BaP with ozone. The epoxides were derivatized with N-acetylcysteine (NAC) and then analyzed by an LC-MS/MS. In addition to mono epoxide, diol epoxides were determined for the first time from BaP/O<sub>3</sub> system. By assuming similar ionization efficiencies between the diol epoxides from the reaction and the standards, a diol epoxide yield is estimated to be as high as ~25%. Moreover, mono and diol epoxides were also observed when BaP was exposed to indoor air.

**2AC.22**

**Formation and Evolution of Molecular Products in alpha-Pinene Secondary Organic Aerosol.** XUAN ZHANG, Renee McVay, Dandan Huang, Nathan Dalleska, Bernard Aumont, Richard Flagan, John Seinfeld, *California Institute of Technology*

Much of our understanding of atmospheric secondary organic aerosol (SOA) formation from volatile organic compounds derives from laboratory chamber measurements, including mass yield and elemental composition. These measurements alone are insufficient to identify the chemical mechanisms of SOA production. We present here a comprehensive dataset on the molecular identity, abundance, and kinetics of alpha-pinene SOA, a canonical system that has received much attention owing to its importance as an organic aerosol source in the pristine atmosphere. Identified organic species account for 58 ~ 72% of the alpha-pinene SOA mass, and are characterized as semi/low-volatility monomers and extremely low volatility dimers, which exhibit comparable oxidation state yet different functionalities. Features of the alpha-pinene SOA formation process are revealed for the first time from the dynamics of individual particle-phase components. While monomeric products dominate the overall aerosol mass, rapid production of dimers plays a key role in initiating particle growth. Continuous production of monomers is observed after the parent alpha-pinene is consumed, which cannot be explained solely by gas-phase photochemical production. Additionally, distinct responses of monomers and dimers to alpha-pinene oxidation by ozone vs. hydroxyl radicals, temperature, and relative humidity are observed. Gas-phase radical combination reactions together with condensed-phase rearrangement of labile molecules potentially explain the newly characterized SOA features, thereby opening up further avenues for understanding formation and evolution mechanisms of alpha-pinene SOA.

**2AC.23**

**Direct Measurements to Compare the Surface and Bulk Properties of Mixed Component Aerosol Droplets: Simultaneous Surface Tension and Viscosity Measurements.** BRYAN R. BZDEK, Allen E. Haddrell, Young-Chul Song, David Topping, Jonathan P. Reid, *University of Bristol*

Aerosol surface tension and viscosity impact key atmospheric processes such as cloud droplet activation, semivolatile partitioning, and chemical aging. Direct measurements that compare the surface composition of an airborne particle to bulk properties are required. We will report studies that explore both the surface and bulk character of a range of organic aerosol surrogates for atmospheric aerosol. Both properties are simultaneously measured on the same droplet using holographic optical tweezers. Two optically trapped droplets with volumes ~1 pL (radii ~5-10 micrometres) are equilibrated to a desired relative humidity and are coalesced. The coalescence event is monitored using elastically backscattered light directed to an oscilloscope to extract highly time resolved changes in droplet shape (100 ns time resolution). These changes in shape follow a damped oscillator and permit simultaneous determination of both the droplet surface tension and viscosity to <2 mN/m and <1 mPa·s, respectively. Initial measurements of these properties on droplets with supersaturated solute states indicate that surface tension values can be inferred from models of subsaturated bulk measurements. The effect of surfactants on droplet surface tension and the response of droplet surface tension to rapid changes in relative humidity (designed to mimic rapid water vapour condensation during activation) for particles of varying viscosity will be discussed. Finally, surface tension measurements of droplets exposed to laboratory and ambient air suggest aerosol surface tension may trend towards values consistent with those of surfactant coated droplets in most environments, regardless of the droplet bulk composition and potentially impacting our understanding of aerosol activation.

**2AC.24**

**Aqueous-phase Photooxidation of Dimeric Compounds Arising from alpha-pinene.** RAN ZHAO, Dana Aljawhary, Alex K. Y. Lee, Jonathan Abbatt, *University of Toronto*

Our current understanding of the chemistry occurring in the alpha-pinene ozonolysis reaction system is still incomplete. In particular, the chemistry of dimers and higher molecular weight organic compounds remains elusive. Kinetic data for the photochemistry of dimeric compounds is limited due to the fact that the dimeric compounds are comprised of a large number of trace compounds with highly variable structures and functionalities, making the separation and identification of each individual compound highly challenging. In this study, we have investigated the aqueous-phase photooxidation of dimeric compounds arising from the alpha-pinene ozonolysis system. SOA was produced in a 1 m<sup>3</sup> chamber, and the water-soluble fraction of particles collected on a filter was photo-oxidized in the bulk aqueous phase. Employing Aerosol Chemical Ionization Mass Spectrometry (Aerosol-CIMS), we have observed rapid decay of dimeric compounds upon oxidation by the OH radical. Using pinonic acid as a reference compound, we obtained the effective 2nd order rate constant of total dimer signal reacting with the OH radical ( $k_{OH}^{II}$ ). The  $k_{OH}^{II}$  values monitored by three different reagent ions (iodide, acetate and protonated water clusters) showed agreement within a factor of two. Given that the three reagent ions are detecting three overlapping yet diverging populations of compounds, we have arrived at a generalized  $k_{OH}^{II}$  value for OH oxidation of dimeric compounds:  $1.5 \pm 0.8 \times 10^9 \text{ M}^{-1} \text{ s}^{-1}$ . Results from this study demonstrate that dimeric compounds from alpha-pinene ozonolysis react with the OH radical essentially at the collision-limited rate. The  $k_{OH}^{II}$  derived from this work can be incorporated into existing cloudwater chemistry models. We further performed positive matrix factorization analysis to the Aerosol-CIMS data, and the results are discussed.

**2AC.25**

**Comprehensive Modeling Study of Chemistry of Oxidation Flow Reactors.** ZHE PENG, Julia Lee-Taylor, Douglas Day, Amber Ortega, Brett Palm, Weiwei Hu, Harald Stark, Rui Li, Kostas Tsigaridis, Richard Valorso, Bernard Aumont, Sasha Madronich, William Brune, Jose-Luis Jimenez, *University of Colorado-Boulder*

Oxidation flow reactors (OFRs) using OH produced from low-pressure Hg lamps at 254 nm (OFR254) or both 185 and 254 nm (OFR185) are commonly used in aerosol chemistry and other fields. OFR254 requires the addition of externally formed O<sub>3</sub> since OH is formed from O<sub>3</sub> photolysis, while OFR185 does not. We perform a comprehensive modeling study of OFR chemistry and provide guidelines for OFR operation. OFR radical chemistry is systematically characterized as a function of H<sub>2</sub>O concentration (H<sub>2</sub>O), UV intensity (UV), external OH reactivity (OHR<sub>ext</sub>), and initial O<sub>3</sub> concentration (only for OFR254). OH suppression due to OHR<sub>ext</sub> can be orders of magnitude, which can be understood in terms of increase in OH loss rate. The similarities and differences between the evolution of OH reactivity and HO<sub>x</sub> recycling across VOCs is explored with the fully explicit GECKO-A model. We also investigate the contribution of non-OH reactants (UV, O<sub>3</sub> etc.) to the VOC fate in OFR. For field studies in forested regions or the LA urban area, VOCs are predominantly consumed by OH. At low H<sub>2</sub>O and/or high OHR<sub>ext</sub>, the importance of non-OH reactants is enhanced. Non-tropospheric VOC photolysis (at 185 and 254 nm) may have been a problem in some laboratory and source studies, but can be avoided by experimental planning, which may be aided by the OFR exposure estimator (<https://sites.google.com/site/pamwiki/hardware/estimation-equations>). RO<sub>2</sub> fate under most conditions is similar to the low-NO<sub>x</sub> atmosphere. Self-reactions of primary RO<sub>2</sub> may be significant at high OHR<sub>ext</sub>. NO is rapidly oxidized in OFR under most conditions, while it may have a lifetime >10 s and react with RO<sub>2</sub> significantly under very specific conditions in OFR185. A comparison of multiple aspects of OFRs with typical chamber studies and with the atmosphere is presented. This study further establishes OFRs' usefulness and enables better experiment design and interpretation.

**2AC.26**

**The Effect of Different Atmospherically Relevant Salts and Salt Mixtures on Aqueous Phase Partitioning of Organic Vapors.** CHEN WANG, Ying Duan Lei, Frank Wania, *University of Toronto*

Dissolved inorganic salt(s) influence the partitioning of organic compounds into the aqueous phase. This influence is especially significant in atmospheric aerosol, which usually contains highly concentrated solutions of various ions, including sodium, ammonium, chloride, sulfate and nitrate. These ions originate from both natural (e.g. sodium chloride from sea spray) and anthropogenic sources (e.g. nitrate and sulfate from  $\text{NO}_x$  and  $\text{SO}_2$ ). However, empirical data on this salt effect are very sparse in the literature. Since it is very difficult to quantify the contribution of individual ions, salting constants are typically only measured for combined salts. In this study, the partitioning of numerous organic compounds into solutions of  $\text{Na}_2\text{SO}_4$ ,  $\text{NH}_4\text{NO}_3$ , and  $\text{NH}_4\text{Cl}$  was measured and compared with existing data for  $\text{NaCl}$  and  $(\text{NH}_4)_2\text{SO}_4$ . Salt mixtures were also tested in order to establish whether the salt effect is additive. In general the salt effect for various ion combinations showed a trend of  $\text{Na}_2\text{SO}_4 > (\text{NH}_4)_2\text{SO}_4 > \text{NaCl} > \text{NH}_4\text{Cl} > \text{NH}_4\text{NO}_3$  for the studied organic compounds. This implies the following relative strength of the salt effect of individual anions:  $\text{SO}_4^{2-} > \text{Cl}^- > \text{NO}_3^-$  and cations:  $\text{Na}^+ > \text{NH}_4^+$ . The salt effect of different salts is moderately correlated. Data obtained in this study can be used for predictive model development. The experimental data indicate that the salt effect of mixtures may not be entirely additive. However, the deviation from additivity, if it exists, is small. Data of very high quality are required to establish whether the effect of constituent ions or salts is additive or not.

**2AC.27**

**A Study of the Chemical Composition and Hygroscopicity of Chemically Aged Cooking Organic Aerosol.** Antonios Tasoglou, Yanwei Li, Evangelia Kostenidou, Peishi Gu, Leif Jahn, Kerrigan Cain, SPYROS PANDIS, *Carnegie Mellon University*

Cooking activities have been identified as an important source of particulate matter in urban areas. However, the atmospheric evolution of the cooking organic aerosol (COA) remains unknown. Smog chamber experiments were conducted to study the chemical aging of emissions from meat cooking (hamburger charbroiling). Two types of chemical aging experiments were conducted either by adding ozone or exposing the emissions to UV light. The changes in the COA chemical composition were investigated using a Soot Particle Aerosol Mass Spectrometer (SP-AMS) and Positive Matrix Factorization analysis. The hygroscopicity and the volatility of the fresh and aged COA were measured using a Cloud Condensation Nuclei Counter (CCNC) and a thermodenuder. The shape of the COA particles was characterized using electron microscopy. Rapid changes in both the chemical and physical properties of COA during atmospheric aging were found. A simple model based on the results of the PMF analysis was developed for the description of the corresponding changes.

**2AC.28**

**Thermodynamic Properties of Weakly Dissociating Organic Acids Found in Atmospheric Aerosols.** LUCY NANDY, Cari Dutcher, *University of Minnesota, Twin Cities*

Organic acids make up a significant fraction of the organic mass in atmospheric aerosol particles. Predictions of gas-liquid-solid equilibrium partitioning of the organic acid by thermodynamic modeling and measurements is critical for accurate determination of atmospheric particle properties and processes at temperatures and relative humidities relevant to the atmosphere. Statistical mechanics based on an existing adsorption isotherm model for capturing thermodynamic properties of multicomponent aqueous solutions over the entire concentration range (Dutcher et al. JPC 2011, 2012, 2013, Ohm et al. JPC 2015), is applied to partially dissociating organic acids to understand atmospheric aerosol water content. In addition to the modeling approach, water loss of aerosol particles is measured by microfluidic experiments to parameterize the model.

In this work, weakly dissociating semi-volatile organic acids like dicarboxylic acids are treated as a mixture of non-dissociated organic solute (HA) and dissociated organic solute ( $H^+ + A^-$ ) considering a static solute concentration ratio (Nandy et al. JPC – under review). It was found that the apparent dissociation was greater than that predicted by known dissociation constants alone, emphasizing the effect of dissociation on activity coefficient predictions. The acids are then treated with varying solute concentration ratios to study the degree of dissociation over the entire concentration range. This work results in predictive correlations for estimation of organic acid and water activities for which there is little or no activity data. The model is complemented with experiments by biphasic microfluidics to measure efflorescence relative humidities and supersaturation behavior by generating and trapping aqueous droplets.

**2AC.29**

**Spatial and Seasonal Variations of Isoprene Secondary Organic Aerosol in China.** XIANG DING, Quan-Fu He, Ru-Qin Shen, Qing-Qing Yu, Yu-Qing Zhang, Xin-Ming Wang, *Guangzhou Institute of Geochemistry, CAS*

Isoprene is a substantial contributor to global secondary organic aerosol (SOA). The formation of isoprene SOA (SOAI) is highly influenced by anthropogenic emissions. Currently, there is rare information regarding SOAI in polluted regions. In this study, one-year concurrent observation of SOAI tracers was undertaken at 12 sites across China for the first time. The tracers formed from the HO<sub>2</sub>-channel exhibited higher concentrations at rural sites, while the tracer formed from the NO/NO<sub>2</sub>-channel showed higher levels at urban sites. 3-Methyltetrahydrofuran-3,4-diols exhibited linear correlations with their ring-opening products, C<sub>5</sub>-alkenetriols. And the slopes were steeper in the southern China than the northern China, indicating stronger ring-opening reactions there. The correlation analysis of SOAI tracers with the factor determining biogenic emission and the tracer of biomass burning (levoglucosan) implied that the high level of SOAI during summer was controlled by biogenic emission, while the unexpected increase of SOAI during winter was largely due to the elevated biomass burning emission. The estimated secondary organic carbon from isoprene (SOC<sub>I</sub>) exhibited the highest levels in Southwest China. The significant correlations of SOC<sub>I</sub> between paired sites implied the regional impact of SOAI in China. Our findings implicate that isoprene origins and SOAI formation are distinctive in polluted regions.

**2AC.30**

**Experimental Characterization of Secondary Aerosol from D5 Cyclic Siloxane Oxidation.** NATHAN JANECHKEK, Nathan Bryngelson, Traci Lersch, Kristin Bunker, Gary Casuccio, William Brune, Charles Stanier, *University of Iowa*

Cyclic siloxanes are anthropogenic chemicals present in personal care products such as antiperspirants. These are volatile chemicals that are readily released into the atmosphere by personal care product use. Since personal care products used by people are the primary source of cyclic siloxanes, population density strongly determines concentrations, with urban and indoor environments having the greatest concentrations. In the atmosphere, cyclic siloxanes undergo reaction with atmospheric hydroxyl radicals (OH) forming oxidation products that can form aerosol species. While the parent compounds have been well studied, the oxidation products have largely been unexplored, no ambient measurements or physical property data are currently available. More importantly, ultrafine particles are known to adversely affect human health, and cyclic siloxanes may represent an important source of ultrafine particles due to ubiquitous use and high exposure potential indoors. Therefore, understanding the behavior of the aerosol species is important. In this work, we characterize generated cyclic siloxane particles in order to provide thermodynamic parameters important to understand the secondary aerosol formation. The Potential Aerosol Mass (PAM) photochemical chamber is used to oxidize the cyclic siloxane D5 to generate aerosol species. The particles are characterized by imaging with Scanning Electron Microscopy Energy Dispersive X-ray Spectroscopy (SEM-EDS), and volatility, hygroscopicity, and yield data are measured. Volatility data was collected using a Volatility Tandem Differential Mobility Analyzer (V-TDMA) which heats the particles. Comparing shifts in particle size, vapor pressure and enthalpy of vaporization are estimated. Hygroscopicity (water uptake) data was collected using a Droplet Measurement Technologies Cloud Condensation Nuclei Counter (DMT-CCN), using Kohler theory the hygroscopicity parameter is calculated. PAM chamber conditions of OH production, residence time, gas phase concentrations, and seed aerosols are varied to determine the sensitivity to aerosol yield.

**2AC.31**

**Re-evaluating the Contribution of Sulfuric Acid in Atmospheric Nanoparticle Growth.** VILLE VAKKARI, Petri Tiitta, Kerneels Jaars, Philip Croteau, Johan Paul Beukes, Miroslav Josipovic, Veli-Matti Kerminen, Markku Kulmala, Andrew D. Venter, Pieter G. van Zyl, Douglas Worsnop, Lauri Laakso, *Finnish Meteorological Institute, Helsinki, Finland*

In atmospheric new particle formation the survival probability of a newly-formed 1-2 nm particle depends strongly on its growth rate and subsequently on the concentration of condensable vapors in the air. However, atmospheric chemistry responsible for the growth of newly-formed aerosol particles to climate-relevant sizes is still not very well known. We utilized one year of simultaneous measurements of aerosol particle size distributions and on-line PM1 chemical composition with an aerosol chemical speciation monitor (ACSM) at the Welgegend measurement station in South Africa to investigate the composition of the growth in regional scale new particle formation (NPF) events.

During the measurement period from September 2010 to August 2011 we could estimate the chemical composition of the growth for 88 NPF events. Not surprisingly, the growth was dominated by either sulfuric acid accompanied by ammonium or organic compounds depending on the air mass origin and size of the growing particles. The contribution of sulfuric acid was larger during the early phases of the growth, but in clean conditions organic compounds originating from either biogenic emissions or savannah fires dominated the growth from 1.5 nm up to climatically relevant sizes.

Finally, we compared the observed growth by sulfuric acid to the calculated growth by sulfuric acid from gas phase sulfuric acid concentration, which is a commonly-used method if no aerosol chemical composition measurements are available. In clean conditions these two methods agreed reasonably well, but in high sulfuric acid concentrations the gas phase sulfuric acid calculation underestimated the observed growth by sulfuric acid by up to a factor of ten.

**2AC.32**

**Limonene Ozonolysis: SOA Formation, Nucleation Threshold and Impact of Anthropogenic VOCs.** WAED AHMAD, Cecile Coeur, Arnaud Cuisset, Thomas Fagniez, Patrice Coddeville, Alexandre Tomas, *SAGE-DOUAI, LPCA-ULCO, UNIV LILLE, France*

On a global scale, emissions of biogenic volatile organic compounds (BVOCs) are higher by a factor of ten than anthropogenic VOCs. Among the BVOCs, monoterpenes (alpha-pinene, limonene ...) represent a significant part of the emissions and can generate secondary organic aerosols (SOA) through their atmospheric oxidation by OH, NO<sub>3</sub> and O<sub>3</sub>. Measurements show that organic aerosols (OA) constitute a very important fraction of the total aerosol mass (20 to 90%) and SOA are often the main components of that mass, comprising between 63 and 95% of the total. However, atmospheric chemistry models frequently deviate from OA concentration measurements, sometimes up to a factor of 100 in specific environments. Several reasons have been invoked for this difference, in particular the influence of anthropogenic air masses on SOA formation from BVOCs.

In this communication, we will present studies performed on limonene (C<sub>10</sub>H<sub>16</sub>) ozonolysis which is known to strongly produce SOA. Experiments were carried out in two complementary setups: a laminar flow reactor and an 8 m<sup>3</sup> atmospheric simulation chamber. Different gas and particulate phase analysis tools (GC-FID / MS, CPC, SMPS) were used.

The formation of SOA through limonene ozonolysis was studied in terms of SOA yield, mass and number distribution, nucleation threshold and identification of products under various experimental conditions. The effect of anthropogenic VOCs on this formation was investigated using different compounds such as acetone, acetic acid, methylamine, 1-butanol and toluene. The results regarding the influence of anthropogenic contaminants selected as stabilized Criegee Intermediates or OH radical scavengers will be presented.

**2AC.33**

**Changes in CCN Solubility from Cloud Processing.** STEPHEN NOBLE, James Hudson, *Desert Research Institute*

Cloud processing (physical: collision-coalescence and Brownian capture; chemical: aqueous oxidation) changes activated cloud condensation nuclei (CCN). When droplets evaporate they leave modified CCN. Activated CCN collect material from cloud processing, which affect size, solubility ( $\kappa$ , here  $K$ ), and critical supersaturation ( $S_c$ ). Thus, these processed CCN are larger (lower  $S_c$ ) and separate from unactivated CCN creating bimodal spectra with processed and unprocessed peaks. Comparison of CCN  $S_c$  spectra with aerosol size spectra provides information about  $K$ . Marine Stratus/Stratocumulus Experiment (MASE) provided simultaneous CCN and DMA (differential mobility analyzer) aircraft measurements. MASE also provided bulk chemistry measurements.  $K$  was calculated from comparisons of CCN and DMA processed and unprocessed peaks ( $K_p$ ,  $K_u$ ).  $K_u$  ranged from 0.06 to 1.28 and  $K_p$  from 0.10 to 1.28. Mean  $K_p$  (0.51) was larger than  $K_u$  (0.45), while  $K$  from unimodal spectra was smallest (0.34). Bimodal spectra were also associated with higher Na<sup>+</sup>, Cl<sup>-</sup>, SO<sub>4</sub><sup>2-</sup>, and NO<sub>3</sub><sup>-</sup> measurements as well as lower SO<sub>2</sub> and O<sub>3</sub> measurements. This suggests that aqueous oxidation of dissolved gases increased  $K_p$  during cloud processing. However, for some spectra  $K_u$  was larger than  $K_p$ . The majority of these coincided with strong horizontal winds (>8.5 m/s). Larger wind speeds increase sea spray leading to finer sea salt particles. At these high winds  $K_u$ ,  $K_p$ , Na<sup>+</sup>, Cl<sup>-</sup>, SO<sub>4</sub><sup>2-</sup>, and NO<sub>3</sub><sup>-</sup> measurements were larger. Also, larger SO<sub>2</sub> and O<sub>3</sub> concentrations were concurrent with unimodal spectra, which likely preceded cloud processing. Thus, the larger  $K_u$  near  $K$  for sea salt is reduced by chemical processing making lower  $K$  materials and smaller  $K_p$ . For other cases of  $K_u > K_p$ , cloud droplets most likely collect the smallest CCN (high  $S_c$ , low  $K$ ) via Brownian capture reducing  $K_p$ . CCN solubility can remain fixed, increase, or decrease from cloud processing depending on the previous material and processing type.

## 2AC.34

**Fine Particle pH and the Partitioning of Nitric Acid during Winter in the Northeastern United States.** HONGYU GUO, Amy P. Sullivan, Pedro Campuzano-Jost, Jason Schroder, Felipe Lopez-Hilfiker, Jack Dibb, Jose-Luis Jimenez, Joel A. Thornton, Steven S. Brown, Athanasios Nenes, Rodney J. Weber, *Georgia Institute of Technology*

Particle pH is a critical but poorly constrained quantity that affects many aerosol processes and properties, including aerosol composition, concentrations, and toxicity. We assess  $PM_1$  pH as a function of geographical location and altitude, focusing on the northeastern US, based on aircraft measurements from the Wintertime Investigation of Transport, Emissions, and Reactivity (WINTER) campaign (01 Feb to 15 Mar 2015). Particle pH and liquid water were predicted with the ISORROPIA-II thermodynamic model and validated by comparing predicted to observed partitioning of inorganic nitrate between the gas and particle phases. Good agreement was found for relative humidity (RH) above 40%; at lower RH observed particle nitrate was higher than predicted, possibly due to organic-inorganic phase separations or nitrate measurement uncertainties associated with low concentrations (nitrate < 1 micro-gram  $m^{-3}$ ). Including refractory ions in pH calculations did not improve model predictions suggesting they were externally mixed with  $PM_1$  sulfate, nitrate, and ammonium. Sample line volatilization artifacts were quantified and found to be minimal. Overall WINTER particle pH for altitudes up to 5000 m ranged between -0.51 and 1.9 (10<sup>th</sup> and 90<sup>th</sup> percentiles) with a study mean of  $0.77 \pm 0.96$ , similar to those reported for the southeastern US ground-based sites and eastern Mediterranean. This expansive aircraft data set is also used to investigate causes in variability in pH and pH-dependent aerosol components, such as  $PM_1$  nitrate, over a wide range of temperatures (-21 to 19 °C), RH (20 to 95%) and inorganic gas and particle concentrations. This study provides further evidence that particles with low pH are ubiquitous, which has implications for atmospheric chemistry and environmental and health impacts.

## 2AC.35

**Ageing at the Molecular Level of the Chemical Fingerprint of Emissions Generated by Wood Burning: A TAG-AMS Smog Chamber Study.** AMELIE BERTRAND, Giulia Stefanelli, Emily Bruns, Coty Jen, Simone Pieber, Brice Temime-Roussel, Jay Slowik, Andre Prévôt, Allen H. Goldstein, Imad El Haddad, Henri Wortham, Nicolas Marchand, *Aix-Marseille Université, CNRS, LCE FRE 3416*

Biomass burning is a predominant source of organic aerosol (OA) during winter months and could potentially be largely underestimated because the secondary fraction of OA generated by these types of emissions is often overlooked. This underestimation is partly due to the large gap that remains in our comprehension of the chemical transformation of primary emissions in the atmosphere. It is only recently that instruments capable of analyzing such complex transformation occurring at its most resolved level: the molecular level and within a relatively short time frame were developed. The TAG (Thermal Desorption Aerosol Gas Chromatograph) coupled with an HR-ToF-AMS is an online chromatographic system which permits the collection and analysis of the aerosol at the molecular level, with a time resolution of less than an hour. Thus, the TAG-AMS can be deployed on smog chamber studies to offer detailed chemical speciation of the aerosol. Such experiments were carried out in the PSI (Paul Scherrer Institute, Villigen, Switzerland) smog chamber. The goal was to characterize primary and secondary emissions from wood burning. Emissions were generated by a variety of stoves (two traditional logwood stoves and one pellet stove). Primary emissions were then injected into the chamber and photo-oxidized for 4 hours during which 5-7 samples were collected and analyzed by the TAG-AMS. A set of online instrumentations such as PTR-ToF-MS, HR-ToF-AMS, Aethalometer AE33, and SMPS provided auxiliary measurements. Molecular identification was further investigated through GCxGC EI-HR ToF MS analysis performed on filter samples. This allows us to look at the evolution of a hundred of fine particulate organic compounds, including but not limited to, levoglucosan and its isomers mannosan and galactosan, and to evaluate the degradation that may occur as well as the implication of such results for marker based source apportionment studies.

**2AC.36**

**Constraining Organic Aerosol Volatility from Evaporation Rate Measurements from Thermodenuders.** JAMES HITE, Rebecca Schwantes, Kelvin Bates, Tran Nguyen, Richard Flagan, John Seinfeld, Athanasios Nenes, *Georgia Institute of Technology*

Thermodeunders (TD) are commonly used now in laboratory and ambient studies of aerosols to provide information about organic aerosol volatility. Experiments involving thermodenuder observations tend to conflate the aerosol evaporation rate with the thermodynamic driving force – volatility – without adequately constraining the kinetic limitations of the mass transfer, namely the mass accommodation coefficient ( $\alpha$ ). In light of more recent developments in research concerning secondary organic aerosol (SOA), the likelihood that SOA can exhibit characteristics that would act as kinetic limitations to volatilization ( $\alpha < 1$ ) presents a challenge for the interpretation of data collected with TDs and demonstrates the need for experimental methods and analysis techniques to constrain this critical unknown.

Laboratory results for dicarboxylic acid aerosol generated from aqueous solution via atomization using the GT TD system and variable pressure technique will be presented. Parameter optimization from minimal data will be discussed to demonstrate this method's feasibility for ambient, high-temporal, and thus potentially airborne retrieval of aerosol volatility. Select data from environmental chamber SOA experiments sampled with this system will also be presented, making use of the volatility basis set (VBS) approach.

**2AC.37**

**Secondary Organic Aerosol Production from Pinanediol, a Semi-Volatile Precursor.** PENGLIN YE, Yunliang Zhao, Wayne Chuang, Neil Donahue, *Carnegie Mellon University*

We have investigated the production of secondary organic aerosol (SOA) from pinanediol (PD), a precursor chosen as a semi-volatile surrogate for the first-generation oxidation products of monoterpenes. Because PD is semi volatile, we assessed its interactions with the CMU Teflon smog-chamber walls before determining SOA mass yields from PD oxidation. PD showed a large chamber wall deposition and reached a steady-state concentration with only 14% left in the gas phase. We observed a factor of three increase in the PD vapor concentration when increasing the chamber temperature from 13 to 44 oC, consistent with the release of PD from the chamber walls. However, we did not observe significant release of PD during isothermal dilution of the chamber with fresh air at 22 oC, which simulated the depletion of PD during isothermal oxidation and SOA production. Consequently, we consider the release of PD from the chamber walls to be negligible under our experimental conditions. As with the PD itself, we also consider wall losses of the PD oxidation products forming SOA. As a first-order approximation, we assume that the condensation of PD oxidation products to the Teflon is effectively irreversible. The condensation of oxidation products to the suspended particles competes with the direct vapor chamber wall loss. The fraction is determined by the condensation sink of the suspended particles and the vapor wall loss rate, which we assume to be a constant, 1/16 min<sup>-1</sup>, based on our earlier measurements of semi-volatile organic wall losses. After correcting for both particle and vapor wall losses we obtain the SOA mass yields from PD of between 0.1 and ~1, which are 2-3 times larger than monoterpenes.

**2AC.38**

**Modeling Cr Speciation in Atmospheric Droplets.** MEHDI AMOUEI TORKMAHALLEH, Dinara Konakbayeva, Altyngul Zinetullina, Marios Fyrillas, *Nazarbayev University*

The two chromium oxidation states found in ambient atmospheric particulate matter are trivalent [Cr(III)] and hexavalent [Cr(VI)] chromium. Cr(III) is a trace element essential for the proper function of living organisms. However, Cr(VI) is toxic and exposure to Cr(VI) may lead to cancer, asthma and bronchitis. Therefore, it is important to accurately discriminate between these two species in atmospheric particulate matter (PM). Little is known regarding atmospheric Cr chemistry. It was found that atmospheric Cr(III) is oxidized to Cr(VI) in the presence of dissolved ozone in liquid coated particles or droplets or even at dry conditions, while Cr(VI) is reduced to Cr(III) in the presence of organic carbons and metal ions such as Fe(II), As (III) and V(II) at high humidity. This inter-conversion between Cr(III) and Cr(VI) results in some biases in measuring atmospheric Cr concentrations. Therefore, it is critical to estimate the interconversion rate of Cr(III) and Cr(VI) to be able to quantify Cr(VI) concentrations in the ambient air. This study focuses on the simulation of interconversion of atmospheric chromium in the atmospheric droplets in the presence of PM matrix. Recent field measurements of concentrations of atmospheric Cr and other reductants and oxidants were used as model input. The simulation results demonstrated that the major form of Cr(VI) in the atmosphere is insoluble Cr(VI) which is in agreement with the literature findings. Insoluble Cr(VI) forms quickly within few seconds while the system reach steady state after approximately 15 hours. No insoluble form of Cr(III) was found when initial Cr(III) concentration was zero, and small amount of soluble Cr(III) was formed. However, the final form of Cr(III) can be influenced by the initial Cr(III) concentrations that may vary with the type of the source and the measurement location. This study is being continued for different pH of the solutions and initial Cr(VI) and Cr(III) concentrations.

**2AC.39**

**Incremental Secondary Organic Aerosol Formation in Controlled Reactivity Urban Atmospheres with and without Biogenic Influence.** MARY KACARAB, Lijie Li, William P. L. Carter, David R. Cocker III, *University of California, Riverside*

Current SOA models, which are typically based off of aerosol yields from environmental chamber experiments, regularly under predict ambient aerosol formation. The aerosol yields used are determined from classic single precursor chamber experiments. However, yields determined from only one precursor cannot give an accurate representation of a species' reactivity levels in the ambient atmosphere as the overall reactivity of the chamber system is then dictated by the single precursor itself. This work seeks to overcome this obstacle by using a surrogate mixture of hydrocarbons to control the overall reactivity in the chamber system and thus define an incremental aerosol yield in different representative reactive systems. In this work, two reactive organic gas (ROG) mixtures were developed to represent urban atmospheres with and without a heavy biogenic influence. Experiments were run in the UCR/CE-CERT dual 90m<sup>3</sup> atmospheric chambers studying the resulting incremental aerosol from two monoaromatic compounds, a monoterpene, and a polyaromatic hydrocarbon. For all compounds studied, slightly higher incremental yields were found in the biogenic influenced ROG mixture than in the strictly anthropogenic mixture. Furthermore, all precursors yielded slightly higher aerosol formation in both surrogate environments than in single precursor experiments. However, aerosol properties of incremental aerosol formed in both systems (including bulk chemical composition from HR-ToF-AMS) are very comparable to aerosol from single precursor experiments. This work presents a novel characterization of aerosol yields in different urban environments and raises an interesting question of how to look at different aerosol yields.

**2AC.40**

**Accelerated Free Radical Chemistry and Enhanced Volatilization in the Heterogeneous Oxidation of Semisolid Organic Aerosol by OH Radicals.** AARON WIEGEL, Kevin Wilson, William Hinsberg, Frances Houle, *Lawrence Berkeley National Laboratory*

In regional climate and air quality models, organic aerosol is treated as a well-mixed liquid in thermodynamic equilibrium with the surrounding gas, but several recent studies have shown that organic aerosol often exists in soft semi-solid or glassy states as well. However, how these phase states influence the heterogeneous oxidation of these organic aerosols is not well understood. To investigate the effect of phase state on the free radical chemistry, a stochastic kinetics model is developed that provides spatial information about the particle as a function of time and self-diffusion coefficient. This model has been successfully validated against experiments investigating the liquid OH + squalane and semi-solid OH + triacontane organic aerosol systems, which are proxies for hydrocarbon organic aerosols.

This model is then used to investigate how chemical aging affects the physical and chemical properties of the aerosol as a function of diffusion coefficient. Typical kinetic decays observed for the initial starting organic material are found to be sensitive to the reactivity towards OH radicals, the self-diffusion coefficient, and the rate of volatilization from the aerosol. In more diffusion limited cases, chemical pathways that are normally too slow in well-mixed, liquid, or aqueous particles as well as volatilization from the particle are enhanced due to the confinement of the free radical intermediates near the surface of the semisolid particle. Intriguingly, incompletely mixed organic aerosols with diffusion coefficients in between fluid and rigid systems show the most volatilization from the organic aerosol during chemical aging. Under atmospheric conditions, these model results suggest that semisolid secondary organic aerosol formed under dry conditions may actually experience enhanced volatilization upon exposure to OH radicals.

**2AC.41**

**Petroleum Fuels and Biofuels: A Comparative Environmental Chamber Study of Nighttime Secondary Organic Aerosol Formation.** SHAO KAI GAO, *Phillips 66 Research Center*

A federal mandate requires that U.S. oil refiners blend biofuel, such as ethanol, into gasoline. Ethanol has long been promoted as a 'green' fuel because its combustion tends to produce lower emissions of some regulated pollutants. However, the impact on air quality of a wholesale transition from gasoline to biofuel has been difficult to assess, with different atmospheric chemistry models predicting a variety of consequences.

In this study, to better understand ethanol's environmental impact, nighttime secondary organic aerosol (SOA) formation behavior from the interaction of petroleum fuels (straight-run gasoline, refinery naphtha) and their ethanol blends with NO<sub>x</sub> and O<sub>3</sub> were investigated in a series of environmental chamber experiments. Effects of relative humidity and seed acidity on SOA formation behaviors were also studied. The experimental results showed that despite its high volatility, ethanol could interact with different fuel components under certain circumstances, contributing significantly to nighttime SOA formation. It was found that higher seed acidity could promote SOA formation while higher relative humidity could suppress SOA formation. It was proposed that in addition to oxidation reaction, small molecules such as ethanol could also go through other reaction pathways such as hydration, oligomerization etc. under acidic conditions forming low volatility products, which could further lead to SOA formation. This was confirmed by the lower f<sub>44</sub> of the SOA formed from ethanol blends under acidic conditions.

Considering recent experimental results which showed increased emissions of aldehyde compounds (strong precursor for O<sub>3</sub> formation) from tailpipe for higher ethanol blends, it is recommended that the environmental impacts of ethanol be evaluated in greater detail.

**2AC.42**

**Atmospheric Impacts of Hydraulic Fracturing: Aerosol Production from Flowback Fluid.** Jeffrey Bean, DONGYU WANG, Sahil Bhandari, Lea Hildebrandt Ruiz, *University of Texas at Austin*

Natural gas production has increased dramatically in the United States in recent years due to technological advances such as horizontal drilling and hydraulic fracturing. However, the environmental impacts of hydraulic fracturing remain poorly understood. One such process is the storage of flowback fluid. Though mostly composed of water, flowback fluid typically contains a multitude of organic and inorganic compounds, many of which can evaporate. Atmospherically vented storage tanks are a source of hydrocarbon and other emissions, which could contribute to local and regional production of aerosol.

We report results from laboratory studies which were conducted to assess the atmospheric impacts of flowback fluid. The concentration of total volatile organic carbon determined for twelve hydraulic fracturing flowback fluid samples ranged from 0 to 114 mg carbon/L. The formation of particulate matter under atmospheric oxidative conditions was quantified by evaporating samples into an environmental chamber. During photo-oxidation using HONO as a source of OH and NO<sub>x</sub>, ammonium nitrate and organic aerosol were formed, indicative of ammonium contents in flowback fluid. In several experiments the amount of ammonium nitrate formed was greater than the amount of organic aerosol, suggesting the importance of ammonia emissions to the atmospheric effects of flowback fluid. A high resolution time of flight chemical ionization mass spectrometer (HR-ToF-CIMS) was used in combination with a filter inlet for gas and aerosols (FIGAERO) to identify compounds in the gas and particle phases following photo-oxidation. The majority of gas-phase compounds observed with the HR-ToF-CIMS contain 8-13 carbon atoms but many particle-phase compounds contain more than 13 carbon atoms. The study highlights the potential of emissions from hydraulic fracturing activity to impact atmospheric composition.

**2AC.43**

**Surface Properties of Organic-Inorganic and Organic-Inorganic-Surfactant Aerosol Droplets using Holographic Optical Tweezers.** BRYAN R. BZDEK, Hallie Boyer, Cari Dutcher, Jonathan P. Reid, *University of Bristol*

Atmospheric aerosol surface properties can impact processes such as cloud droplet activation, evaporation kinetics, and morphology and therefore requires a better understanding. In this work, we utilise holographic optical tweezers to investigate the coalescence dynamics of two airborne droplets (~1 pL volume, 5-10 micrometres radius). Coalescence of the two droplets excites oscillatory modes that manifest in the form of a damped shape oscillation of the composite droplet. The oscillation frequency gives information about the surface properties (e.g. surface tension) of the droplet, whereas the relaxation time gives information about the bulk (e.g. viscosity). Droplets containing sodium chloride and glutaric acid in known ratio were captured in optical traps and coalesced. Droplet surface tension trended with the glutaric acid concentration, as glutaric acid tends to favour the interface over sodium chloride. These experimental results were in quantitative agreement with surface tension predictions from a statistical thermodynamic model. Next, ionic and non-ionic surfactants were mixed with sodium chloride, glutaric acid, or mixtures of the two solutes. For droplets containing glutaric acid and any surfactant as well as mixtures of sodium chloride and a non-ionic surfactant, the oscillation frequency measured during the experiment was in agreement with expectations based on the surfactant concentration. However, for mixtures of sodium chloride and ionic surfactants, the oscillation frequency was less than a third of that expected based on the droplet bulk composition. Solutions of varying ionic strengths containing an ionic surfactant gave oscillation frequencies between those measured for the non-ionic and ionic solutes. Combined, these results suggest the presence of surfactant micelles in the droplets. The implications of these results will be discussed.

**2AC.44**

**Effect of Photochemical Aging of 2-Methyltetrol on the Ambient Environment.** ALISON FANKHAUSER, V. Faye McNeill, *Columbia University*

2-Methyltetrol (2-MT) is a trace compound found in ambient aerosol particles and an important tracer species for isoprene photooxidation and aqueous secondary organic aerosol formation. However, very little is known about the rates, mechanisms, and products of the photochemical aging of this species in the atmosphere. Kinetic insights from photochemical aging experiments of 2-MT in aqueous sulfate particles were incorporated into GAMMA (Gas-Aerosol Model for Mechanism Analysis), a photochemical box model with coupled gas-phase chemistry and detailed aqueous aerosol chemistry [McNeill et al. 2012]. The original model was modified to allow for gas-particle partitioning of 2-MT, which is controlled by an experimentally determined effective Henry's Law constant. Furthermore, as indicated by our experiments, particle-phase oxidation is represented as a surface reaction, which is controlled by an experimentally determined reactive uptake coefficient. This allows for the extrapolation of our laboratory results to relevant atmospheric conditions. We will present predictions on the impact of photochemical aging of 2-MT on the ambient environment.

**2AC.45**

**Organic Aerosol Growth through Photosensitized VOC Oxidation.** MELISSA GALLOWAY, Michael Ippolito, Jessica Ackendorf, Rachel Barron, *Lafayette College*

Recent work has indicated that organic aerosol growth through photosensitized VOC oxidation may be a significant contributor to ambient aerosol mass. Most studies have focused on imidazole photosensitization under dry conditions ( $RH \leq 15\%$ ), and have worked to characterize the photosensitized oxidation of limonene by imidazole-2-carboxaldehyde (IC). IC is formed from the aqueous reaction of glyoxal and ammonia and has been shown to be a contributor to brown carbon. The conditions under which this photosensitized growth occurs have not been fully explored, and we must understand them in order to predict the importance of this aerosol growth pathway. We present experiments probing photosensitized aerosol growth under a variety of conditions. The magnitude of observed photosensitized growth varies as a function of ambient relative humidity, particle pH, photosensitizer concentration, and VOC concentration. This work indicates that the extent of photosensitized growth may be highly dependent on regional atmospheric conditions.

**2AC.46**

**The Role of MSA for New-particle Growth and the Cloud-albedo Aerosol Indirect Effect.** ANNA HODSHIRE, Betty Croft, Jeffrey R. Pierce, *Colorado State University*

New-particle formation (NPF) is a significant source of aerosol particle number to the atmosphere. In order to impact climate, these ~1 nm in diameter particles must grow to ~30-100 nm. New-particle growth is facilitated primarily by net uptake of sufficiently low-enough volatility species emitted by both natural and anthropogenic sources. Dimethylsulfide (DMS), emitted by the oceans, can oxidize to methanesulfonic acid (MSA), a compound that may reach a low-enough volatility to have the potential to contribute to new-particle growth on regional scales. However, the volatility of MSA -- and therefore its ability to contribute to growth -- depends upon temperature, relative humidity, and concentration of gas-phase bases available for salt formation. Furthermore, presently there are knowledge gaps about whether MSA in its lowest volatility state can contribute to particle nucleation or if it only participates in growth. Currently, global aerosol microphysics models often do not include MSA in aerosol growth. Using a global chemical-transport model with aerosol microphysics (GEOS-Chem-TOMAS), we calculate the impacts of MSA on: aerosol growth, the aerosol size distribution, and the cloud-albedo aerosol indirect effect. We present results of limiting-case simulations, which treat MSA as 1) a sulfuric-acid-like compound that participates in nucleation, 2) a non-nucleating extremely low-volatility organic compound, and 3) a semi-volatile organic compound. Further, we present a simulation where the volatility of MSA is a function of relative humidity, temperature, and amount of gas-phase base available, based on offline thermodynamic calculations done in the Extended Aerosol Inorganic Model (E-AIM). We discuss the implications of omitting MSA from global aerosol models.

**2AC.47**

**Modeling the Production and Composition of Secondary Organic Aerosol from a Diesel Engine using Parameterized and Semi-Explicit Chemistry and Thermodynamic Models.** Sailaja Eluri, Christopher Cappa, Beth Friedman, Delphine Farmer, SHANTANU JATHAR, *Colorado State University*

Photochemistry experiments were performed with the potential aerosol mass (PAM) reactor at Colorado State University in the summer of 2015. The goal was to investigate primary emissions and secondary production of organic aerosol (OA) from a representative non-road diesel engine under varying engine load and fuel combinations. SOA production dominated POA emissions by an order of magnitude after ~1 day of simulated atmospheric aging, idle loads produced the highest POA and SOA levels and biodiesel results were identical to those from diesel. In this work, we used two state-of-the-science frameworks, namely the volatility basis set (VBS) and the statistical oxidation model (SOM) to simulate the production and composition of SOA in those experiments. Leveraging recent laboratory-based inputs, both frameworks accounted for a semi-volatile and reactive POA, SOA production from volatile organic compounds (VOCs) and intermediate-volatility organic compounds (IVOCs), NO<sub>x</sub>-dependent multigenerational gas-phase chemistry and dynamic gas/particle partitioning. Both model frameworks demonstrated that for model predictions of SOA mass and composition to agree with measurements across all engine load-fuel combinations, it was (a) quintessential to account for SOA formation from IVOCs (IVOCs were found to account for about three-quarters of the model-predicted SOA) and (b) necessary to dynamically model the gas/particle partitioning using a mass accommodation coefficient of ~0.1. Model predictions of the gas-phase organic compounds (resolved in carbon and oxygen space) from the SOM compared favorably to gas-phase measurements made using a Chemical Ionization Mass Spectrometer (CIMS). Qualitatively, this finding substantiates the semi-explicit chemistry captured by the SOM and the measurements made by the CIMS. Work is under way to examine the sensitivity of the findings to the use of alternate emissions profiles and treatment of vapor wall-losses.

**2AC.48**

**Global Modeling of Secondary Organic Aerosol Production from Reaction of NO<sub>3</sub> Radical with Speciated Monoterpenes.** MAKOTO KELP, Havala Pye, Emily Fischer, Jared Brewer, Juliane L. Fry, *Reed College*

Historically, global modeling of secondary organic aerosol (SOA) formation from monoterpenes has been based on a simple lumped mechanism, which parameterizes all monoterpene + NO<sub>3</sub> reactions as having the aerosol yield of beta-pinene + NO<sub>3</sub>. The resulting global spatial patterns and annual budgets of organic aerosol often do not match observations, and are inconsistent with recent chamber studies revealing alpha-pinene reaction with NO<sub>3</sub> radical oxidant to have a much lower SOA yield than compared to the other bicyclic monoterpenes. To assess how a more realistic, lower alpha-pinene + NO<sub>3</sub> SOA-producing pathway affects global organic aerosol concentrations, the global 3-D chemical transport model GEOS-Chem was updated with a new volatility basis set (VBS) based aerosol parameterization where alpha-pinene was unlumped from the lumped parameterized terpenes tracer and speciated with unique chemistry. As a result of this new parameterization, there were predicted model differences of up to 3.5 ug/m<sup>3</sup> less SOA in the summer months in high organic aerosol producing source regions. Integrated over the globe, the reduction led to an annual decrease of 2 Tg yr<sup>-1</sup> organic aerosol between the control and novel VBS mechanism, a 10% change from previous model terpene organic aerosol budgets. This work demonstrates that lumped terpene mechanisms may cause substantial errors in predicting SOA spatial patterns, with consequences for global budgets of highly climate relevant aerosol mass loading.

**2AC.49**

**A Study on Potential SOA Mass Fraction from Vehicle Emission using HR-ToF-AMS Coupled with Potential Aerosol Mass Reactor.** GYUTAE PARK, Jihwan Son, Jounghwa Kim, Jeong Soo Kim, Sunmoon Kim, Taehyun Park, Pilho Kim, Seokwon Kang, Kyunghoon Kim, Jihee Ban, Kijae Sung, Ho-Jin Lim, Zaeem Bin Babar, Taehyoung Lee, *Hankuk University of Foreign Studies*

Recent research proposed that Secondary Organic Aerosol(SOA) is important class of predicting future climate change scenarios(Monks et al., 2009; Hallquist et al., 2009). However, there has been lack of studies to investigate SOA formation all over the world. This study tried to focus on understanding potential mass fraction and degree of oxygenated organic aerosol between primary and secondary organic aerosol by chassis dynamometer for in-use vehicle. The test driving cycle was NIER09; developed in real driving pattern in urban area for reproducing on the chassis dynamometer. Also in order to confirm variation in chemical composition by vehicle speed, constant mode(30, 70, 110km/h) was conducted for each 10 minutes. To generate condition of Potential SOA formation, we used Potential Aerosol Mass (hereafter referred to as "PAM") reactor that manufactured by Kyungpook National University. PAM could make a highly oxidizing environment that simulates oxidation processes on timescales of 6-10 hrs in the atmosphere in minutes in real time. Chemical composition of aerosol from vehicle emission and through PAM was measured by the High Resolution-Time of Flight-Aerosol Mass Spectrometer(HR-TOF-AMS, hereafter referred to as "AMS"). The AMS provides non-refractory aerosol mass concentrations including nitrate, sulfate, hydrocarbon-like and oxygenated organic aerosol in real time. As a result, it was revealed that gasoline and LPG vehicle relatively made more potential SOA than diesel vehicle. However, this study is limited for testing group so that additional study needs to acquire testing data for various size vehicles.

**2AC.50**

**Particulate Matter (PM) Episodes at a Suburban Site in Hong Kong: Evolution of PM Characteristics and Role of Photochemistry in Secondary Aerosol Formation.** YIMING QIN, Yong Jie Li, Hao Wang, Berto Paul Yok Long Lee, Dan D. Huang, Chak K. Chan, *Hong Kong University of Science and Technology*

Episodes with high concentrations of particulate matter (PM) across the seasons were investigated during four one-month campaigns at a suburban site in Hong Kong. High-resolution time-of-flight aerosol mass spectrometer (HR-ToF-AMS) measurements revealed that both regional transport and secondary formation contributed to high PM levels during the episodes at this site. Based on distinct meteorological conditions, episodes were categorized into three types: liquid water content (LWC), solar irradiance (IR), and long-range transport (LRT). Despite the difference in meteorological conditions, all episodes were characterized by a high fraction of sulfate (45%-56%) and organics (23%-34%). However, aerosols in LWC episodes were less aged, consisting of the lowest fraction of secondary organics aerosols (SOA) and the highest fraction of small particles. Large particles mixed internally while freshly formed small particles mixed externally in LWC episodes. Aerosols in LRT episodes, by contrast, were the most aged and consisted of the highest proportion of low-volatility oxygenated organic aerosols (LVOOA) and the lowest proportion of small particles. Both small and large particles mixed externally in LRT episodes. The highest proportion of semi-volatile oxygenated organic aerosols (SVOOA) and a medium proportion of small particles were observed in IR episodes. Both small and large particles were likely externally mixed during IR episodes. Unlike in the other two types of episodes, in IR episodes aerosols experienced the most dramatic size increase and diurnal variation, with a time lag between SVOOA and LVOOA and a gradual increase in carbon oxidation state. Five out of ten episodes were of the IR type, further reflecting the importance of this type of episode. The evolution of aerosol components in one particular episode of the IR type, which exhibited a clear land-sea breeze pattern, was examined in detail. Sulfate and SOA due to photochemical aging were very efficiently produced during the course of six hours. The "fresh" SOA (SVOOA) was initially formed at a higher rate than the "aged" SOA (LVOOA). The SVOOA transformed to LVOOA at the later stage of photochemical aging. This transformation was further supported by mass spectral analysis, which showed an increase in the most oxidized ion ( $\text{CO}_2^+$ ) and decreases in moderately oxidized ones ( $\text{C}_2\text{H}_3\text{O}^+$ ,  $\text{C}_3\text{H}_3\text{O}^+$  and  $\text{C}_3\text{H}_5\text{O}^+$ ). By measuring the physical and chemical properties of PM in a highly time-resolved manner, the current study was able to demonstrate the dynamic and complex nature of PM transformation during high-PM episodes.

**2AC.51**

**Effect of OH Induced Aging on the Volatility of alpha-Pinene Ozonolysis Secondary Organic Aerosol Particles.** KEI SATO, Satoshi Inomata, Yuji Fujitani, Yu Morino, Kiyoshi Tanabe, *National Institute for Environmental Studies*

In order to study the changes in product chemical composition and particle volatility during OH induced aging of secondary organic aerosol (SOA), we conducted a series of laboratory chamber experiments of alpha-pinene ozonolysis and exposed SOA particles to OH radicals. OH radicals were produced by the photolysis of methyl nitrite. We investigated the chemical composition of gas and particle products and the volatility of SOA particles before and after OH exposure. The OH exposure of present laboratory experiments corresponded to 1.7-4.2 day exposure at an ambient OH level. The mass fraction remaining (MFR) against the mass at 298 K was measured for SOA particles by thermodenuder-AMS between 323 and 473 K. Slight increase in MFR was observed after OH exposure at 373 and 423 K, and no significant increase after OH exposure was observed at 323 and 473 K. Particle chemical composition was analyzed by offline liquid chromatography/mass spectrometry. The fractions of pinic acid, pinonic acid, and ester dimers to total SOA signal decreased after OH exposure, whereas those of 3-methyl-1,2,3-butanetricarboxylic acid (MBTCA) and  $\text{C}_{10}\text{H}_{14}\text{O}_6$  product to total SOA signal increased after OH exposure. The average carbon oxidation state of particle products increased after OH exposure, whereas the average number of carbon atom included in particle product molecules decreased after OH exposure; these results of offline analysis suggest that functionalization and fragmentation are competitive during OH induced aging.

**2AC.52****Contribution of Water-Soluble “Brown Carbon” Organic Species to Light Absorption by Biomass-Burning Aerosols.**

DEEP SENGUPTA, Vera Samburova, Chiranjivi Bhattarai, Michealene Iaukea-Lum, Adam Watts, Hans Moosmuller, Andrey Khlystov, *Desert Research Institute*

The water soluble fraction of Brown Carbon (BrC) is abundant in both primary and secondary biomass-burning organic aerosols and is considered to be a significant contributor to overall light absorption by aerosols. Humic Like Substances (HULIS), which are complex high-molecular weight atmospheric organic structures, are the largest constituent of water-soluble BrC fraction by mass. Therefore, quantifications of HULIS and their light absorption properties are needed to reduce the uncertainties in radiative forcing estimates for atmospheric biomass-burning aerosols.

In our experiments, selected fuels of regional and global importance were burned under controlled conditions using the DRI biomass combustion chamber. To mimic the atmospheric oxidation process (5-7 days) of biomass-burning smoke, we performed aging of gas- and particle-phase emissions using a Potential Aerosol Mass (PAM) flow reactor. Primary and PAM-aged biomass-burning aerosols were collected on Teflon filters ( $d=47$  mm), soaked in ultrahigh-purity water, and extracted twice in 20 mL of water under ultrasonic agitation for 20 min. The HULIS fraction was separated from inorganics and low molecular weight organics by solid-phase extraction. HULIS were then quantitatively analyzed using Ultra-High Performance Liquid Chromatography (UPLC) coupled with Evaporative Light Scattering Detector (ELSD). To estimate the contribution of HULIS to the overall light absorption by biomass-burning aerosols, HULIS extracts were analyzed with the UV-Vis spectrophotometry technique. Resulting HULIS absorption spectra and mass absorption coefficients were compared with UV-Vis absorption properties of the total water-soluble and non-water-soluble (hexane) fractions. These experiments provide an insight into the effects of atmospheric aging of HULIS in biomass burning aerosols on their light absorption properties.

**2AC.53****Modeling the Production of Secondary Organic Aerosol Material Via Photosensitized Reactions of Imidazole-2-carboxaldehyde.**

WILLIAM TSUI, V. Faye McNeill, *Columbia University*

We have used GAMMA, a photochemical box model with coupled, detailed gas-phase and aqueous-phase chemistry, to simulate the production of secondary organic aerosol material via photoactivated reactions of imidazole-2-carboxaldehyde (IC) in the presence of volatile organic compounds. We use kinetic parameters and mechanisms for IC aqueous reactions with VOCs and  $O_2$  based on our laboratory measurements, and compare modeling output to the laboratory data of Aregahegn et al. (*Faraday Discuss.*, 2013). We show that SOA production via photosensitized pathways via IC primarily occurs at or near the particle surface. We report reactive uptake coefficients for laboratory and ambient conditions, and simulate IC-SOA production in the ambient environment.

**2AC.54****Computational Prediction of UV-Visible Absorbance Spectra of Carbonyl-Containing Aqueous Aerosol Mimics.**Mengjie Fan, Ziwei Dai, JOSEPH WOO, *Lafayette College*

In this work, an empirical model for the estimation of the light-absorbing properties of ammonium sulfate solutions that contain common carbonyl and dicarbonyl mixtures is presented. The formation of light-absorbing oligomers from carbonyl-containing compounds in aqueous aerosol mimics is well-known, but the cross-interactions that exist between similarly-structured species have not been extensively characterized. High-resolution UV-visible light spectra are measured for a wide range of glyoxal/methylglyoxal/acetaldehyde concentrations and aging times, and regressed as composite sums of Gaussian curves. These curves are then represented as functions of initial organic concentration; the resulting functions can be used to predict complex mixtures' absorbance spectra, based upon these values. Concentration-dependent functions for absorbance data can be used for the estimation of aerosol "brown carbon" properties in laboratory-scale aging studies, or as an additional tool to infer a collected aerosol's apparent carbonyl concentration based upon its measured spectrum. This model can also be readily interfaced with existing gas-aerosol chemistry models, to provide ab initio estimates of an aerosol's light absorbance properties.

**2AC.55****Brown Carbon Formation from Aqueous-phase Syringol under Dark Conditions.**JIAN XU, V. Faye McNeill, *Columbia University*

Aerosol brown carbon (BrC) dominates aerosol light absorption at wavelengths up to 500 nm and may contribute significantly to climate forcing. Recent studies reported that biomass burning not only provides a primary source for BrC (Liu et al., 2014) but also serves as an important secondary formation pathway under varying conditions (Chang et al., 2010). More information on the formation mechanisms and light absorbing properties of secondary BrC are needed.

We performed laboratory experiments using syringol, which is a representative model phenolic compound emitted from wood burning, in bulk concentrated salt solutions mimicking aqueous tropospheric aerosol particles. We observed the formation of light-absorbing organic products (brown carbon) within 12 hours under dark conditions. We present kinetic data and propose a mechanism, and products will be discussed. Our results provide new insights into the evolution of aerosol optical properties during aging.

## 2AC.56

**The Effect of Hydrophobic Gas-phase Organics on Formation and Properties of Biogenic Secondary Organic Aerosol.**

Alla Zelenyuk, David Bell, Jacqueline Wilson, Dan Imre, KAITLYN J. SUSKI, Josef Beranek, ManishKumar Shrivastava, *Pacific Northwest National Laboratory*

A number of field measurements indicate that significant fraction of atmospheric secondary organic aerosol (SOA) mass forms from biogenic precursors through pathways that are either driven by or enhanced by anthropogenic pollution, in a phenomenon that has been termed anthropogenic-biogenic interactions. Thus far, the laboratory studies attempting to reproduce this phenomenon were predominantly focused on the effect of acidic sulfate seeds, NO<sub>x</sub>, and SO<sub>2</sub> on SOA formation mechanisms and yields.

We have previously shown that when SOA particles are formed from biogenic precursors in the presence of the vapors of polycyclic aromatic hydrocarbons (PAHs), which are common atmospheric anthropogenic pollutants, these PAHs become incorporated and trapped inside the formed SOA particles. While PAHs comprise only a small fraction of the total particle mass, their presence during particle formation, drastically changes the SOA particle properties. Compared with pure SOA particles, particles formed in the presence of PAHs have higher viscosity and oligomer content, and exhibit significantly lower evaporation rates.

Our recent studies demonstrate that the presence of PAHs during SOA formation significantly increases particles number concentrations and mass loadings, providing direct evidence related to field data indicating that biogenic-anthropogenic interactions could be responsible for an increase in SOA loadings. For example, ozonolysis of alpha-pinene in the presence of pyrene yields significantly higher loadings and particle number concentrations compared to pure alpha-pinene SOA, especially at low precursor concentrations. For 20 ppb alpha-pinene, the presence of pyrene increases mass loading by a factor of 1.7 and particle number concentration by a factor of 1.2, while for 5 ppb alpha-pinene, the presence of pyrene increases mass loading by a factor of 5 and particles number concentration by a factor of 200. Most recently we extended these studies to other biogenic precursors (isoprene and beta-caryophyllene) and hydrophobic organics, including benzo(a)pyrene, phenanthrene, and dibenzothiophene

## 2AC.57

**Explaining Changes in SOA Optical Properties by Evaluating Chemical Characteristics of Chamber-Derived SOA.**

STEPHEN ZIMMERMAN, Justin Min, Justin Dingle, Roya Bahreini, *University of California, Riverside*

Atmospheric particles directly influence the global radiative budget by absorbing and scattering light. Particulate matter formed from gases in the atmosphere, otherwise known as secondary organic aerosol (SOA), influence the optical properties of bulk aerosol. This presentation explores changes in the chemical properties of SOA formed under various experimental conditions in an environmental smog chamber. Individual chamber experiments showcase high and low concentrations of alpha-pinene, toluene, and 1-methylnaphthalene exposed to an oxidizing radical, hydroxyl (OH) or chloride (Cl). Furthermore, these series of experiments are conducted under NO<sub>x</sub>-free, intermediate, and high-NO<sub>x</sub> conditions. An Aerodyne mini-aerosol mass spectrometer (mAMS) is used in this study to obtain fast, size-resolved, non-refractory chemical composition of submicron particles. The data obtained by the mAMS is analyzed to produce mass concentrations of SOA, nitrate, and chloride. High-resolution analysis is performed to determine contributions of C<sub>x</sub>H<sub>v</sub><sup>+</sup>, C<sub>x</sub>H<sub>v</sub>O<sup>+</sup>, and C<sub>x</sub>H<sub>v</sub>O<sub>z</sub><sup>+</sup> ions, from which elemental ratios of O:C and H:C are calculated. Additionally, the effect of aging on the mass spectral characteristics of SOA is tracked by observing the evolution of the contribution of oxygenated vs. hydrocarbon-like ions at key fragments (e.g., m/z 43, 55, 57). Variability of these parameters with oxidation condition, HC/NO<sub>x</sub> ratio, and O<sub>x</sub> (NO<sub>x</sub> + O<sub>3</sub>) are studied in order to explain the observed variabilities in SOA mass absorption efficiency (MAE), single scattering albedo (SSA) and Angstrom exponent of extinction.

**2AC.58**

**Modeling the Size Dependence of Particle Composition and Growth Rates.** MICHAEL APSOKARDU, Murray Johnston, *University of Delaware*

Particle composition measurements of ambient new particle formation (NPF) events suggest that sulfate, base (typically ammonia) and carbonaceous matter are the three major constituents of particles. A challenge of understanding NPF is explaining observed particle growth rates. Sulfate, from sulfuric acid, alone is incapable of explaining observed growth rates, and recent research confirms that carbonaceous matter is responsible for the fraction of growth not attributed to sulfuric acid. However, the ways in which carbonaceous matter contribute to particle growth are not fully understood. For organic compounds, molecular properties such as molar mass and condensed phase vapor pressure (which is modified by the Kelvin effect) can strongly affect mass transport from the gas phase to the particle phase. Since ambient air contains many types of organic compounds across a wide range of molecular properties, it is important to understand how molecular properties influence the particle growth process.

In this work, we have developed and used a kinetic model to study the size dependence of particle growth by carbonaceous matter. The model iteratively calculates volume and composition of a particle as a function of time when it is exposed to gas phase species. The molecular inputs (gas phase mixing ratios and molecular properties such as molar mass and vapor pressure) are similar to those encountered in our previous studies of ambient NPF. These include sulfuric acid, ammonia, water, and organic compounds distributed through a wide range of volatility bins. Using this model, size dependencies of particle composition and growth rate are elucidated. Non-continuum flow contributes significantly to the size dependence below 10nm. While the Kelvin effect is also greatest below 10nm, it can influence particle growth and composition up to 100nm and greater. Of particular interest are the relative amounts of more volatile vs. less volatile organic compounds in the particle as it grows. Where possible, simulations of particle growth and composition are compared to ambient and laboratory measurements.

**2AP.1**

**Ambient Aerosol Extinction in Great Smoky Mountains National Park.** TIM GORDON, Jim Renfro, Anthony Prenni, Gavin McMeeking, Ping Chen, *Handix Scientific*

Light scattering and extinction are fundamental properties of visibility. To quantify extinction the IMPROVE (Interagency Monitoring of Protected Visual Environments) program, which is tasked with monitoring visibility in U.S. National Parks and Wilderness Areas, relies primarily on reconstructions from speciated aerosol (filter) measurements and humidification growth factors (among other parameters). Under many atmospheric conditions reconstructed extinctions compare favorably with measurements; however, at high relative humidities (RH) aerosol-induced light extinction is very sensitive to RH perturbations, and technical challenges (e.g., inlet losses and truncation errors) have thwarted previous efforts to quantify it (extinction) with closed-path instruments. Thus under such conditions not only are the uncertainty bounds large for the humidification growth factors used to reconstruct extinction (and therefore visibility), but also it has not even been possible to provide robust in situ measurements for comparing these reconstructions against.

The Open-Path Cavity Ringdown Spectrometer (OPCRDS) was designed to overcome the RH limitations of previous extinction instruments. The OPCRDS was recently deployed in the Great Smoky Mountains National Park (GSM), where the high RH and high photochemical activity typical in summer provided an opportunity to explore the upper limits of the aerosol hygroscopicity ( $f(RH)$ ) curve and the accuracy of the IMPROVE extinction reconstruction algorithm. True ambient extinction measured by the OPCRDS and dry extinction measured by a traditional closed-cell extinction monitor were used to investigate the hygroscopicity of aerosol at GSM and the importance of coarse-mode particles to light extinction. In addition, extinction obtained with the OPCRDS was used to validate the reconstructed extinction currently reported by IMPROVE. We also discuss the broader implications of these data for radiative transfer simulations in remote sensing and climate forcing research.

## 2AP.3

**Electric Field Directed Self-Assembly and Fragmentation of Dendritic Soot Structures as a Means for Amplifying Soot Detection.** DAVID BILBY, David Kubinski, Matti Maricq, *Ford Motor Company*

The native charge on combustion generated soot allows for effective particle capture in an electrostatic trap. The deposited soot grows into surface-attached dendritic structures whose features depend upon electric field strength. For instance, the height of the dendritic structures is curtailed when the van der Waals adhesion force is overpowered by the electric force. Dendrites which would otherwise grow above this force-balance limited height instead undergo fracture. Upon fracture, dendrite fragments carry charge from one electrode to another in the electrostatic trap. The current delivered by the dendrite fragments is about 1000 times larger than the native soot charge current, thereby amplifying the effect of soot deposition. We present scanning mobility particle sizer evidence of soot capture and of large, highly charged soot fragments exiting the trap. Using transparent traps, we show micrographs with evidence of soot dendrite growth and fragmentation. We also use current measurements on electrostatic traps in order to investigate the influence of flow and electric field on the dendrite fragmentation mechanism. Finally, we describe the dendrite growth and fragmentation using a kinetic model and are able to reproduce our experimental observations of trap current. This work provides a self-consistent explanation of how soot dendrite fragmentation can be used to amplify the current signal measured via electrostatically captured soot. Furthermore, this amplification mechanism could potentially provide the basis for a cheap, robust On-Board Diagnostics sensor for particulate filter monitoring in vehicle applications.

## 2AP.4

**A General Method for Calculating the Rayleigh Scattering by an Arbitrary Shape.** JUSTIN MAUGHAN, Chris Sorensen, Amit Chakrabarti, *Kansas State University*

A general method for calculating the Rayleigh scattering by a particle of arbitrary shape is introduced. Although analytical solutions for Rayleigh scattering exist for spheres and ellipsoids, analytical solutions for more complicated shapes don't exist. We find that in general the Rayleigh differential cross section goes as  $k^4 R^6 |\alpha(m)|^2$  where  $k=2\pi/\lambda$  and  $\lambda$  is the wavelength,  $V$  is the volume of the particle and  $\alpha(m)$  is the average volume polarizability, which is dependent on the shape and the complex index of refraction  $m$ . We use existing computational techniques, such as the discrete dipole approximation (DDA), to calculate the differential scattering cross section divided by  $k^4$  and plot it vs  $V^2$  to determine  $\alpha(m)$ . We show that once  $\alpha(m)$  is known it can be used to calculate the Rayleigh scattering for any combination of and volume within the Rayleigh limit for a given shape and index  $m$ . Furthermore, we show that this leads to a general description of the internal coupling parameter  $\rho=2\pi V/A|\alpha(m)|$  where  $A$  is the cross sectional area of the particle in the direction of incident light.

**2AP.5**

**Measurements of the Volatility Distribution of Organic Aerosols Combining Thermodenuding and Isothermal Dilution.** Evangelos Louvaris, ELENI KARNEZI, Evangelia Kostenidou, Spyros Pandis, *FORTH/ICEHT, Patra, Greece*

The volatility distribution of complex organic aerosol can be better constrained combining thermodenuder and isothermal dilution measurements (Karnezi et al., 2014). Smog chamber experiments were conducted in the FORTH Laboratory of Air Quality studies using organic aerosol produced during meat charbroiling. The emissions were then fed in a 10 m<sup>3</sup> chamber filled with clean air. The thermodenuder was operated at a temperature range from 25 to 250°C with a 16 s centerline residence time coupled to a High Resolution Time-of-Flight Aerosol Mass Spectrometer (HR-AMS) and a Scanning Mobility Particle Sizer (SMPS). In parallel, a smaller chamber (~1 m<sup>3</sup>) filled with clean air was used to dilute isothermally the aerosol of the larger chamber facility by approximately a factor of 10. The evolution of the OA size distribution in the smaller chamber was followed using an SMPS. The measurements in both systems were corrected for the size-dependent wall losses. The OA mass fraction remaining was measured as a function of temperature in the thermodenuder and as a function of time in the dilution chamber. These two sets of measurements were then used together with the approach of Karnezi et al. (2014) to estimate the volatility distribution of the OA and its effective enthalpy of vaporization.

In most of the isothermal dilution experiments 20-30% of the aerosol mass evaporated at ambient temperature after approximately an hour. In the thermodenuder almost all the organic aerosol evaporated at 200°C. The resulting volatility distribution suggests that 20% of the cooking OA consisted of extremely low volatility organic compounds, 65% of low volatility compounds, and the remaining 15% of semi-volatile organic compounds.

**2AP.6**

**Rebound Behavior of Nanoparticle-Agglomerates.** MANUEL GENSCH, Alfred P. Weber, *TU Clausthal*

The rebound behaviour is described by the coefficient of restitution (COR) which is defined as the ratio of the rebound velocity to the impaction velocity. The COR depends on the adhesion and mechanical properties of the particles and substrate. First, the COR increases when the onset velocity for rebound ( $v_{cr}$ ) is exceeded where the kinetic impaction energy is mostly converted to rebound energy, until the particles start to deform plastically which leads to a decrease of the COR. While the understanding of the rebound behavior of single spherical nanoparticles has progressed substantially over the last few years, the rebound characteristics of nanoparticle agglomerates are scarcely studied so far. The aim of this work is to investigate the rebound of differently structured agglomerates and compare it to single particles.

The fraction of bouncing particles is used to determine  $v_{cr}$  and the inset velocity for plastic deformation (i.e. the yield pressure), where the bounced fractions as a function of the impaction velocity are measured in a low pressure impactor.

The experimental results show that for a mica substrate  $v_{cr}$  of single spherical particles scales with the particle size in agreement with theoretical predictions, whereas for a copper substrate a stronger size dependence was found indicating a size dependent COR.

The  $v_{cr}$  of openly structured agglomerates is independent of the agglomerate size and determined by the primary particles. However, absence of rebound is observed when the fragmentation starts before  $v_{cr}$  is reached where the impaction energy is consumed by fragmentation. Closely structured agglomerates show a similar rebound behavior as single spherical particles. But, the maximum bounced fraction occurs at lower impaction energies caused by fragmentation and not by plastic deformation as confirmed TEM analysis.

## 2AP.7

**A Comparison of Morphological Differences in Aggregates Grown via Diffusion-Limited Aggregation and Percolation Schemes.** Thomas Hildebrand, WILLIAM HEINSON, Rajan Chakrabarty, *Washington University in St. Louis*

A comparison of aggregate properties grown via three aggregation schemes— diffusion-limited cluster-cluster aggregation (DLCA), diffusion limited aggregation (DLA), and percolation—is presented. For a statistically significant number of aggregates grown via these three schemes, their volume fractions versus radii of gyration are compared against their structure factors. Results show that independent of aggregate size, the different methods of aggregate formation yielded the same power law behaviors. The only distinguishing feature between the three aggregation schemes was the scaling of the structure factor.

## 2AP.9

**Optical Properties of Secondary Organic Aerosols from Oxidation of alpha-pinene, toluene, and 1-methylnaphthalene.** JUSTIN MIN, Stephen Zimmerman, Justin Dingle, Roya Bahreini, *University of California, Riverside*

Although many sources of secondary organic aerosol (SOA) precursors are identified, the optical properties of SOA formed in the atmosphere are not well characterized. In this investigation, we will focus on calculating optical properties such a single scattering albedo (SSA), Angstrom exponents of extinction ( $A_{\text{ext}}$ ), mass absorption coefficients (MAC), and mass extinction coefficients (MEC) of SOA produced from the oxidation of alpha-pinene, toluene, and 1-methylnaphthalene. We will relate changes in chemical characteristics of the SOA to the observed changes in the optical properties. Precursors will be oxidized by OH radicals generated from  $\text{H}_2\text{O}_2$  and HONO photolysis or Cl radicals from  $\text{Cl}_2$  gas in a Teflon chamber with black lights radiating at 350 nm. Furthermore, reactions will be carried out with variable precursor concentrations, relative humidity, and nitrogen oxide levels to mimic different atmospheric oxidation conditions. Optical properties will be characterized using a Cavity Attenuated Phase shift extinction monitor (CAPS- $\text{PM}_{\text{ex}}$ ) which measures the optical extinction coefficients at 632 nm while a Photoacoustic Extinctionmeter (PAX-375) will be used to measure the absorption and scattering coefficients at 375 nm. The CAPS- $\text{PM}_{\text{ex}}$  paired with the PAX-375 will help us to determine MEC's at 375 nm and 632 nm, mass absorption and scattering coefficients and SSA at 375 nm, and  $A_{\text{ext}}$  of the SOA.

**2AP.10**

**Scattering Directionality Parameters of Fractal Black Carbon Aerosols.** APOORVA PANDEY, Rajan Chakrabarty, *Washington University in St Louis*

The magnitude of aerosol direct radiative forcing effect is significantly affected by the angular distribution of aerosol light scattering. In radiative transfer schemes, this distribution is typically condensed into single-valued parameters. An analytical expression known as the Henyey-Greenstein (HG) phase function is widely used to connect three single parameter representations of aerosol scattering directionality: the hemispherical upscatter fraction ( $\beta$ ), the backscatter fraction ( $b$ ), and the asymmetry parameter ( $g$ ). The HG phase function does not take particle morphology into account, which could lead to significant errors for non-spherical particles. We calculated these single parameters for fractal black carbon (BC) aerosols using the numerically exact superposition T-matrix method. Here, we illustrate the effect of particle size and morphology on  $\beta$ ,  $g$  and  $b$  for single particles. We developed empirical equations to capture the relationships between these parameters. For a known value of  $b$ , which can be obtained through direct measurement, the errors in  $\beta$  and  $g$  estimated using the HG phase function could be up to 35%. However, the large mass absorption cross-section of BC aerosols dominates their radiative forcing effect. Therefore, the rather large errors in scattering directionality result in  $\leq 8\%$  error in BC direct forcing efficiency at 550 nm wavelength.

**2AP.11**

**Application of Combined Particle Charging Mechanism to Computational Fluid Dynamics.** RAVI SANKAR VADDI, Igor Novosselov, *University of Washington*

Exposure to complex environmental agents such as ultrafine particulate matter derived from combustion sources or engineered nanomaterials can trigger or exacerbate diseases, including asthma and cardiovascular disease. Compact electrostatic collectors can be used to collect ultrafine particles based on mobility to assess environmental exposure. Devices with diffusion charging are most widely used in the air quality monitoring systems and are usually large and difficult to use. The simpler way is, corona discharging which combines both field and diffusion charging and it is easy to implement in a low-cost compact device.

This work primarily focuses on developing a numerical model for particle charging using combined diffusion and field charging and particle transport in the electrical field. The numerical model is carried out by coupling the interactions between fluid mechanics, electrostatics, particle charging and particle transport. Unsteady, 2-D axisymmetric computational fluid dynamics modelling was used to develop the particle charging and particle transport model. The combined field-diffusion particle charging model is dependent on the ion concentration through which a particle passes by and the particle exposure time to ions. The results from the model are compared with the experimental results of needle to ring ionizer and wire-and-tube collector. The effect of flow rate and electric field on the particle charging is evaluated and compared with experiments.

**2CO.1****Chemical Composition Analysis of Wood Pellets.**

MOHAMMED RAHMAN, Philip K. Hopke, Lisa Rector, George Allen, *Clarkson University*

Wood now ranks nationally as the third most common heating fuel after gas and electricity. The most convenient form of wood is pellets. However, the combustion of wood pellets produces atmospheric pollution. Several voluntary standards have been established for wood pellets including ENplus, CANplus, and PFI. As part of the consideration for the development of a regional standard, wood pellet samples manufactured in the United States were analyzed for their energy, ash, moisture, and chemical composition. The pellet samples from different manufacturers were obtained from various locations in New England and New York. Calorific value, moisture and ash content of the samples were determined according to the American Society for Testing and Materials (ASTM) methods, sulfate and chloride samples were prepared using ASTM methods and analyzed by ion chromatography (IC). The elemental compositions of the wood pellet samples were determined using inductively coupled plasma mass spectrometry (ICP-MS) following sample preparation. Samples were prepared using two different methods, direct digestion and digestion of ash, and the results compared. The results varied between the two sample preparation methods within ~5% in elemental concentrations. Mercury was measured by direct analysis of wood samples. The distributions of the sample characteristics, such as heating value (7917-8542 BTU/lb), ash content (0.27-0.76%), moisture content (2.60-8.25%), ions (sulfate: 236-595 mg/Kg; chloride: 199-690 mg/Kg) and heavy elements (As: 0.01-0.20; Cr: 0.18-0.77; Cd: 0.02-0.05; Pb: 0.05-0.89; and Hg: 0.001-0.003 mg/Kg) were measured. Most of the commercially available wood pellets in this study would meet German and European standards for elemental content. These results will help in the development of regional wood pellet standards that would reduce environmental problems related to air emissions and ash disposal and use as fertilizers for agriculture soils.

**2CO.2****Physicochemical Properties and Toxicity of Fine Particles Produced from Pulverized Coal Combustion.**

HUNGSOO JOO, Tsatsral Batmunkh, JiYi Lee, KwangYul Lee, Lucille Joanna Borlaza, Kihong Park, *Gwangju Institute of Science and Technology*

The aims of this study are 1) to characterize physical and chemical properties of particles produced from laboratory scale-coal combustion system; 2) to evaluate toxicity of the particles by using direct (air-liquid interface) and indirect (submerged) exposure systems to cells; and 3) to measure oxidative potential (OP) of the collected PM on filter. A bench scale high temperature (up to 1200°C) drop-tube furnace (Lindberg/Blue M, Model HTF55342C, Thermo Electron Corp., USA) with a quartz tube was used to generate coal combustion particles. Bituminous coals from a coal power plant (Korea South Power Co. Ltd., Hadong, Korea) were pulverized and subjected to sieving using a 200 mesh (less than 75µm) before use. Coal combustion particles were generated at various burning temperature conditions ranging from 550 to 1100°C. Coal combustion particles were collected on filters using PM2.5 cyclone. These samples were subjected to biological response (cell viability, genotoxicity, and oxidative stress) and chemical response (oxidative potential by dithiothreitol and electron spin resonance assay). Particle size distribution, PM2.5 mass concentration, black carbon (BC) concentration, and chemical components of non-refractory submicrometer particles were measured with a scanning mobility particle sizer (SMPS) (DMA 3088 and CPC 3022, TSI, USA), Dust Trak DRX (TSI, USA), Aethalometer (Aethlabs, USA), and aerosol mass spectrometer (AMS)(Aerodyne Inc., USA). Cultex® RFS compact module (Cultex Laboratories GmbH, Germany) was used for the air-liquid interface exposure system. It was observed that burning temperature conditions significantly affected size distribution, emission factor, chemical properties (ions, metals, organic carbon (OC), elemental carbon (EC), and OC speciation), oxidative potentials, and biological response of coal burning particles.

**2CO.3**

**Measurement of the Volatility Distribution of Emission Factor of Diesel Automobile by Isothermal Dilution.** YUJI FUJITANI, Kei Sato, Kiyoshi Tanabe, Katsuyuki Takahashi, Jyunya Hoshi, *National Institute for Environmental Studies*

The volatility distribution of emission factor (volatility basis set) at combustion sources is improving inventory of PM<sub>2.5</sub> and it enable to predict properly atmospheric organic aerosol concentrations by air quality model. Emission from diesel automobile is one of the major emissions of PM<sub>2.5</sub> and SVOC in urban area and we conducted isothermal dilution studies using light duty diesel truck equipped with oxidative catalyst. Tail pipe exhaust was diluted with HEPA and charcoal filtered air and dilution ratios were controlled at ranging from 10 to 13000 times (corresponding organic aerosol concentrations were 2251 to 0.5 µg/m<sup>3</sup>). Temperature in diluted exhaust was kept at 25°C for any dilution ratio and online measurements and sampling were conducted.

Aerosols were measured by SP-AMS, DustTrak, Aethalometer, and SMPS. SVOC and VOC were measured by PTR-MS. Also, aerosol was collected with filters, and SVOC and VOC were sampled with adsorbents and canister, respectively. Offline analysis for OC, EC, ions, metals, and up to 300 organic species were conducted. From these data, we obtained volatility distributions by different methods and the results were compared. SP-AMS data show that emission factor of particle phase of organics decrease as increase dilution ratio, and this relationship was used to determine volatility distribution of emission factor for log C\* = -2 to 3. The PTR-MS data were used to derive for log C\* = 4-6 using relationship between molar mass and C\* of organic species contained in diesel exhaust. Bimodal distribution of emission factor was obtained with maximum at log C\* = 5 to 6 and minor peak was at log C\* = 0 in log C\* = -2 to 6. We are going to compare the volatility distribution derived from offline data of organic species.

**2CO.4**

**Air Quality Implications of Biomethane Combustion in Microturbines, Industrial Engines, and Home Appliances.** YIN LI, Jian Xue, Joshua Peppers, Christoph Moschet, Chris Alaimo, Peter Green, Norm Kado, Minji Kim, Christoph Vogel, Thomas Young, Michael Kleeman, *University of California, Davis*

Biomethane has the potential to act as a major renewable energy resource in California and other locations where the use of traditional fossil fuels is not consistent with GHG mitigation goals. Biomethane is produced from the anaerobic digestion of waste streams containing organic material over a period of several weeks. The unique production pathway combined with the rapid timescales lead to trace compounds in biomethane that are not present in traditional natural gas. Product biogas typically contains 50% methane that is then purified to +95% methane prior to use. The health effects of the residual trace compounds must be fully analyzed before widespread adoption of biomethane as a fuel for use in industry, transportation, and residential applications.

In this study the chemical composition and possible health impacts of biomethane were studied across multiple end-use scenarios. As a first step, the composition of raw biogas was measured to characterize fugitive emissions from production facilities. As a second step, the exhaust from micro-turbines and industrial engines burning raw biogas was drawn into a 5.5 m<sup>3</sup> Teflon reaction chamber and aged for 3 hrs to study the photochemical reaction products and regional exposure. Gas and PM samples were collected on a wide variety of sampling media to support comprehensive analysis. As a third step, upgraded biomethane was produced from the biogas and was then used in home appliances. The exhaust from these appliances was once again drawn into a 5.5 m<sup>3</sup> Teflon reaction chamber and aged to study residential exposure. The chemical, biological, and toxicity results from all samples will be presented, and the air quality implications of widespread biomethane adoption will be discussed.

**2CO.6**

**An Analysis of Trace Metals in Car Emissions.** JOSEPH SALAZAR, Benton Cartledge, Allen Robinson, Yunliang Zhao, Rawad Saleh, Greg Drozd, Allen H. Goldstein, Brian Majestic, *University of Denver*

Motor vehicles are a major contributor to the release of combustion particulate matter (PM) in the atmosphere. In 2015, 9.16 million barrels of gas per day were burned by motor vehicles. Soluble and insoluble metals are contained in the PM resulting from breakdown of the vehicle steel, as well as from the combustion, the motor oil, and trace concentrations already present in the fuel. Soluble element fractions from PM contribute to the creation of reactive oxygen species, which create oxidative stress on the respiratory system. To better understand combustion products, PM was collected from vehicle tail pipes. The vehicles were driven on a dynamometer operated by the California Air Resources Board (CARB) primarily on the California Unified (UC) Drive Cycle. This drive cycle lasts for 1435 seconds and runs for approximately 15.7 km and simulates driving conditions in California including driving on and off the highway. The UC drive cycle has a maximum speed of 104.6 km/h and an average speed of 39.6 km/h, including several stops. PM from the exhaust was collected on acid-cleaned Teflon filters. To improve detection limits, we first developed a method to measure both water-soluble and total metals using the same filter. This method included soaking the filters in Milli-Q (>18.0 M ohm) water for two hours then filtered with nitro-cellulose filters. The remaining PM was digested via a strong acid microwave digestion and measured for trace elements using ICP-MS. Total and soluble elements were quantified the most significant being Fe with a range 0.0015-0.098 micro-grams/km and average of 0.013 micro-grams/km, Cu with a range 0.0004-0.047 micro-grams/km and average of 0.0070 micro-grams/km, and Zn with a range 0.0033-0.16 micro-grams/km and average of 0.039 micrograms/km. The results also showed a high fraction of average soluble Fe (28%), Cu (63%), and Zn (64%) from the filters.

**2CO.7**

**Field Measurements of Solid-Fuel Cookstove Emissions from Uncontrolled Cooking Tests in China, Honduras, Uganda, and India.** ROSE EILENBERG, Kelsey Bilsback, Kristen Fedak, Michael Johnson, Jack Kodros, Eric Lipsky, Christian L'Orange, Jennifer Peel, Jeffrey R. Pierce, R. Subramanian, John Volckens, Allen Robinson, *Carnegie Mellon University*

Approximately three billion people across the developing world rely on traditional, solid-fuel burning cookstoves. Because incomplete combustion in cookstoves emits toxic gases and particulate matter (PM), cookstoves have wide-reaching impacts on human health, air quality, and the climate. Due to the costs and logistical challenges of conducting field experiments in developing countries, most emission inventories are derived from laboratory tests. Studies have repeatedly shown, however, that lab tests do not accurately reflect real-world usage. To address this gap, we performed a total of 41 uncontrolled cooking tests (with stove operators cooking as if a normal day) in China, Honduras, Uganda, and India. A battery-powered portable emissions sampler was designed to collect both integrated and real-time measurements. Sites were chosen to represent a range of stove types, including so-called improved stoves, as well as fuels and cooking practices. We measured emission factors (EFs) using the carbon balance method. PM EFs from gravimetric filter measurements ranged from 0.35 to 169.4 g/kg fuel; the majority of measurements within the range of previously published field tests. Test average CO EFs were between 33.4 and 268.2 g/kg fuel, similar to the literature. OC/EC ratios ranged from 0.075 to 120. Coal stoves in China had the highest PM and CO EFs, while charcoal stoves in Uganda had the lowest PM EFs and Indian wood stoves had the lowest CO EFs. Real time data for gases and particles (black carbon and scattering) were measured to quantify the contribution of intermittent events to overall emissions. This presentation will provide an overview of the data, including an analysis of variations in emissions by country, fuel type, and stove technology. These data are being incorporated into an ongoing stove emissions laboratory study and emission inventories to decrease the uncertainties in both climate and public health intervention models.

**2HR.1**

**Colloidal Probe Analysis of Cohesion Forces between Monodisperse, Monomorph Microparticles with Rough Surfaces.** Alberto Baldelli, REINHARD VEHRING, *University of Alberta, Canada*

The effect of roughness, particle size, and crystal size on the cohesion forces between two microparticles of different size and shape was investigated. A piezoceramic dispenser was used to produce nearly identical solution droplets with an initial droplet diameter of about 70  $\mu\text{m}$ . The aqueous droplets were dried under controlled conditions to create monodisperse and monomorph sodium nitrate microparticles in a diameter range of 0.7 to 17  $\mu\text{m}$ . Initial conditions of the drying process differed in solution concentration, from 5 to 5 $\cdot$ 10<sup>-4</sup> mg/ml, and in drying gas temperature, from 50 to 150°C. By varying the process conditions, particles with different roughness were reproducibly produced. For instance, the mean squared roughness of the dried microparticles was controlled in a range from 2 to 6 $\cdot$ 10<sup>-5</sup>  $\mu\text{m}$ . Colloidal probe microscopy (CPM) was selected to analyze cohesion forces between pairs of particles of the same or different morphology. Because all microparticles produced for a given set of processing conditions had very similar morphology, cohesive interactions for a large set of fifteen morphology type combinations could be studied. For every case analyzed, the measured cohesion forces were compared with seven different theoretical models for the prediction of pull-off forces between two microparticles. Cohesion forces were found to vary by a factor of about 50 for particles of different roughness, with higher roughness leading to less cohesion. The best fit of the experimental results was achieved with cohesion models that accounted for surface roughness at different lengths scales. Cohesion models without roughness parameters, such as the Hamaker interaction model, yielded very poor correlation with the experimental results.

**2HR.2**

**The NO<sub>x</sub> Effect on the Chemical Composition And DTT Response of Water-soluble Secondary Organic Aerosols.** HUANHUAN JIANG, Zechen Yu, Myoseon Jang, *University of Florida*

As a major fraction of particulate matter (PM), secondary organic aerosol (SOA) is supposed to be a significant contributor to the adverse health effects of PM. A well-known toxicity mechanism of PM in biological systems is that its redox activity leads to the production of reactive oxygen species (ROS) and then a cascade of inflammation responses. Metals, quinones, and PAHs are supposed to significantly contribute to the ROS generation. However, there are no metals in SOA, and the amount of quinones and PAHs in SOA are relatively low compared to those in PM. In order to have a deep insight into the mechanisms of SOA toxicity, its compositions and potential toxicity are needed to be characterized. In this study, SOA was produced via the photooxidation of four different hydrocarbons (toluene, 1,3,5-trimethylbenzene, isoprene and alpha-pinene) in the presence of different NO<sub>x</sub> conditions using a large outdoor photochemical smog chamber. The ability of SOA to consume dithiothreitol (DTT), a surrogate biological reducing agent SOA, was used as an indicator of SOA toxicity and estimated by mass-normalized DTT consumption rate, i.e. the DTT activity. The compositions of SOA were characterized by a series of chemical assays, such as the DTT enhancement assay, Griess assay and peroxide assay. The results showed that no significant NO<sub>x</sub> effect observed on the DTT activity of 135-TMB SOA and alpha-pinene SOA. The DTT activity of toluene SOA with relative high NO<sub>x</sub> condition is higher than SOA with low NO<sub>x</sub> condition. However, the opposite trend appeared with isoprene SOA. The chemical assays showed that concentration of PAN types compounds in aerosol phase was relatively low, and conjugated carbonyls, and peroxides were main contributors to the DTT activity of SOA.

**2HR.3**

**Hydrogen Peroxide Produced by Carbonaceous Particles in Physiologically Relevant Medium.** Dan Hinz, Jeff Barnes, Clara Gutierrez, JUSTIN RODRIGUEZ, Juan Rodriguez, Anne Johansen, *Central Washington University*

The detrimental effects of carbonaceous nanoparticles emitted from fuel combustion are well-known, and despite strong indications that one potential mechanism is driven by the in vivo production of reactive oxygen species (ROS), consequential particle characteristics remain elusive. Here, experiments were carried out to investigate the production of hydrogen peroxide ( $H_2O_2$ ), an ROS, as a function of soot characteristics in the presence of biological electron donors at biologically representative low concentrations. Results indicate that the presence of soot is essential in the continuous production of  $H_2O_2$  at concentrations on the order of hundreds of nM and that a small redox-active pool of iron is likely responsible for the conversion of  $H_2O_2$  to the most potent ROS, namely hydroxyl radical (OH). Data from this study increase our understanding of the reactivity of carbonaceous particles in a variety of settings.

**2HR.4**

**Experimental and Computational Study of Reaerosolization of 1 to 5 micro-meter PSL Microspheres using Jet Impingement.** JANA KESAVAN, Pamela Humphreys, Babak Nasr, Goodarz Ahmadi, Craig Knox, Erica Valdes, Vipin Rastogi, Suresh Dhaniyala, *US ARMY ECBC*

Chemical, biological, radiological and explosive incidents produce immediate as well as delayed hazards as a result of reaerosolization of deposited particles from surfaces. Understanding reaerosolization mechanisms is important for hazard prediction and mitigation processes. Efficient reaerosolization methodology of small particles is currently not available; therefore, this study was conducted to test a simple and effective method to reaerosolize small particles in the size range of bacterial spores. In this work, we adapted a high-speed vertical impinging jet to reaerosolize small (1 – 5 micro-meter) polystyrene latex microspheres from a substrate, and compared our measured removal efficiencies with numerical predictions. Experiments were conducted to determine the effect of location, number of puffs, particle size, aerosol generation methodology (wet and dry), and relative humidity (RH) on the amount of reaerosolization. The experimental results agreed with numerical predictions of maximal reaerosolization location of about 1 mm from the center. Reaerosolization increased slightly with increasing number of puffs at the peak removal location, and reaerosolization amount decreased as the particle size decreased. Dry deposited particles also had significantly higher reaerosolization compared to the wet deposited particles. Two hours of equilibration of samples at high (80%) or low (20%) RH showed higher reaerosolization with lower RH conditions for dry deposited particles compared to the high RH conditions. In conclusion, this study demonstrated the effectiveness of using a single vertical impinging jet for local reaerosolization of bacteria-sized particles from surfaces.

**2HR.5**

**Diesel Exhaust Exposure and Lung Cancer: A Case Study in Data Access, Exposure Assessment, and Extended Analyses.** Kenny Crump, Cynthia Van Landingham, ROGER MCCLELLAN, *Private Consultant*

The International Agency for Research on Cancer (IARC) in 2012 classified diesel exhaust exposure as a "human carcinogen" largely based on findings from the Diesel Exhaust in Miners Study (DEMS). This action raises the question - Are results of analysis of the DEMS data sufficiently robust to support Quantitative Risk Assessment? DEMS was designed to test for an association between exposure to Diesel Engine Exhaust (DEE) and lung cancer in workers in 8 nonmetal mines from dieselization through 1997. Respirable Elemental Carbon (REC) was used as a metric for DEE and estimated from diesel equipment Horse Power (HP), earlier measurements of CO in the mines and assumed relationships among HP, CO, and REC. Cox proportional hazard models revealed a statistically significant association between REC and lung cancer in the total cohort and ever underground workers. Statistically significant associations were also observed in a nested case - control study controlling for smoking. The authors of this abstract gained access to DEMS data and extended the original analyses. Uncertainties in the REC estimates using CO as a surrogate for REC prompted us to develop alternative REC estimates using only HP and CFM. The alternative REC exposure estimates were applied in a conditional logistic regression of the case-control data. Trend slopes calculated with new REC estimates were not statistically significant. Slopes were smaller by a factor of 5 without control and factors of 12 with control for radon exposure compared to slopes in original analyses. A consistent lung cancer effect was not observed in always underground miners, a sub-group not originally analyzed. The varied results from different analyses should be considered in conducting quantitative risk assessments using DEMS data. This study illustrates the value of data sharing, construction of alternative exposure estimates and conduct of alternative analyses.

**2HR.6**

**Predicting Hygroscopic Particle Growth in Upper Human Airways.** LAWRENCE LEBLANC, Ralph Altmaier, Ching-Long Lin, Patrick O'Shaughnessy, *University of Iowa*

Under high humidity, hygroscopic compounds attract, absorb, and retain water molecules resulting first in deliquescence followed by an increase in the resulting droplet solution up to an equilibrium size. The human airways provide an environment suitable for hygroscopic particle growth which will ultimately affect their deposition sites. A series of published coupled differential equations for predicting droplet growth with droplet temperature change were used in conjunction with predicted lung temperature and relative humidity profiles up to six generations to model the growth of sodium chloride aerosols with diameters in the nanometer range in the human lung. Differential equations were solved using a built in MATLAB ODE solver. Experimental validation of the models was accomplished with the use of differential mobility analyzer coupled with an optical particle counter to measure growth during the transient growth phase of the droplets. Numerical models were validated through comparison with experimental data over a time period of 0.2 seconds, consistent with the average residence time needed for transport of air from the top of the trachea to the first lung bifurcation. Numerical results under the condition of changing air temperature and relative humidity as a particle progresses through the upper airways indicated particle growth to a lesser magnitude than predicted when a consistent temperature and relative humidity associated with the deep lung (37 C and 99.5%) were applied to the model. Depending on initial diameter, final diameter size after 0.2 seconds were consistently 20-45% lower than predicted. Current numerical models in the literature do not incorporate the time needed for full deliquescence of the salt particle to a liquid solution droplet. Experimental data suggests that such a lag in overall growth occurs. The deliquescence phenomenon is therefore a critical component missing from currently published particle growth models.

**2HR.7****Oxidative Potential of Coarse Particulate Matter (PM<sub>10-2.5</sub>) and Its Relation to Water Solubility and Sources of Trace Elements and Metals in the Los Angeles Basin.**

FARIMAH SHIRMOHAMMADI, Sina Hasheminassab, Dongbin Wang, Arian Saffari, James Schauer, Martin Shafer, Ralph J. Delfino, Constantinos Sioutas, *University of Southern California*

Results from this study emphasize the role of non-exhaust traffic emissions, which are currently understudied and largely unregulated, in the potential toxicity of ambient coarse particles (CPM) ( $2.5 < dp < 10$  micro-meter). The relative importance of non-exhaust traffic-related emissions has increased as the contribution of vehicle tailpipe emissions to total ambient PM concentrations has decreased due to the stringent regulations in the Los Angeles (LA) Basin. In this study, potential sources of water-soluble (WS) and water-insoluble (WI) fractions of metals and trace elements in CPM were identified and their association with the redox properties of CPM, measured by means of reactive oxygen species (ROS), was explored. CPM was collected during 2012–2013 in Central LA and 2013–2014 in Anaheim, CA. Generally, WI components contributed to a larger fraction of CPM ROS activity (as much as 64% and 54% at Central LA and Anaheim, respectively). Two major source factors were identified by principal component analysis for both the WS and WI fractions: vehicular abrasion and re-suspended road dust. In WS fraction, metals such as Mn, Fe, Cd and Zn were associated with WS ROS, while in WI fraction Ti, Fe, Ni, Pb and Cr had the highest correlations with WI ROS activity. Multiple linear regression analysis revealed that both vehicular abrasion and re-suspension of road dust were associated with WS ROS activity, while only vehicular abrasion contributed significantly to the WI ROS activity. Moreover, comparison with previous studies indicated that the ROS activity of CPM has increased in the past 5 years in Central LA. We attribute this increase mainly to the elevated levels of re-suspension of road dust caused by the increase in vehicle speed and number of trucks in recent years in this area, reaffirming the growing importance of non-tailpipe traffic emissions on CPM toxicity.

**2HR.8****Chemical and Cellular Oxidant Production from Secondary Organic Aerosols (SOA) Generated from the**

**Photooxidation of Volatile Organic Compounds.** WING-YIN TUET, Yunle Chen, Shierly Fok, Rodney J. Weber, Julie Champion, Nga Lee Ng, *Georgia Institute of Technology*

Results from epidemiology studies have found associations between elevated particulate matter (PM) concentrations and increased incidences of cardiopulmonary disease. Toxicology studies suggest that PM-induced oxidant production, including reactive oxygen and nitrogen species (ROS/RNS), may be a possible mechanism by which PM exposure results in adverse health end points. Here, we present chemical and cellular measurements of ROS/RNS from SOA formed from the photooxidation of six commonly emitted volatile organic compounds (VOCs). Photo-oxidation experiments were conducted in the Georgia Tech Environmental (GTEC) facility under both dry and humid conditions in the presence of ammonium sulfate seed. H<sub>2</sub>O<sub>2</sub> was used as an OH radical precursor. Compounds were chosen to represent the main classes of hydrocarbons found in biogenic and anthropogenic emissions. Filter samples were collected at the end of each experiment. Murine alveolar macrophages were used to measure intracellular ROS/RNS production, while dithiothreitol (DTT) was used to measure the concentration of redox-active species. Intracellular ROS/RNS was characterized using response parameters obtained by fitting dose-response data using the Hill equation. These response parameters (maximum response, EC<sub>50</sub>, Hill slope, threshold, and area under the dose-response curve) were compared with the concentration of redox-active species as measured by DTT activity to determine whether chemical assays were representative of cellular response. We found that SOA generated from different precursor VOCs contained different concentrations of redox-active species as measured by DTT and induced different levels of cellular ROS/RNS. In particular, SOA generated from naphthalene produced the highest DTT activity and ROS/RNS production. These results will also be discussed in the context of aerosol chemical composition and properties.

**2HR.9****Screen Collection and Harvesting of Airborne Glass Fibers.**

BON KI KU, G.J. Deye, Leonid Turkevich, *Centers for Disease Control and Prevention, NIOSH*

Fiber length is believed to be an important variable in determining various toxicological responses to asbestos and other elongate mineral particles. In order to prepare samples for toxicology studies, it is necessary to develop and evaluate methods for separating fibers by length. Recent studies have shown that the collection of airborne glass fibers on a screen is useful for classifying fibers by length. We have extended these studies to harvest the screens, using a periodic back-flushing purge flow. Regeneration of a selected size would refine length selection for that size range. In a second set of experiments, a well-dispersed aerosol of glass fibers (mean length ~ 20  $\mu\text{m}$ ), generated by vortex shaking, was fed directly into the Baron Fiber Length Classifier, in order to produce monodisperse length fibers. With nylon mesh screens (10, 20, 30, 40 and 60  $\mu\text{m}$  mesh sizes), the screen collection efficiency was measured using an aerodynamic particle sizer. As the screen mesh size decreases, the screen collection efficiency increases for the longest fibers (~ 53  $\mu\text{m}$ ) tested in the study. Also, the collection efficiency for fibers with a given physical length was found to be nearly constant for aerodynamic diameters 1-4  $\mu\text{m}$  for screen 20 and 30  $\mu\text{m}$ , but to rise significantly at higher aerodynamic diameters. These results indicate that it will be possible to use a screen collection process to prepare short fibrous aerosol controls free from longer fiber contaminants as well as long fibers if we would harvest the screens.

**2HR.10****Improved in vitro Inhalation Toxicology Method for Nanoparticles and Combustion Emissions.**

PASI, I JALAVA, Kari Kuuspalo, Mika Ihalainen, Oskari Uski, Tuukka Ihtola, Olli Sippula, Jarkko Tissari, Jorma Jokiniemi, Maija-Riitta Hirvonen, *University of Eastern Finland*

Air liquid interface (ALI) methods have been introduced to improve the accuracy of aerosol toxicology studies. However, particle deposition in the ALI methods have been least effective with the particles <100nm in aerodynamic diameter. In our new system, thermophoresis has been applied to increase deposition of the particles in combustion emission and, thus, reliably study the toxicological effects of emissions and nanoparticles (Ihalainen et al. AAAR abstract).

We used the new exposure device in exposing human alveolar A549 cells to wood combustion aerosol. The aerosol was measured for the gaseous and particulate compounds. The cells were cultured at the membrane inserts for four to six days to form an epithelial barrier at air liquid interface. The cells were exposed at air liquid interface for one hour to diluted wood combustion aerosol from a stove operated with the batches of beech wood logs. We also studied the effects of aged wood smoke. After the one hour exposures, cell culture inserts were moved to the support plates and allowed to recover in an incubator for 24 hours. Thereafter, toxicological endpoints were measured including fluorescence imaging of the cells in the inserts. The other toxicity endpoints using detached cells, included analyses of thiol reduction, mitochondrial potential, cellular metabolic activity and oxidative stress. In addition, the cell culture mediums were analyzed for cytokine concentration.

The new ALI exposure device showed to be well suited for combustion emission toxicology studies, in addition to nanoparticles described in the other abstract. The constantly good viability of the clean air exposed control cells provides good repeatability of the studies and reduces artifacts in the comparability between the clean air and aerosol exposed cells. In the experiments we saw differences in toxicological responses both between the clean air and aerosol samples as well as between fresh and aged emissions.

**2HR.11**

**Evaluating the Effect of Altitude on Medium-High Resistance Dry Powder Inhalers.** Conor A. Ruzycski, Andrew R. Martin, Reinhard Vehring, WARREN H. FINLAY, *University of Alberta*

An experimental setup capable of simulating high altitude conditions was used to evaluate the performance of three medium-to-high resistance, commercially available dry powder inhalers, including Symbicort<sup>R</sup> Turbuhaler<sup>R</sup>, Pulmicort<sup>R</sup> Turbuhaler<sup>R</sup>, and Asmanex<sup>R</sup> Twisthaler<sup>R</sup>, at a simulated high elevation of 4300 m, with controls established at an elevation of 700 m (the elevation of Edmonton, Alberta, Canada). Inhaler performance was quantified based on measurements in a Next Generation Impactor placed downstream of an Alberta Idealized Throat using a similar procedure to that specified in the USP 601 monograph.

Using standard pressure drops, all inhalers showed consistent performance when maintaining a 4 kPa pressure drop across the device regardless of altitude. When instead using constant volumetric flowrates at altitude, resulting in lower pressure drops being generated across the devices, Pulmicort Turbuhaler and Asmanex Twisthaler showed decreases in performance; at a volumetric flowrate of 55 L/min, deposition in plates 2-8 of the NGI with the Pulmicort Turbuhaler decreased from 41% of label claim at an elevation of 700 m to 27% at an elevation of 4300 m. For Asmanex Twisthaler used at a volumetric flowrate of 50 L/min, deposition in plates 2 to 8 of the NGI decreased from 13% of label claim at an elevation of 700 m to 9% at an elevation of 4300 m.

When devices were evaluated at lower inhalation flow rates (considered on the threshold of reduced performance *in vivo*), all inhalers yielded relatively consistent, though poor, performance using either constant pressure drops or matched flow rates regardless of altitude.

These results indicate that when medium-to-high resistance DPIs are used with a standard pressure drop of 4 kPa, device performance appears to be independent of altitude. However, when certain DPIs are instead evaluated using constant volumetric flowrates, altitude may cause small but significant decreases in device performance.

**2HR.12**

**Characterizing Chemical Components of Particles in Thirdhand Tobacco Smoke.** XIAOCHEN TANG, Noelia Ramirez Gonzalez, Xavier Correig, Marion Russell, Lara Gundel, Hugo Destailats, *Lawrence Berkeley National Laboratory*

While tobacco control strategies protect non-smokers from secondhand smoke (SHS) in public places, they are not as effective for indoor environments such as homes, where non-smokers are vulnerable to both SHS and thirdhand smoke (THS), i.e., residual smoke contaminants remaining airborne or absorbed to surfaces. While little is known about the changes in chemical composition of THS as it ages indoors, exploring these changes is critical in understanding its health impacts on occupants.

Fresh tobacco smoke generated in a room-sized chamber at Lawrence Berkeley National Laboratory was sampled at different times after smoking commercially available cigarettes. Semi-volatile and particulate constituents in SHS and THS were collected using a High Capacity Integrated Organic Gas and Particle Sampler (IOGAPS). Samples were collected serially on XAD-coated diffusion denuders (for gases), Teflon-coated glass fiber filters (for particles) and XAD-coated quartz filters (for semi-volatile gases that evaporated from the particles). Targeted and untargeted analyses were carried out to identify and quantify smoke components using gas chromatography coupled with ion trap mass spectrometry (GC-IT-MS<sup>n</sup>), comprehensive gas chromatography (GC×GC-TOF) and high-resolution quadrupole time-of-flight gas chromatography (GC-Q-TOF) and liquid chromatography (UHPLC-Q-TOF) methods. Target compounds include alkanes, polycyclic aromatic hydrocarbons (PAHs), tobacco-specific nitrosamines (TSNAs) and other potential tracers for tobacco PM. Gas and particle phase chemicals specific to THS could be used as tracers to differentiate SHS from THS, and they could also be included in exposure and harm assessment models to evaluate integrated health risks, thus promoting the advancement of effective environmental and health policies.

**2HR.13**

**Investigation of Health Effects of Beijing's Air Using a Mouse Model.** XIANGYU ZHANG, Maosheng Yao, *Peking University*

In recent decades, China is experiencing frequent haze events especially during the winter seasons. However, its adverse health effects are still not clearly elucidated. Here, we used mice as experimental models which were exposed to different dose of PM<sub>2.5</sub> collected from Beijing during clear and haze days via injection. Blood samples were collected before injection and 1h, 2 days, 4 days, 6 days, 8 days after injection respectively. Five different biomarkers indicating oxidative damage and inflammatory responses were studied. Five main organs (heart, liver, spleen, lung and kidney) were also taken after euthanizing the rats, for anatomy and histopathological analysis. Simultaneously, we also recoded all behaviors of those control and exposed mice. The results showed that after 1h of PM<sub>2.5</sub> injection, the levels of interleukin-6, C-reactive protein and endotoxin increased significantly compared to the control. In addition, our video recordings of those exposed mice with high PM<sub>2.5</sub> loadings had a slow response to external interruption. PM<sub>2.5</sub> collected from the haze days were shown to be more harmful than those collected from clear days.

**2HR.14**

**Chemical and Toxicological Characteristics of Diesel Exhaust Particles.** MINHAN PARK, HungSoo Joo, KwangYul Lee, Lucille Joanna Borlaza, Heung-Bin Lim, Han-Jae Shin, JiYi Lee, Kihong Park, *Gwangju Institute of Science and Technology*

Diesel exhaust particles has been known to have significant adverse effects on human health (U.S. EPA, 2002). In this study, chemical and toxicological characteristics of diesel exhaust particles were simultaneously measured to relate chemical properties to toxicity of diesel exhaust particles. Chemical composition of diesel exhaust particles such as ions (sodium, ammonium, potassium, magnesium, calcium, chloride, nitrate and sulfate), metals (Al, V, Mn, Fe, Ni, Cu, Zn, As, Cd, Ba, Pb, Co, Se, Cr, Ca and Mg), organic carbon (OC)/elemental carbon (EC) were determined by ion chromatography (IC), inductively coupled plasma mass spectrometer (ICP-MS), and Sunset OC/EC analyzer, respectively. Also, detailed speciation of the OC was conducted by using a gas chromatography-mass spectrometer (GC-MS). To determine toxicity, various chemical and biological tests were conducted including cytotoxicity, mutagenesis and oxidative potential (OP). The cytotoxicity was tested via neutral red uptake (NRU) assay using chinese hamster ovary (CHO) cell. Half maximal effective concentration (EC<sub>50</sub>) of diesel exhaust particles was found to be 58.2±2.0 µg/ml. Mutagenesis and oxidative potential of diesel exhaust particles were also tested by Ames test and several chemical assays (dithiothreitol (DTT) and electron spin resonance (ESR) assays). Preliminary results showed that diesel exhaust particles had the highest mutagenic activity among PM samples (e.g., biomass burning samples, coal combustion samples (1100 °C combustion), and road dust) analyzed in this study.

**2HR.15**

**Increased Oxidative Potential of Fine Particulate Matter (PM<sub>2.5</sub>) Measured On-road of Major Freeways of Los Angeles, CA.** FARIMAH SHIRMOHAMMADI, Dongbin Wang, Sina Hasheminassab, Vishal Verma, James Schauer, Martin Shafer, Constantinos Sioutas, *University of Southern California*

This study describes a series of on-road sampling campaigns conducted using a mobile instrumentation platform to assess the chemical composition and oxidative potential of fine particulate matter (PM<sub>2.5</sub>) on three representative roadway environments in Los Angeles: 1) I-110, a highly trafficked freeway, consisting of almost exclusively light-duty vehicles (LDVs); 2) I-710, a freeway with higher fraction of heavy-duty vehicles (HDVs), which serves as the main corridor to and from the Ports of Los Angeles and Long Beach, and; 3) Wilshire/Sunset boulevards, which are two of the busiest surface streets in Los Angeles. Sampling was also conducted at the main campus of the University of Southern California (USC), representing an urban stationary reference site. The PM<sub>2.5</sub> samples were chemically analyzed for elemental carbon (EC), organic carbon (OC), polycyclic aromatic hydrocarbons (PAHs) and 50 elements. PM<sub>2.5</sub> oxidative potential was also quantified using the dithiothreitol (DTT) assay. The cumulative mass fraction of the measured PAHs on the freeways was 3 and 3.3-fold higher than at Wilshire/Sunset and USC site, respectively. Mass fractions of Ba, Cr, Cu, Mn, Ni, Pb, Sb and Zn as common tracers of vehicular abrasion were 3.8±0.8 times higher on both freeways in comparison to surface streets (Wilshire/Sunset). The observed PM mass-normalized DTT activity was greatest on freeways, roughly 1.9 and 2.1 times higher than the values obtained at Wilshire/Sunset and USC, respectively. This observation underscores the important role of both tailpipe and non-tailpipe traffic emissions on the overall oxidative potential of urban PM. The higher freeway DTT activity levels (i.e. by a factor of 1.5-1.6) measured in our study compared to those in dynamometer facilities reflected the additional contribution of non-tailpipe emissions (e.g. re-suspended road dust and vehicular abrasions of brake and tire wear) to the PM<sub>2.5</sub> oxidative potential.

**2HR.16**

**Do 16 PAHs Adequately Represent Atmospheric PAH Toxicity?** VERA SAMBUROVA, Barbara Zielinska, Eric Fujita, Andrey Khlystov, *Desert Research Institute*

Atmospheric polycyclic aromatic hydrocarbons (PAHs) are of major concern in all environmental compartments due to their mutagenic and carcinogenic properties. The most common carcinogenic effect of PAHs on human cells is DNA damage through the formation of adducts in a number of organs, including liver, kidney, lungs, etc. For this reason, the role of atmospheric PAHs in carcinogenic potency of atmospheric emissions has to be carefully estimated.

PAHs are mainly formed during natural and anthropogenic combustion processes of fuels like wood, coal, peat, oil, fossil fuels, waste, crop/agricultural waste, animal dung, etc. In the present study, concentrations of 113 gas- and particle phase PAHs measured during various ambient (mostly urban locations) and source studies (including vehicular, biomass burning, etc. emissions) were used to estimate relative carcinogenic risks of gaseous and particulate PAHs based on their toxicity equivalency factors.

Among the 16 EPA PAHs, particle phase PAHs were found to have significantly larger total estimated toxicity. However, by measuring only particle phase PAHs, a significant part of aerosol toxicity could be missed. Further, when emitted into the atmosphere, gas-phase PAHs may be transformed into products with stronger carcinogenic and mutagenic properties (i.e., oxo- and nitro-PAHs) via photo-chemical reactions. Some PAH species, which are not included in the list of 16 EPA PAHs, are very abundant. This raises a question whether the 16 EPA PAHs adequately represent the total PAH toxicity. Carcinogenic properties of most of the analyzed 113 PAHs are still unknown and need to be determined for accurate determination of aerosol carcinogenic potency.

**2HR.17**

**Deposition of Multi-Walled Carbon Nanotube (MWCNT) Aerosols in Human Nasal, Oral, and Lung Airways.** WEI-CHUNG SU, Yung-Sung Cheng, Teh-Hsun Chen, *University of Texas Health Science Center at Houston*

Multi-Walled Carbon Nanotubes (MWCNTs) has been widely applied as additives in many commercial products today due to their unique physical properties. MWCNT materials might become airborne during manufacturing and application processes, and they could be inhaled by related workers and researchers causing potential lung problems. Therefore, studying the deposition of MWCNT aerosols in human respiratory tract is especially important from the viewpoint of occupational health to estimate associated MWCNT lung dosimetry. This study tried to use a special experimental approach to obtain original data for MWCNTs human airway deposition. In this study, the test MWCNT material was aerosolized by an unique generation system developed by NIOSH. A differential mobility analyzer (DMA) was employed to size classify the generated MWCNT aerosols into three designated classification diameters (nominal diameters: 100, 200, and 300 nm). The human airway deposition experiments were conducted by delivering the size classified MWCNT aerosols into well-defined human nasal, oral, and lung airway replicas. The deposition fraction and the deposition efficiency of the MWCNT aerosols in the human airway were determined by measuring the differential concentration of MWCNT aerosols between the inlet and outlet(s) of the airway replica using a sequential mobility particle sizer (SMPS). The deposition data obtained from this study showed that MWCNT deposition fractions found in most airway sections used in this study were generally less than 7%. This result implies that, within the aerosol size range studied, most of the MWCNT aerosols inhaled into the human airways can easily pass through the upper airways and transit down to the lower airways where adverse health effects might be induced. The experimental method used in this study is believed also could be applied on other nanomaterial aerosols to investigate the human airway deposition, which would greatly facilitate the health risk assessment for exposure to various nanomaterials in laboratories or workplaces.

**2HR.18**

**Oxidative Potential and Chemical Characteristics of Water-soluble Particles Produced by Burning Rice Straw and Pine Wood.** LUCILLE JOANNA BORLAZA, Bhuwan Paudel, Arom Seo, KwangYul Lee, HungSoo Joo, Shila Maskey, Kihong Park, *Gwangju Institute of Science and Technology, South Korea*

Fine particulate matter (PM<sub>2.5</sub>) produced from biomass burning emissions has been increasingly associated with respiratory diseases (Laumbach et al., 2012; Torres-Duque et al., 2008; Arbex et al., 2007). Exposure to PM<sub>2.5</sub> has been known to cause adverse health effects through several mechanisms of action including oxidative stress. In lieu of common assessment of PM<sub>2.5</sub> health effects, this study investigated the capacity of biomass burning – related PM<sub>2.5</sub> to cause oxidative stress through the formation of reactive oxygen species (ROS). Laboratory – generated PM<sub>2.5</sub> from burning of rice straw and pine wood was sampled in a controlled volume chamber and collected using URG cyclones on teflon filters at different burning phases (approximately 1- 20 mins, 21- 40 mins, and 41- 60 mins after burning of sample). Particle size distribution and mass concentration was monitored by coupling an optical particle counter and a scanning mobility particle sizer. Two chemical assays were used to characterize OP of water-soluble PM<sub>2.5</sub>: dithiothreitol (DTT) and electron spin resonance (ESR) assay. OP-DTT was carried out through assessment of the capability of redox active compounds in PM<sub>2.5</sub> to transfer electrons from DTT to oxygen thereby generating superoxides. The consumption of DTT over specific time intervals (5, 15, 25, 35 and 45 mins) was interpreted as a measure of the capability of ambient PM<sub>2.5</sub> to produce ROS. On the other hand, OP-ESR was performed using ESR with a spin trap (5,5 – dimethylpyrroline – N – oxide or DMPO) which measures the capability of PM<sub>2.5</sub> to generate hydroxyl radicals ( $\bullet$ OH) through Fenton type reactions with the presence of hydrogen peroxide. Dithiothreitol (DTT) assay was used to characterize OP of water – soluble PM<sub>2.5</sub>. Varying physical and chemical properties; and OP results with biomass types and combustion conditions will be presented.

**2HR.19****Making Water-suspension of Hydrophobic Nanomaterial Powder Using Condensation-impaction Technique.**

KENJIRO IIDA, Hiromu Sakurai, Kensei Ehara, Kazuhiro Yamamoto, Masashi Gamo, *AIST*

It is very difficult to suspend nanomaterial powder whose surface are coated with strongly hydrophobic. Therefore, surfactants are generally added to water to suspend hydrophobic nanomaterials. We propose a new method for making water-suspension of hydrophobic nanomaterial powder without adding any surfactants. The method implements water-based growth tube collector (GTC) manufactured by Aerosol Dynamics, Inc. First, nanomaterial powder is aerosolized using a dry dispersion technique. The aerosolized nanomaterial forms agglomerates whose aerodynamic diameter is in a few micrometer range. These aerosol particles are sampled by a GTC whose sampling flowrate is set at 3.1 L/min. Supersaturated water-vapor condense onto nanomaterial powder, and condensation-grown particles are collected onto a substrate using inertial impaction technique. During the collection process the substrate is kept wet to keep the condensed water on the nanomaterial surface. Immediately after the collection process the collected material is dispersed in ultrapure water placed in an ultrasonic bath. Two types of titanium dioxide (TiO<sub>2</sub>) nanomaterial powder were used in our experiments. First type was Aeroxide P25 whose surfaces are naturally hydrophilic. Second type was Tayca JMT-150IB whose surfaces were presumably coated with isobutyl-functional group. Mass based collection efficiencies of the GTC were evaluated. The values were about 80% and 30% for P25 and JMT-150IB, respectively, indicating that the probability of activating condensation is lower for hydrophobic material. Collected JMT-150IB in water were periodically re-suspended by applying ultrasonic waves, and the particle number concentration in the suspension was monitored qualitatively by light scattering technique up to two weeks. It was concluded that initial state of the dispersion can be easily reproduced.

**2HR.21****The Contribution of Organic Aerosol to the Reactive Oxygen Species Formation on Lung Lining Fluid Interface.**

LIJIE LI, Shinichi Enami, Michael Hoffmann, Agustin Colussi, *California Institute of Technology*

Epidemiological studies consistently reveal the adverse impacts of airborne particulate matter (PM) on human health. Asthma and chronic obstructive pulmonary diseases are deemed to associate with the reactive oxygen species (ROS) generated in lung lining fluids (LLF) upon inhalation of PM and oxidant pollutants. Primary and secondary organic aerosols are determined as ROS by bulk liquid chemical assays involving dithiothreitol (DTT) and ascorbic acid (AA). However, the interactions of PM with LLF are multiphase processes. Interfacial reactions may proceed at different rates, mechanisms and therefore generate different products compared with those in bulk media. Our previous work has demonstrated that some chemical reactions at the air-water interface proceed  $10^3$  to  $10^6$  faster than in bulk water. Thus, it is important to investigate the oxidative potential of organic aerosol at interfaces. Furthermore, it is important to identify the key intermediate species that induce oxidative stress and adverse health effect

This work incorporates the technique of gas-beam modulation and pulsed ion-gating detection to the existing coupled reactor and ES-MS (Electrospray Mass Spectrometry) system to investigate the ROS formed on the respiratory surface. The contribution of aerosol components to oxidation stress on LLF is evaluated. The cross effect of different components on ROS formation is further investigated.

**2HR.22****Characterization of the Dust from Sawing Preservative-Treated Woods.** CHAOLONG QI, Alan Echt, *NIOSH*

The use of copper compounds as wood preservatives has been growing rapidly. However, the increasing use of copper nanoparticles in wood treatment raises the concern of workplace exposure to these nanoparticles.

In this study, we conducted laboratory experiments to characterize the dust from sawing wood treated with different copper preservatives. The dust generation rate, size distribution of the dust, and copper content in the particles of different sizes were characterized in details.

In an evaluation of saw dust generation, in the aerodynamic particle size range from 0.5 and 20  $\mu\text{m}$ , the mean particle generation rates (10 tests) for Micronized Copper Azole Ground Contact (MCA-GC) treated wood and Copper Azole, Type C Ground Contact (CAC-GC) treated wood were significantly higher ( $p < 0.0001$ ) than all other types. Additionally, those values for untreated wood and Micronized Copper Azole Above Ground (MCA-AG) treated wood were significantly higher ( $p < 0.0001$ ) than 4,5-dichloro-2-N-octyl-4-isothiazolin-3-one-Imidacloprid-Stabilizer Above Ground (EL2-AG) treated wood.

In the range of particle mobility diameters from 5.6 to 560 nanometers, statistically significant differences were observed in the mean particle generation rates among the wood types. CAC-GC and MCA-AG mean particle generation rates were significantly ( $p < 0.0001$ ) higher than all the other wood types (untreated, MCA-GC, and EL2-AG). MCA-GC mean (10 tests) particle generation rate was also significantly ( $p < 0.0001$ ) higher than EL2-AG and untreated wood, and EL2-AG wood was in turn significantly higher ( $p < 0.0001$ ) than untreated wood, which had the lowest value among all types.

Analyses of the copper content of wood dust showed that statistically significant differences in copper content were only observed in two dust sizes, 7.5  $\mu\text{m}$  ( $p = 0.02$ ) and 0.7  $\mu\text{m}$  ( $p = 0.019$ ). Tukey's multiple comparison test showed that MCA-GC and MCA-AG had significantly more copper in both the 7.5  $\mu\text{m}$ -size and 0.7  $\mu\text{m}$ -size samples than CAC-GC.

**2HR.23****Rethinking Dithiothreitol based PM Oxidative Potential – Measuring Antioxidant Consumption versus ROS**

**Generation.** Qianshan Xiong, Runran Wang, Haoran Yu, VISHAL VERMA, *University of Illinois Urbana-Champaign*

The capability of ambient particles (PM) to generate reactive oxygen species (ROS) is proposed as a biologically relevant property. Among the various methods developed to measure the oxidative potential of ambient PM, dithiothreitol (DTT) assay has been most widely used. In this assay, the rate of DTT oxidation catalyzed by the ambient PM is measured, which is assumed to be proportional to the rate of superoxide radical generation. These superoxide radicals can further react with the metals (e.g. Fe and Cu) to generate hydroxyl radicals. However, in the conventional protocol, where we measure the rate of oxidation of DTT, this important step of hydroxyl radical generation is not captured. This is probably a great caveat of DTT assay causing an underestimation of the role of transition metals, which are otherwise known to generate ROS in biological system. To overcome this limitation, for the first time, we measured the hydroxyl radical generation catalyzed by ambient PM in the DTT assay. This is accomplished by adding sodium terephthalate in the reaction vial, which gets oxidized by hydroxyl radicals to 2-hydroxyterephthalic acid (2-OHTA). 2-OHTA is a highly fluorescent compound and the fluorescence intensity is measured at 425 nm (excitation wavelength 310 nm). Preliminary tests conducted with pure compounds revealed new insights on the pattern of ROS generation in DTT assay. For example, four quinones known to oxidize DTT in the efficiency order of phenanthrenequinone (PQN) > 5-hydroxy-1,4-naphthoquinone (5-hydroxy-1,4-NQN) > 1,2-naphthoquinone (1,2-NQN) > 1,4-naphthoquinone (1,4-NQN), showed a different efficiency order (5-hydroxy-NQN > 1,2-NQN > PQN > 1,4-NQN) in the hydroxyl radicals generation. Cu, which is a dominant metal in the DTT assay, has a long lag period (up to 2-5 hours depending on the concentration of Cu) in the hydroxyl radicals generation. Most importantly, ROS generation by both quinones and Cu was enhanced by 2-3 folds in presence of Fe, which was supposed to be inactive in the DTT assay. Our results show that DTT-oxidation and ROS-generation are two different aspects, and measuring both in the same assay is important to incorporate the contribution from all major aerosol components and to provide a comprehensive picture of the total ROS activity of ambient aerosols.

**2IM.1****Performance Characterization of a Handheld Nebulizer.**

TSUNG-HAN YANG, Ning Yu, Yu-Mei Kuo, Chih-Wei Lin, Sheng-Hsiu Huang, Chih-Chieh Chen, *National Taiwan University*

Vibrating mesh aerosol generators have been reported to have increased output efficiency, minimal residual volume, and high percentage of particles in the emitted respirable and fine particle fraction. This work aimed to thoroughly characterize a miniaturized vibrating mesh nebulizer, uniquely applying capillary force for solution delivery.

The miniaturized vibrating mesh aerosol nebulizer tested in this work consisted of a nebulization unit, a liquid reservoir and transport device. One triple-A battery was used to power the nebulizer, in order to miniaturize the device and operate for long hours. The vibrating mesh plate was placed on top of the solution transport device which was composed of two circular tubes, designed to deliver solution by capillary force. The aperture size of vibrating mesh plate was 15 micro-meter. There were 2375 tapered holes on the mesh and the between-aperture distance was 160 micro-meter. The effect of the orientation, including vertical, horizontal, and up-side-down, of the nebulizer was investigated. An aerosol size spectrometer was employed to measure the aerosol number concentration and size distribution. This nebulizer was mainly evaluated with 0.9% NaCl.

The power consumption of this device was 0.925 watt. It could continuously operate for over 6 hours. The feeding rate was around 0.15 mL/min and only negligibly affected by the device orientation. However, the residual was slightly influenced by the orientation, 7.0%, 5.6%, 2.6% for vertical, horizontal and up-side-down, respectively. The CMD of the aerosol output was around 0.55 micro-meter, with geometric standard deviation about 2. The aerosol number concentrations were 6,878, 11,724, and 16,101 #/cm<sup>3</sup> for vertical, horizontal, and up-side-down, respectively. The most significant feature of this hand-held nebulizer was almost orientation independent. This made it ideal for medical use, especially for patients lying on bed. The residual volume could be further reduced by adjusting the design of the solution transport device.

**2IM.2****Influence of Solvent Residue from Aerosol Generation on Ion Properties and Aerosol Charging in a Soft X-ray Neutralizer.**

XIAOTONG CHEN, Dongsen Yang, Runlong Cai, Qiang Zhang, Jun Zheng, Jingkun Jiang, *Tsinghua University*

Solutions, such as di-octyl sebacate (DOS) in isopropyl alcohol (IPA), tetra-heptyl ammonium bromide (THABr) in methanol and sodium chloride in water, are often used to generate standard aerosols through atomization or electrospray. After aerosol generation, some solvent residue remains in the carrier gas. Upon entering the aerosol neutralizer, solvent residue may participate in the dynamic processes of ion generation and aerosol charging. In this study, we tested the influence of IPA, methanol, and water vapor on neutralizer ion properties, charging fractions, and subsequent size distribution measurement. A bubbler was used to add different levels of solvents into nitrogen (99.999%), simulating solvent residue in the carrier gas when generating aerosols. A half-mini DMA (long/thin type) and an electrometer (Model 3068B, TSI, Inc.) were used to measure ion mobilities downstream a soft X-ray aerosol neutralizer (Model 3088, TSI, Inc.). Ion compositions were characterized by an atmospheric pressure interface high-resolution time-of-flight mass spectrometer (APi-HR-ToFMS). Based on these measured ion parameters, charging fractions were estimated using Fuchs diffusion charging theory. DOS aerosol size distributions with different levels of solvent residue were also measured. When increasing the concentration of IPA or methanol vapour in the carrier gas, the mobilities of both positive and negative ions were found decreased, indicating that organic vapour molecules might have participated in ionization reactions. An increase in water vapour concentration did not influence positive ions significantly, while the mobilities of negative ions were found increased, possibly due to the promotion of NO<sub>3</sub><sup>-</sup> generation by adding water vapour. Significant influences on DOS size distribution measurement were observed when there are IPA vapour left in the carrier gas.

**2IM.3****Development of a Thoracic Personal Sampler System for Co-Sampling of Sulfuric Acid Mist and Sulfur Dioxide Gas.**

CHIH-HSIANG CHIEN, Alexandros Theodore, Chang-Yu Wu, Yu-Mei Hsu, Brian Birky, *University of Florida*

A novel personal sampler has been designed to measure inorganic acid mists and gases in workplaces for determining human exposure levels to these acids. This sampler consists of a parallel impactor for classifying aerosols with size following ISO/CEN/ACGIH defined human thoracic fraction, a cellulose filter to collect the residual sulfuric acid mist but allowing penetration of sulfur dioxide gas, and an accordion-shaped porous membrane denuder (aPMD) for adsorbing the penetrated sulfur dioxide gas. To minimize sampling interference, antistatic PTFE is selected as the housing material as it is inert and is easy to machine. The novel flat design is easily adaptable to a light-weight and portable device that an individual could carry.

Monodisperse aerosol generated from a vibrating orifice aerosol generator and sulfur dioxide gas from a cylinder were used to test the performance of the personal sampler. The results showed the parallel impactor operated at 2 Lpm flow rate had a cutoff size of 10.2  $\mu\text{m}$  and its penetration curve agreed well with the defined thoracic fraction. 94% sampling bias is within 10% for particle size distributions with MMAD between 1 – 25 micro-meter and GSD between 1.75 – 4, which meets the criteria of the EN 13205 standard. The aPMDs maintained a gas collection efficiency greater than 95% for 4 hours when sampling 10 ppm of sulfur dioxide gas, demonstrating that the aPMD meets the criteria for collection efficiency and collection capacity. While the aPMD has similar performance to popular annular or honeycomb denuders made of glass, this shatterproof aPMD is only half of the volume and 1/25th the weight of the honeycomb denuder. All the test results illustrate the aPMD is a more advantageous personal sampler that enables a more accurate assessment of human exposure to sulfuric acid aerosol in thoracic mass.

**2IM.4****The Optimization of Inkjet Operating Parameters for the Generation of Monodisperse Aerosol Particles.**

HANEOL LEE, Youngsu Jung, Kibong Choi, WeonGyu Shin, *Chungnam National University*

We investigated the effect of inkjet operating parameters on the size control of aerosol particles. Droplets with agglomerates of polystyrene latex particles were generated from an inkjet nozzle and continuously dried up at the temperature of 38 degrees of Celsius. When droplets have the size range of 30 to 70 micrometer in diameter, aerosol particles with the size range of 3.5 to 7.1 micrometer were generated after the drying process. We controlled the particle size easily within a factor of two by adjusting rising/falling time and voltages of an actuating waveform. Generated particles were shown to have a narrow particle size distribution. Thus, the particle concentration of aqueous suspension does not need to be adjusted precisely in order to control the size of generated aerosol particles.

**2IM.5**

**Numerical Study on the Particle Trajectory inside an Optical Cavity with Direct Flow Configuration.** HANEOL LEE, Youngsu Jung, Kibong Choi, WeonGyu Shin, *Chungnam National University*

As a first step towards developing an effective method of detecting bioaerosol particles, we conducted numerical simulations on the particle trajectory inside an optical cavity with direct flow configuration by using commercial code ANSYS FLUENT 15.0 solver. Two opposing nozzles were located inside optical cavity and sheath flow was used to focus particles effectively onto the line where light source passes through. In numerical simulations, Discrete Phase Model (DPM) and Discrete Random Walk Model (DRW) were used to obtain particle trajectory varying the aerosol sampling flow and sheath flow. Simulation results showed that using sheath flow greater than 0.5 L/min was effective way to prevent particles less than 4 micrometer from recirculating into optical cavity. For 0.7 L/min sheath flow rates, the average residence time of particles larger than 3 micrometer decreases as the size of particles becomes smaller. In contrast, the average residence time of particles smaller than 3 micrometer increases with the size of particles.

**2IM.6**

**PM Badge: A Wearable, Low-Power, Cellular-Enabled, Direct-Read Mass MEMS PM<sub>2.5</sub> Sensor.** DORSA FAHIMI, Omid Mahdavi-pour, Paul A. Solomon, Lara Gundel, Richard White, Igor Paprotny, *University of Illinois at Chicago*

This work describes the development of a wearable fine particulate matter (PM<sub>2.5</sub>) sensor optimized for low-power and small-size. The micro-electromechanical (MEMS) based PM<sub>2.5</sub> sensor is capable of real-time detection of particle mass. In this sensor, an air-microfluidics circuit separates fine particles from the airstream by means of an elutriator, and a film bulk acoustic resonator (FBAR) directly measures the mass of fine particles deposited on its surface by thermophoresis. Taking advantage of microfabrication technologies, the footprint area of the sensor is miniaturized to a few cm<sup>3</sup>, enabling the operation of the sensor at very low flowrates (< 5 ml/min). The relatively low pressure drop of the elutriator at such low flow rates enables low power usage, which in turn allows for the integration of this device into a wearable package for continuous personal air quality monitoring.

We report on the design of the sensor, an optimized air-microfluidics circuit for low-power, and experimental results of testing the sensor in the presence of incense smoke. The sensor has shown the sensitivity of few hertz cubic meter per microgram per minute, with a low detection limit of single micrograms per cubic meter for PM<sub>2.5</sub> mass. We also report on the connectivity of the wearable PM<sub>2.5</sub> sensor to a cellular phone through Bluetooth for real-time displaying of the data acquired from the FBAR.

**2IM.7****Laboratory Measurements of Total Suspended Organic Carbon: Technique Development and Application to Chamber Experiments.** JOSHUA MOSS, Jesse Kroll, *MIT*

Secondary Organic Aerosol (SOA) composes a major fraction of particulate matter in the atmosphere and is principally formed through the oxidation of volatile organic compounds (VOCs). However, past bottom-up studies aimed at elucidating the underlying chemical mechanisms pertaining to SOA formation and evolution have been unable to fully identify and enumerate all SOA organic species, largely due to the extreme chemical complexity of the system and poorly constrained depositional losses to chamber walls. In order to provide a new “top-down” constraint on this chemical system, here we describe the measurement of Total Organic Carbon (TOC) for use in laboratory studies of SOA formation and oxidative aging. This work builds on an established technique for TOC measurement, involving the use of a palladium catalyst to fully oxidize VOCs to carbon dioxide, which to our knowledge has not been adapted for laboratory oxidation studies. A number of characterization studies, focused on measuring the oxidation efficiency for compounds spanning a wide range of volatilities (from volatile species in the gas phase to compounds present only in particles), will be described. Additionally, we describe the use of this technique within chamber SOA experiments, comparing measurements of TOC with results from a suite of instruments measuring gas- and particle-phase organic species. This “top-down” vs. “bottom-up” comparison provides new constraints on the extent of “carbon balance” measured in atmospheric oxidation studies.

**2IM.8****Ambient and Laboratory Evaluation of a Low-Cost PM sensor.** KERRY KELLY, Chris Widmer, Jonathan Whitaker, Anthony Butterfield, *University of Utah*

Low-cost, light-scattering-based particulate matter (PM) sensors are becoming more widely available and are being deployed in ambient and indoor environments because they can provide improved spatial and temporal resolution PM measurements. In fact, some community groups are posting PM concentrations based on these measurements. Researchers have begun to evaluate some of these sensors under laboratory and environmental conditions. In this study, the PlantPower PMS 1003/3003 was evaluated in a controlled wind-tunnel environment with alumina oxide particles and in the ambient environment during a winter season that was punctuated by several cold-pool events with corresponding high ambient PM levels. Under the ambient conditions tested the PMS sensor correlated well with 24-hour federal reference measurements ( $RSQ > 0.88$ ) and hourly federal equivalent methods ( $RSQ > 0.90$ ); these correlations are generally higher than correlations reported by other ambient studies of low-cost sensors. In the wind tunnel, the PMS also correlated well with mass-adjusted DustTrack measurements ( $RSQ > 0.87$ ). Although the correlations between the PMS sensor and the federal reference/equivalent methods and research-grade instruments was high, the PMS sensor overestimated PM<sub>2.5</sub> concentrations under the winter-time ambient conditions tested and underestimated the PM<sub>2.5</sub> concentrations in the wind-tunnel environment. This study provides a suggested model for the PMS sensor response, emphasizes the importance of particle composition and size on sensor response, and highlights some of the differences between laboratory and field performance of these low-cost sensors.

**2IM.9**

**Detection and Quantification of Organic Aerosol Species with Thermal Vaporization-Electron Impact Ionization in the Aerodyne Aerosol Mass Spectrometer.** WEN XU, Manjula Canagaratna, Philip Croteau, Andrew Lambe, Leah Williams, Lindsay Renbaum-Wolff, Timothy Onasch, John Jayne, Douglas Worsnop, *Aerodyne Research, Inc.*

Organic aerosol (OA) constitutes a large fraction of the ambient submicron particulate mass. Real-time detection and quantification of OA is complicated by the fact that it consists of hundreds of individual species. In the Aerodyne aerosol mass spectrometer (AMS), OA is detected via a two-step process of thermal vaporization and electron impact ionization. Quantification of the detected OA mass is dependent on empirically parameterized particle collection efficiency and relative ionization efficiencies (RIE). In this study we compare OA measurements obtained with a standard AMS vaporizer (where solid particles are known to experience particle bounce) and a capture vaporizer that has near unity particle collection efficiency. Commercially available organic species with varying functionalities are used on their own or as mixed solutions with ammonium nitrate (the primary calibrant of AMS ionization efficiency) to generate pure as well as mixed aerosol particles in the laboratory. Secondary organic aerosols generated with a Potential Aerosol Mass (PAM) oxidation flow reactor are also examined. We utilize the results to obtain more detailed information about the OA detection process and to evaluate the current empirical parameterization of RIE that is utilized in AMS quantification of organics.

**2IM.10**

**Investigating Gaseous and Coarse, Fine and Ultrafine Particle Emissions from Advanced Biomass-Fueled Appliances Operating Under Different Operational Loads.** PATRICIA FRITZ, Brian P. Frank, Shida Tang, David Guerrieri, Marilyn Wurth, Thomas Wainman, Todd Crawford, Nathan Walz, Nicole Vitillo, Jake Lindberg, David Barnes, Thomas Giorgio, Gil H. LaDuke, Thomas Butcher, Rebecca Trojanowski, *New York State Dept. of Health*

Due to economic and environmental factors, biomass-fueled heat, hot water, and steam systems are increasingly being considered for operation in residential, school and commercial-settings. Biomass combustion emissions are likely to increase with continued financial incentives, and as an alternative to fossil fuel products. As with the mobile source sector, there will be regulatory and market pressure to control particulate and air toxics emissions while increasing energy efficiency. Our work addresses data gaps around the magnitude and type of emissions that will result as the biomass fuel sector expands: the contribution of coarse, fine, and ultrafine PM, as well as carbon monoxide, carbon dioxide, and nitrogen dioxide to local ambient and indoor air quality from biomass-fueled appliances evaluated under laboratory and field conditions. We are evaluating fresh and aged primary and secondary aerosol emissions in ambient and indoor air with respect to particle mass, number and size in real time, and elemental and organic carbon, polycyclic aromatic hydrocarbon content and particle morphology in aggregate and size segregated samples. Evaluating the EC/OC ratio of emissions has been suggested as a tool for particulate source attribution to guide controls to protect public health and to estimate influences on radiative forcing. We are applying and expanding emission measurement techniques previously used to characterize particle emissions from mobile sources to characterize emissions from high efficiency biomass appliances. Our data can contribute to efforts to develop functional policy options that are compatible with public health and protection of the environment as this alternative energy sector expands.

**2IM.12****Exploring the Applicability and Limitations of Selected Optical Scattering Instruments for PM Mass Measurement.**

JIE ZHANG, Joseph P. Marto, James Schwab, *University at Albany, SUNY*

Three optical scattering instruments for PM mass measurement were evaluated in our laboratory using poly- and monodisperse test aerosols. Two instruments are commercially mature instruments (the Thermo Personal DataRAM (pDR-1500), and the TSI Environmental DustTrak DRX (Model 8543)) and one is a newly developed low cost PM sensor (the Alphasense Optical Counter (OPC-N2)). Monodisperse test aerosol (NH<sub>4</sub>HSO<sub>4</sub>, black carbon, PSLs and other pure species) were produced by a constant output atomizer and characterized by a TSI scanning mobility particle sizer (SMPS) system. Larger particles can be generated with a vibrating orifice aerosol generator. The response of these three optical scattering instruments to different particle characteristics (size, composition, concentration) were measured and used to evaluate the performance of these instruments. At the same time, particle mass concentration from these three instruments were compared with the SMPS determined concentrations to study the applicability and limitations of these optical scattering instruments for measurements of PM mass concentration. The detailed laboratory evaluation and comparison of these three optical scattering methods will provide guidance to the suitable application for each instrument when considering accuracy and precision as well as cost.

**2IM.15****Using Dynamic Mesh to Investigate Deposition Pattern of NanoParticle Controlled by Electric-field.**

ALI MOHAMADI NASRABADI, Jungho Hwang, *Yonsei University, Department of Mechanical Engineering*

Defined particle deposition is a well-established process in the field of printing applications. However, the demand for precision beyond the resolution of the human eye was hardly considered in these applications. In this work, we simulated deposition of 30 nm silver nano-particles over silver grid structures. For this goal, a complete aerosol deposition process was studied and simulated using a commercial CFD code, FLUENT v14. Electrical field has been simulated by solving a scalar transport equation and electrostatic force was applied by using a User Define Function, DEFINE\_DPM\_BODY\_FORCE. Simulation of deposition process is carried out by using Fluent Dynamic Mesh option. By using DEFINE\_DPM\_BC, it is possible to extract necessary data for calculating deposition height, for example mass flux of hit particle on the substrate, area, place and number of deposited particles. Taking into account particles density and time, it is possible to calculate deposition growth height in each cell. DEFINE\_GRID\_MOTION can move each grid vertices on the substrate independently. Calculated height is compared with experimental data to verify simulation process. The measurement of the deposited thickness on the target gives an overall verification of the accuracy of the numerical model for particle trajectories.

**2IM.16****Measuring Flame-generated Sub-3-nm Particle Size Distributions with a TSI 1-nm DMA and Nano Enhancer.**

YANG WANG, Sherrie Elzey, Pratim Biswas, *Washington University in St Louis*

While flame synthesis is a dominant method for producing nanoparticles in large quantities, the initial stages of particle formation during combustion are not fully understood. Existing work conducted with a high-resolution differential mobility analyzer (DMA) coupled with an electrometer have shown that a large amount of highly charged sub-3-nm particles can be generated from flames (Wang et al, 2014; Fang et al, 2014). However, measuring nanoparticle concentration with electrometers may suffer from background noise and high detection limits, especially for the smallest nuclei particles < 3 nm. Newly developed CPCs with enhanced working fluids, such as diethylene glycol (DEG), can significantly lower the limit of detection for sub-3-nm particles. In this study, flame-generated sub-3-nm particle size distributions were measured for the first time with a 1-nm DMA (TSI 3086) coupled with a DEG-based Nano Enhancer (TSI 3777) and a butanol-based CPC (TSI 3772). A comparison against a conventional SMPS system which includes a Nano DMA (TSI 3085) and a butanol-based CPC (TSI 3025A) was conducted. The effects of the synthesis precursor type, precursor concentration, and particle residence time on the particle size distribution were further investigated.

Wang, Y. et al., (2014). *J. Aerosol Sci.*, 71, 52-64.

Fang, J. et al., (2014). *Anal. Chem.*, 86, 7523-7529.

**2IM.17****From Certified Regulatory PM Monitoring over Portable Measurements up to Studies in Airspace - Simultaneous Determination of PM Fractions, Particle Number and Particle Size Distribution in High Time Resolution Applying One and the Same Optical Measurement.**

KARSTEN PLETSCHER, Maximilian Weiss, Leander Mölter, *Palas GmbH*

Air pollution due to particulate matter and the related negative effects (health problems, economic damages) has become one of the major problems our society is faced with today. In order to be able to investigate and to assess the real exposition of the general public in a comprehensive way, the performance of precise and accurate measurements of particulate matter is an essential part of air pollution control.

The measurement technology of the Fidas® sensor allows the simultaneous measurement at a high time resolution of the relevant PM fractions like e.g. PM10 and PM2.5, the particle number as well as the particle size distribution.

The Fidas® sensor applies the well-approved measurement technology of optical light scattering on single particles and is equipped with a polychromatic LED light source with long-term stable output. The scattered light intensity is detected under 90° through a patented aperture technology, thus preventing border-zone error and enabling for coincidence detection. The implemented approach allows for an easy external field verification and calibration as well as a permanent online-monitoring of the calibration status.

Due to its modular design, the Fidas® sensor technique has been adapted to specific devices to cover a large range of possible applications. For regulatory monitoring of PM2.5 and PM10 in official networks, the type-approved and EN-certified Fidas® 200 has demonstrated equivalence with the gravimetric standard reference method, but can deliver much more information due to particle number and particle size measurements. This can be especially useful for source appointment, studies of aerosol composition.

Apart from monitoring ambient air, also indoor and workplace environments can be closely inspected with Fidas® sensor technique – and due to portable Fidas® devices in a very flexible way!

Last but not least it is also possible – due to its very light weight - to install the Fidas® technique to carrier systems like flight robots. This allows the performance of particle measurements at inaccessible locations and can be used for the assessment especially of line and area sources and also deliver valuable parameters for R&D purposes (e.g. for prognosis models).

Keywords: PM monitoring, particle size distribution, certified monitor, ambient air, workplace, indoor

**2IM.18**

**Evaluation of the Alphasense Optical Particle Counter (OPC-N2) and the Grimm Portable Aerosol Spectrometer (PAS-1.108).** SINAN SOUSAN, Kirsten Koehler, Laura Hallett, Thomas Peters, *University of Iowa*

Although optical particle counters (OPCs) measure in real-time particle number concentration by size, their cost (e.g., >\$15,000, PAS-1.108, Grimm Technologies) restricts their widespread use in exposure assessment. We compared the performance of a new, extremely low-cost (~\$500) and compact OPC (OPC-N2, Alphasense) to the PAS-1.108. First, we measured detection efficiency by size from 0.5  $\mu\text{m}$  to 5  $\mu\text{m}$  for monodispersed polystyrene latex (PSL) spheres. Then we compared the output of the OPC-N2 to that of the PAS-1.108 and reference instruments for three aerosols (non-absorbing fine particles, nebulized salt solution; absorbing fine particles, welding fume; and coarse dust, aerosolized Arizona road dust) at concentrations up to 12,000  $\mu\text{g}/\text{m}^3$ . For particles larger than 0.8  $\mu\text{m}$ , the detection efficiency of the OPC-N2 was similar to that of the PAS-1.108, ranging from 66% [1  $\mu\text{m}$ ] to 101% [3  $\mu\text{m}$ ]. For 0.5- $\mu\text{m}$  particles, the efficiency of the OPC-N2 was 78%, whereas that for the PAS-1.108 was 183%. The number concentration measured with the two OPCs were under or overestimated compared to reference instruments, depending on aerosol type and size. The mass concentration output by the OPCs was highly linear with that measured with the reference instruments ( $r \geq 0.97$ ), but the slope and intercept depended strongly on aerosol type suggesting the need to develop a site-specific correction factor. Mass concentration was overestimated with the OPCs for Arizona road dust (OPC-N2, slope = 1.6; PAS, slope = 2.7) and underestimated for welding fume (OPC-N2, slope = 0.05; PAS, slope = 0.4). The coefficient of variation (CV, precision) for OPC-N2 for all experiments was between 4.2% and 16%. These findings suggest that the given site-specific calibrations OPC-N2 can provide similar information to the PAS-1.108 for particles larger than 1  $\mu\text{m}$ .

**2IM.19**

**A New Direct Bromide Anion Chemical Ionization Mass Spectrometry (Br-CIMS) Technique for the Measurement of HO<sub>2</sub>.** JAVIER SANCHEZ, Dexian Chen, David Tanner, Greg Huey, Nga Lee Ng, *Georgia Institute of Technology*

Hydroperoxy radicals (HO<sub>2</sub>) play an important role in secondary organic aerosol (SOA) formation. Despite their importance, laboratory chamber experiments designed to understand SOA formation do not routinely measure HO<sub>2</sub>. The lack of HO<sub>2</sub> measurements restricts the applicability of chamber experiments to the real atmosphere. HO<sub>2</sub> are not routinely measured due to the difficulty associated with the measurements as well as the need for additional instrumentation. In this work, we evaluated a number of reagent ions for the detection of HO<sub>2</sub> using chemical ionization mass spectrometry and present a new direct bromide anion chemical ionization mass spectrometric (Br-CIMS) technique for the detection of HO<sub>2</sub>. The direct nature of the technique eliminates the need for chemical titration with NO, which sidesteps artifacts contributed by organic peroxy radicals. The technique has a sensitivity of 4.95 Hz/ppt with a 0.7 ppt detection limit for 1 minute integration times. Ambient data collected in Atlanta demonstrates high selectivity towards HO<sub>2</sub> at mass-to-charge 112, suggesting that high resolution instrumentation is not necessary for obtaining accurate HO<sub>2</sub> measurements. The technique is applicable to both laboratory and ambient sampling and aims to exploit the increasing popularity of CIMS to improve the atmospheric relevance of laboratory chamber experiments. Ambient data collected in Atlanta and laboratory applications will be presented to showcase the usefulness of the technique.

**2IM.20**

**Two New Ambient Air Quality Monitoring Instruments for Fine and Ultra-Fine Airborne Particulates – Initial US Results.** DRITAN XHILLARI, Rudolph Jaeger, Max Urscheler, Daniel Bachman, Martin Blaustein, Gediminas Mainelis, *CH Technologies (USA)*

CH Technologies Inc. (USA) and collaborators tested the performance of a Fidas 200 Fine Dust Aerosol Spectrometer (Palas, GmbH, Germany) and a Partector (Naneos, Switzerland) for a four month period at the PAM site located at the Rutgers Horticulture Research Farm 3 (East Brunswick, NJ). Continuous measurements of  $PM_1$ ,  $PM_{2.5}$ ,  $PM_4$ ,  $PM_{10}$ ,  $PM_{total}$  plus Particle Number concentration were provided by Fidas 200 and Alveolar Lung Deposited Surface Area (LDSA) by the Partector.

A direct comparison of  $PM_{2.5}$  concentrations measured by the Fidas 200 and a co-located FEM device, a Beta Attenuation Monitor (BAM) was performed. Correlation analyses were performed based on  $PM_{2.5}$  hourly and daily averages from the two devices. When  $PM_{2.5}$  daily averages were compared, the Fidas 200 measurements correlated very well with the BAM data ( $r^2 = 0.896$ ). However, hourly averages exhibited a slightly weaker correlation ( $r^2 = 0.705$ ). The BAM exhibits lower sensitivity at lower PM concentrations, hence it has to sample for extended periods in order to obtain sufficient signal.

Examination of the relationship between Partector, Fidas 200 and BAM measurements revealed that the measured LDSA trended better with the BAM  $PM_{2.5}$  daily averages ( $r^2 = 0.602$ ) and less so with daily averages of various Fidas 200's PM fractions measurements.

This study indicated that the Fidas 200 (a certified Equivalent Methods (EM) in Europe) is well suited to provide reliable  $PM_{2.5}$  measurements. It correlates well with an FEM device, provides 99.97% completeness of hourly average time series and runs at lower cost than existing FRM or FEM devices. A collocation measurement campaign with an FEM  $PM_{2.5}$  is under way at the George Washington Bridge and the Fort Lee, NJ, Public Library. Additional testing will involve co-location at Queens College for  $PM_{2.5}$ ,  $PM_{10}$  and ultrafines measurements.

**2IM.21**

**A New, Automated System for the Simultaneous Determination of Gaseous Ammonia and Particulate Ammonium.** MICHAEL BATTAGLIA JR., Julian Paige, Justin Thaggard, Christopher Hennigan, *University of Maryland, Baltimore County*

A new method is presented for the automated, on-line measurement of gaseous ammonia and particulate ammonium. A mist chamber (MC) collects ammonia while a Particle-into-Liquid Sampler (PILS) simultaneously collects water-soluble aerosol components, including ammonium. The liquid extracts from the MC and the PILS undergo reaction according to a simplified Berthelot method, in which ammonium undergoes reaction and forms a compound easily detected by colorimetric analysis. The method, which is used extensively for the analysis of water samples, is applied to atmospheric measurements for the first time. On-line mixing and liquid handling is performed using syringe pumps, calibrated to deliver the mixed reagent/sample to a liquid waveguide capillary cell with a 50 cm path length at a precise reaction time for color evolution. Spectrophotometric analysis using a modular spectrometer was performed at 660 nm. The on-line system was tested and validated against an AiRRmonia gas-phase ammonia analyzer and Metrohm 850 IC in preparation for field deployment and integration into existing liquid-phase collection and analysis protocols. Benefits of this modular online system are operational simplicity relative to gas-phase analyzers and IC, lighter-weight and more portable for field deployment, less expense than IC and gas-phase analytic instruments (instrumentation and operation), higher time resolution, and high sensitivity at atmospheric concentration levels (demonstrated to  $> 0.001$  a.u. sensitivity).

**2IM.22****Application of Aerosol-LIBS (Laser Induced Breakdown Spectroscopy) for Real-time Detection of Contamination Particles in Semiconductor Manufacturing Process.**

GIBA EK KIM, Kyoungtae Kim, Hyun Ok Maeng, Hae Bum Lee, Kihong Park, *Gwangju Institute of Science and Technology*

The laser-induced breakdown spectroscopy (LIBS) has been used as a useful tool for rapid detection of elements in various samples (solid, liquid, gas, and aerosols), and can be operated under extreme conditions (high/low pressure and high temperature) (Noda et al. 2002; Thiem et al. 1994; Effenberger Jr and Scott 2010). In this study, the modular aerosol-LIBS was developed to monitor process-induced particles (contamination particles in the semiconductor manufacturing process) in real time. Since the semiconductor manufacturing process can occur at high temperature and low pressure with various chambers and exhaust lines, more flexible and durable LIBS system is required. The modular aerosol-LIBS is developed to allow easy adjustment to the various chambers and exhaust lines in the semiconductor manufacturing process and to operate at extreme temperature and pressure conditions. The modular aerosol-LIBS mainly consists of three modules (laser module, spectrometer module, and flexible and interchangeable chamber module). Several types of chamber modules were designed and each module was interchangeable in the modular LIBS system. The modular LIBS system was evaluated by using various laboratory-generated particles. Various solutions having elements of Co, Cu, Fe, K, Mg, Na, Ni, Si and P that can be detected in the semiconductor manufacturing process were aerosolized into the LIBS system and their emission lines were measured. Further evaluation of the modular LIBS system is being carried out.

This work was supported by Samsung Electronics, Co., Ltd.

**2IM.23****Aerosol Spark Emission Spectrometer.** LINA ZHENG, Pramod Kulkarni, M. Eileen Birch, *Centers for Disease Control and Prevention, NIOSH*

An Aerosol Spark Emission Spectrometer (ASES) has been developed for near real-time measurement of elemental concentration of submicrometer aerosols for personal and mobile applications. The instrument employs atomic emission spectroscopy using spark microplasma as the excitation source. The compact, hand-held instrument can simultaneously measure over 25 elements, including carbon, at a time resolution of few seconds to few minutes and detection limits of 0.01 to 1 micrograms per cubic meter. Its performance was evaluated in different workplace settings and the measurements were compared with time-integrated filter measurements. Overall design and development of the instrument will be presented; results from the laboratory and field studies, designed to evaluate analytical figures of merit of this new instrument will be discussed.

**2IM.24**

**Development and Field Evaluation of an Online Monitor for Continuous Measurement of Metals in Coarse Particulate Matter.** MOHAMMAD SOWLAT, Dongbin Wang, Giulia Simonetti, Martin Shafer, James Schauer, Constantinos Sioutas, *University of Southern California*

This study presents a novel system for online, field measurement of three toxicologically relevant redox-active metals (Fe, Mn, and Cr) in ambient coarse particulate matter (PM). This new system utilizes two virtual impactors combined with a modified liquid impinger (BioSampler) to collect coarse PM directly as concentrated slurry samples. The concentrations of target metals in the collected slurries are subsequently measured using a Micro Volume Flow Cell (MVFC) coupled with spectrophotometry to quantify the light absorption of colored complexes resulting from the reaction between the target metals and analytical reagents. In the field evaluations, very good agreements for total concentrations of target metals were obtained between online spectrometer-based measurements and those analyzed by means of inductively coupled plasma mass spectrometry (ICP-MS). Moreover, this coarse PM metal monitor was deployed in the field for continuous operations and measurements for three months. Diurnal variations of the target metals and their associations with meteorological parameters were also explored in the current study. The average concentration of Fe, Mn and Cr in coarse PM obtained in this study is  $57.8 \pm 2.5$ ,  $15.0 \pm 0.6$ , and  $6.9 \pm 0.6$  ng/m<sup>3</sup>, respectively. All three metals represent similar diurnal variations, with peak values observed during 8-10AM and lowest levels observed during midnight (10PM to 2AM) throughout the sampling campaign. Metal concentrations are also affected by other meteorological parameters such as wind speed and relative humidity. Results from this study suggest that it is an effective technology for characterization of three important metals in ambient coarse PM.

**2IM.25**

**A Compact "MAGIC" Water Condensation Particle Counter.** GREGORY LEWIS, Steven Spielman, Arantzazu Eiguren Fernandez, Susanne Hering, *Aerosol Dynamics Inc.*

A miniature, water-based condensation particle counter has been developed for portable monitoring of particle number concentrations. Called MAGIC, for moderated aerosol growth with internal water cycling, this counter operates from a combination of the the water vapor recovered from the sampled airstream, and from that recovered internally. There are no water reservoirs, yet it is capable of days to weeks of unattended operation. It may be tipped or shaken without affecting the measurement. Previously we have presented a prototype instrument, showing comparability of this approach to bench top condensation particle counters, and detection of particles as small as 5nm. This paper presents a new, compact commercial prototype MAGIC system.

The sustained operation is achieved through MAGIC's three-stage design, with a single wetted wick throughout. The first stage is a "conditioner" and is generally operated with cooled walls while the second stage, referred to as the "initiator", is relatively short with warm walls. This initiator stage provides the water vapor that creates the super-saturation to initiate droplet growth. The third "moderator" stage has cool walls, and captures the water vapor released by the initiator stage. The stages are lined with single wick that provides wetted surfaces throughout. Once the wick is wet, instrument operation is sustained through a combination of water vapor removed from the sampled air flow and internal capture of added water vapor. Consistent with modelling, experiments show that the performance is independent of the operating temperature selected for the third stage. Taking advantage of this aspect, the system presented here controls the third stage set-point temperature based on input conditions so that the water content of the exiting flow may match that which enters. This allows sustained operation for extended periods ranging from days for dry conditions, to months when the ambient dew point is above 10°C.

**2IM.26**

**Characterization of Marine Aerosol by the Novel Event Trigger (ET) Single Particle Mode of an Aerodyne Aerosol Mass Spectrometer during the NAAMES Campaign.** CHIA-LI CHEN, Derek Price, Raghu Betha, Maryam Lamjiri, Lynn Russell, Derek Coffman, James Johnson, Patricia Quinn, Timothy Bates, *Scripps Institution of Oceanography*

The influence of ocean ecosystems on the physical properties and chemical composition of marine aerosol was investigated during the North Atlantic Aerosols and Marine Ecosystems Study (NAAMES). Measurements of marine aerosol were taken over two separate 26-day research cruises (winter and spring) on the R/V Atlantis. The ship embarked from Woods Hole Massachusetts and measured ambient particles while following an approximately triangular transect with turning points at 57 N, 40 W and 40 N, 40 W. Primary marine aerosol was modeled using a bubble-bursting/collection technique (Sea Sweep). The ambient and generated marine aerosol was characterized by a suite of instruments, including a high resolution – time of flight – aerosol mass spectrometer (HR-ToF-AMS, Aerodyne Inc.) upgraded with an event trigger (ET) single particle operating mode. The ET mode was set to have three regions of interest (ROI), including  $m/z$  43,  $m/z$  55-79, and  $m/z$  48-150 with optimized event trigger levels. A k-means algorithm was used to cluster the single particles into different composition classes. Four composition classes were determined for the ambient marine aerosol and include a hydrocarbon-like organic aerosol (HOA) class, an oxygenated organic aerosol (OOA) class, and two sulfate classes. The two sulfate classes account for more than 50% of the total ambient marine aerosol and are from organosulfate and sulfuric acid compounds likely formed from dimethyl sulfide (DMS) and methanesulfonic acid (MSA) precursors from the ocean plankton ecosystem. The HOA and OOA classes are more abundant in continental aerosol, likely due to anthropogenic emissions from North America. Four composition classes were determined for the Sea Sweep aerosol and include two HOA classes, a combined OOA and sulfate class, and a sea salt class. Sea salt particles are typically refractory and are not easily detected by the HR-ToF-AMS. Therefore, the sea salt class contributes only 8% of the total non-refractory aerosol.

**2IM.27**

**Low-cost Air Quality Monitoring: Characterizing the Real-time Affordable Multi-Pollutant (RAMP) Sensor Package.** R. SUBRAMANIAN, Misha Schurman, Bryan Tomko, Jason Gu, Albert A. Presto, Naomi Zimmerman, Srinivasa Prabhu, *Carnegie Mellon University*

Distributed sensing of air quality has been made possible with relatively inexpensive sensors for carbon monoxide, nitrogen dioxide, sulfur dioxide, ozone, carbon dioxide, and particulate matter. However, such sensors suffer from cross-sensitivity to other gases as well as environmental factors like temperature and relative humidity. We have recently developed a new low-cost air quality monitor, the Real-time Affordable Multi-Pollutant (RAMP) sensor package, which measures CO, SO<sub>2</sub>, NO<sub>2</sub>, O<sub>3</sub>, CO<sub>2</sub>, temperature, and RH. PM mass is measured using an external sensor. The AlphaSense OPC-N2 shows some promise, with collocated ambient measurements of two units showing a correlation coefficient of 0.78 and a slope of 0.8, and number concentrations compared well with a TSI optical particle sizer. However, reliability of the OPC-N2 units has been a major concern. Alternative PM measurement approaches are being explored (see “Assessment of compact, real-time PM<sub>2.5</sub> and ultrafine particle counting instrumentation with a spatially-distributed network in Pittsburgh, Pennsylvania” by Zimmerman et al.) The RAMP transmits all this data to a central web server over a GSM network. We have developed a new calibration technique to properly characterize the sensor response, as well as algorithms for converting sensor response (accounting for interferences) into air quality parameters comparable to conventional monitoring networks. This poster shall present the results of these efforts. As part of various projects, over 50 RAMPs will be deployed in the city of Pittsburgh, PA, in 2016.

**2IM.28**

**An Online Method to Characterize the Reversibility of Secondary Organic Aerosol Formed in Aerosol Liquid Water.** MARWA EL-SAYED, Christopher Hennigan, *University of Maryland, Baltimore County*

A new method is presented for the characterization of the reversible/irreversible nature of secondary organic aerosol formed in aerosol water (aqSOA). The relative contribution of reversible and irreversible uptake processes is a major unknown in our understanding of atmospheric aqSOA formation. The method utilizes simultaneous measurements of water soluble organic carbon in the particle ( $WSOC_p$ ) and gaseous ( $WSOC_g$ ) phases. These bulk measurements are surrogates for SOA and for secondary oxygenated organic gases, respectively. The central feature of this measurement approach is the behavior of  $WSOC_p$  under conditions of drying. To characterize the effect of aerosol water evaporation on aqSOA, the  $WSOC_p$  sample is alternated between an unperturbed ambient channel ( $WSOC_p$ ) and a 'dried' channel in which the air sample passes through a silica gel diffusion dryer ( $WSOC_{p,dry}$ ). The dried channel does not remove all particle-bound water, but rather approximates the lowest relative humidity (RH) that particles are exposed to in the lower troposphere to simulate natural drying processes. The enhancement in SOA formation due to aqSOA is inferred based on the enhancement in the fraction of the total  $WSOC$  in the particle phase,  $F_p$ , as a function of RH. A decrease in the  $WSOC_p$  concentration through the dried channel indicates the evaporation of SOA due to water evaporation – and hence, reversible aqSOA. On the other hand, irreversible aqSOA is inferred if no statistically significant difference is observed in the  $WSOC_p$  concentrations through the two channels. The completely automated system is able to run for weeks with minimal intervention. A single  $WSOC_p$ - $WSOC_{p,dry}$ - $WSOC_g$  measurement cycle is completed in 14 min, allowing for the characterization of dynamic changes in the factors influencing reversible/irreversible uptake processes. Several measures were undertaken to validate the method, minimize particle losses within the system and ensure fully automated and reliable measurements across diverse ambient conditions.

**2IM.29**

**A Low-Cost Black Carbon Monitor for a Community Air Quality Network.** JULIEN CAUBEL, Troy Cados, Chelsea V. Preble, Annie Rosen, Thomas Kirchstetter, *University of California, Berkeley*

Small, low-cost air pollution sensors present community members and researchers with new opportunities to monitor air quality at the local scale. In the current study, we are developing a black carbon sensor and air-monitoring network in West Oakland. West Oakland is a San Francisco Bay Area residential/industrial community adjacent to regional port and rail yard facilities, and is surrounded by major freeways. As such, the community is heavily affected by diesel particulate matter emissions from heavy-duty diesel trucks, locomotives, and ships associated with freight movement. In partnership with Environmental Defense Fund, the Bay Area Air Quality Management District, and the West Oakland Environmental Indicators Project, we will be collaborating with community stakeholders to deploy and maintain a 100-sensor black carbon measurement network for a period of several months.

The sensors employ a filter-based light transmission method to measure black carbon and utilize cellular data communication to operate as remote nodes within the distributed urban network. Each node is battery powered and operates at low sample flow rate to enable unattended deployment. A key challenge that has been overcome is the prevention of water condensation in the sensor during cold periods through the use of adequate insulation. In field trials over several weeks, the sensors were deployed at three monitoring locations. The sensors provided black carbon concentrations comparable to commercial instruments, and operated unattended for about a week until the particle collection filter and battery required replacement.

**2IM.30****Development of a Powder Injection System to Inject Surrogate Material in Rocket Propellant Smoke Plumes.**

ZAHRA CHAUDHRY, Andrea Brown, Felix Sage, Matthew Yeager, Benjamin Alvarez, Drewry Benjamin, Andrew Lennon, *JHU APL*

Under the Aerospace Nuclear Safety Program, there exists a need to understand the dispersal of aerosolized plutonia fuel in the unlikely event of an early launch accident resulting in a fragment of burning solid rocket propellant landing on a space radioisotope power system. To understand the dispersion of plutonia aerosols, several experiments have been carried out to discern the underlying physics and chemical thermodynamics of rocket propellant burns. For the spring 2016 testing, several non-toxic metal oxide powders were selected as surrogates for plutonia for their thermal, chemical, optical and physical properties. A Powder Injection System was developed to meet the following requirements: inject a range of particle masses from 40 mg to 8 g, particles must stay entrained in the smoke plume, it must be easy to clean and change powders, it must withstand high temperatures, and feature automated control for the safety of the operators. The team selected the Lambda Doser (Lambda Laboratory Instruments, Switzerland) to meter the powder into an Aerosol Capacitance Chamber, where the particles were able to deagglomerate prior to injection into the smoke plume. The complete system included air handling and conditioning systems, an ACC and a curved exit region where particles were injected by dried air into a smoke plume created by a block of burning rocket propellant. In order to account for variations between different metal oxides of packing density, particle density and hygroscopicity, calibrations were performed both on the Lambda Doser individually and on the completed Powder Injection System. Three settings of particle mass were selected for each metal oxide and calibrated for airflow and doser speed. Laboratory calibration results along with field results will be presented.

**2IM.31****Alternative metrics for spatially and temporally resolved ambient particle monitoring.** LIEM PHAM, Heejung Jung, *University of California Riverside*

Particle active surface area is regarded as an important alternative metric to correlate particle emissions to adverse health effects. We explore the use of a particle counter and a diffusion charger as a relatively simple means to measure spatiotemporally resolved particle concentrations over a wide region using a mobile platform. Although the scanning mobility particle sizer (SMPS) measurements provide particle size distributions (PSDs) that can be converted into many important metrics, this method is impractical to implement for a routine monitoring over a wide region. In this study, an alternative method and new metrics are introduced using the condensation particle counter (CPC) and electrical aerosol detector (EAD). While the CPC and EAD measure particle number (PN) and particle active surface area (PS) concentrations respectively, the ratio of PS/PN provides an additional information of particle size which is important for particle transport. PSDs measured by SMPS during ambient monitoring were used to verify the concept. The study found that alternative metrics (PN, PS, and PS/PN) can be used to monitor spatiotemporally resolved particle concentrations over a wide region.

**2IM.32**

**Control of Multiply-charging in Microplasma Aerosol Charger.** YUKI KIZU, Hiromu Sakurai, Hiroshi Seki, Hiroshi Okuda, Hidenori Higashi, Takafumi Seto, Yoshio Otani, *Kanazawa University*

Aerosol charging is an important step as a pretreatment to analysis, handling and measurement of aerosol. However, it is known that the charging efficiencies of bipolar chargers are not so high due to the neutralization process, while a unipolar charger suffers from generation of multiply-charged particles for large particles. In the application of aerosol chargers for the electrical mobility classifier, this contrary causes low particle throughput and/or contamination by classifying multiply charged particles having sizes greater than the target size. Therefore, it is desirable to develop a high-efficiency aerosol charger with suppression of multiply-charged particles.

In this study, we developed a new unipolar charger with an acceleration electric field in the aerosol charging area. The electric field is formed parallel to the aerosol flow so that charged particles are accelerated toward outlet before obtaining excess charge. The performance of the new charger was evaluated by measuring charge distribution and penetration of the particles. The number fraction of singly charged particles increased and the multiply charging was successfully suppressed by the present charger. The acceleration electric field in the aerosol charging area introduced in the present work would effectively affect to increase the fraction of singly charged particles and to suppress the fraction of multiply charged particles. At the optimum conditions, the fractions of singly charged particles were 85 and 50 % for 30- and 100-nm particles, respectively, while doubly charged fractions were 8 and 13 %.

**2IM.33**

**Design and Collection Efficiency of A New Electrostatic Capillary Collector For Fine and Ultrafine Particulate Matter.** GAURAV MAHAMUNI, Byron Ockerman, Igor Novosselov, *University of Washington*

Collection of fine and ultrafine particulate matter is used for monitoring exposure to potentially harmful particles: aeroallergens, toxins, emissions from combustion sources that can contribute to cardiovascular and respiratory diseases. We introduce a novel Electrostatic Capillary Collector (ECC) that collects aerosol in the range below 2.5 micron directly onto the outer surface of a capillary that can be used for in-situ analysis. The ECC uses a ring and concentric needle configuration as ionizer to charge particles as they enter the collector. The particles then pass through an electric field between a cylinder and a concentric wire inserted into the bore of the capillary, and are collected on the outer surface of the capillary wall. The capillary is 4 inch long and has an outer diameter of 350 micron. Real time particle sizers (TSI SMPS and APS) are used to maximize the collection efficiency(CE) on the capillary substrate. The sampling flow rates are varied from 1 L/min to 3 L/min. For a specific flow rate, voltage applied across the needle - ring ionizer (corona voltage) and the wire - cylinder (repelling voltage) are optimized. Additionally, CE is measured for the optimized operating conditions using bulk fluorescence method. Collection of fluorescent particles in the size range of 0.2 to 2 micron is done on the capillary and on a reference filter for mono-dispersed particles in aerosol chamber. At the flow rate of 2L/min, typical collection efficiency for particles smaller than 2 micron is higher than 50%. Transparent nature of the capillary collection substrate can be used to obtain spectroscopic signatures of collected sample, in-situ.

**2IM.34****Continuous and Simultaneous Monitoring of PM Mass Concentration and Speciation with a Single Instrument.**

MIZUNO YUSUKE, Aoyama Tomoki, Matsumoto Erika, HORIBA, Ltd,

Several methods exist to continuously monitor particulate mass concentration or particulate elemental composition. Until recently, simultaneous measurement of these two important parameters needed to be carried out with two independent instruments. The need for a simultaneous measurement of these properties is driven by needs to adjust processes quickly and to identify emission sources. We will show data taken in the field using a new instrument that simultaneously measures PM<sub>2.5</sub> mass concentration and elemental composition. The instrument relies on the beta ray attenuation and x-ray fluorescence techniques.

**2IM.35****Design and Optimization of a Compact Low-Cost Optical Particle Sizer.**

TOMAS NJALSSON, Emily Roach, Igor

Novosselov, *University of Washington*

Quantifying personal exposure to particulate matter is an important part of health risk assessment. Upon inhalation, particulate matter may deposit in the respiratory system potentially causing adverse health effects. When assessing personal exposure, temporal data of particle concentration and size distribution is useful but difficult to gather. Large form factor optical particle counters (OPC) can accurately determine particle size and concentration but they have limited applications due to their size and cost. Smaller OPCs generally have large uncertainties associated with particle sizing due to ambiguity in the optical properties of the particles. These devices use assumptions about the particles' refractive indices and therefore may not be accurate over a broad range of environmental aerosols.

We present the design of a compact low-cost OPC capable of sizing particles based on their physical dimensions. The combination of an optimized geometry and an efficient sizing algorithm minimizes the uncertainty caused by variations in the refractive indices of particles, allowing for more accurate measurements over a broader range of environmental aerosols. The photodetector position (proximity and angle) and the sizing algorithm are optimized using numerical simulations based on Mie scattering of spherical particles. The simulations show that by using the optimized design, instances where particles are sized incorrectly can be reduced by 54% on average over the 1-10 micro-meter range when compared to a non-optimized design (photodetector at 90°). An experimental setup utilizing low-cost components is used to validate and test the performance of the design against monodisperse aerosols.

**2IM.36**

**Colloidal Nanoparticle Analysis using a LN-DMA-APM System.** VIVEK RAWAT, Seongho Jeon, Xiaoshuang Chen, Siqin He, Derek Oberreit, Christopher Hogan Jr., *University of Minnesota*

Gas phase size and mass analysis techniques allow for determination of the morphologies and densities of particles in 25-500 nm range. While such techniques are readily applied to aerosol particles, for accurate measurements of colloidal particles in the gas phase it is necessary to aerosolize particles while preserving their size, mass, and shape distributions. Traditional nebulization techniques generate super-micrometer diameter droplets which have high residue content and hence lead to aggregation of particles and residue coating onto the particle surface during aerosolization. To overcome this issue, in this study, we employ a novel liquid nebulizer (LN) with an online ultra pure water dilution system and also a ball impactor. Aerosolization with this LN allows for preservation of particle size and morphology while removing the non-volatile residue that can mask aerosolized particle distributions. We applied the LN in series with a differential mobility analyzer (DMA), an aerosol particle mass analyzer (APM), and a condensation particle counter (CPC) to classify the nanoparticles based on their electrical mobility and mass to charge ratio. To infer accurate size and mass distributions from these measurements, we inverted two dimensional distributions in particle size and mass. Data deconvolution requires consideration of DMA and APM transfer functions as well as corrections for the particle charge distribution, CPC detection efficiency and transport losses in the system. The LN-DMA-APM-CPC system was specifically applied to wet milled silica and titania nanoparticles; suspensions were milled for different times to produce particles of variable morphology, as well as variable size and mass distributions. Measurements and data inversion techniques were also validated by examining polystyrene latex (PSL) nanoparticle standards and accurately determining their sizes and densities.

**2IM.37**

**Detection and Quantification of Atmospheric Compounds with a Compact Selective Reagent Ionization - Mass Spectrometer (C-SRI-MS).** ROLAND SARDA-ESTEVE, Dominique Baisnee, Sebastien Schramm, Geoffroy Chupin, Valérie Gros, Benjamin Loubet, Marc Peyraut, Christophe Bossuet, *CEA*

In the frame of Bio Chemical Collectors (BCC) research project from the French Atomic Energy Commission (CEA) a Compact Mass Spectrometer has been deployed during the spring 2016 in the region of Paris. The observation site chosen was an experimental farm well instrumented for atmospheric fluxes studies. A set of trace gases like Ozone (O<sub>3</sub>), Carbon Dioxide (CO<sub>2</sub>) and Nitrous Oxides (NO<sub>x</sub>) are measured continuously all over the year. All these measurements are done directly in the crops and next to stables and one Bio Gas installation. The measurement site is often impacted by these local sources as it is the case for Ammonia. The Ammonia is an interesting substance. It plays an important role in the atmospheric chemistry and particularly in the formation of Secondary Aerosols like Ammonium Nitrate. It is also an important intermediate for the chemical industry and considered as a Toxic Industrial Chemicals (TICs) substance. This observatory is well known for the detection and the quantification of Ammonia based on annular denuder coupled and ions chromatography quantification. This method which is relatively simple and robust provides semi continuous measurements. It gives integrated information on atmospheric concentrations but not on the fine variability. To solve this problem and identify the sources of NH<sub>3</sub> in this complex environment, we tried to measure NH<sub>3</sub> with a Compact Selective Reagent Ionization Mass Spectrometer (C-SRI-MS). The main objective of this campaign was to test the ability of a C-SRI-MS to monitor (TICs) substances and particularly, Ammonia (NH<sub>3</sub>) in real time and under atmospheric condition. In this work we present our results and describe the calibration procedure used to obtain atmospheric concentrations of NH<sub>3</sub> to track the main sources.

This work is supported by the CBRN-E R&D research program from Joint ministerial program of R&D against CBRN-E threats.

**2IM.38****Miniature Electrostatic Precipitator for Gas Chromatography–Mass Spectrometry Aerosol Analysis.**

JAY RUTHERFORD, Charles Corredor, Byron Ockerman, Igor Novosselov, Jonathan Posner, *University of Washington*

The inhalation of particulate matter (PM) is a significant health risk that can reduce life expectancy due to increased cardio-pulmonary disease as well as exacerbate respiratory diseases such as asthma. PM originates from natural sources, as well as man-made sources such as combustion engines, cigarettes, and agricultural fires. There are a wide range of sampling and chemical analysis tools available for stationary (e.g. roadside, building top, etc.) PM evaluation. Personal PM monitoring devices typically do not provide options for particle chemical analysis, which results in a gap of knowledge of detailed PM exposure to individuals and how this relates to their health. We have developed a wearable miniaturized electrostatic precipitator that can collect PM for subsequent chemical analysis. The personal sampler collects particles on a sampling plate and draws a sampling flow of 1 L/min. In this poster, we will describe the personal electrostatic particle collector and share PM chemical analysis by gas chromatography–mass spectrometry (GC-MS). We collected combustion generated PM from wood smoke, diesel soot, and cigarette smoke and compared the personal sampling results with results from Teflon filters housed in Harvard School of Public Health Personal Exposure Monitors designed to capture PM with aerodynamic diameter less than 2.5 $\mu$ m. Samples were analyzed for the sixteen US EPA priority polycyclic aromatic hydrocarbons (PAHs) and show equivalent results can be obtained with the personal electrostatic sampling device compared to a standard Teflon filter approach. The personal sampler coupled with GC-MS is sufficiently sensitive to provide PM PAH analysis for single day exposures. The electrostatic sampling device will ultimately enable epidemiological studies of PM exposure and chemical analysis that can relate individual exposure to health outcomes.

**2IM.39****The Southeastern Aerosol Research and Characterization Network 1992-2016.**

STEPHANIE SHAW, Eric Edgerton, John Jansen, *Electric Power Research Institute*

The Southeastern Aerosol Research and Characterization (SEARCH) air quality monitoring network is a long-term multi-pollutant effort addressing scientific and regulatory questions on ozone and its precursors, particulate matter mass and composition, mercury speciation and deposition, wet deposition of acidity and nutrients and atmospheric visibility. SEARCH was conceived in the early 1990s as part of the Southern Oxidants Study SCION network. The eight-site network of urban-rural pairs provides a comprehensive suite of measured meteorological, gaseous, and particulate phase chemicals.

SEARCH network monitoring activities at the 5 current sites will cease after 2016, with varying closure dates. The Birmingham, AL, site closed July 1, with Yorkville, AL, and Outlying Field, FL, closing October 1. Jefferson Street/Atlanta, GA, and Centreville, AL, will close January 1, 2017. This poster describes the remaining monitoring plans, closure, and upcoming activities. The physical filter archives created from mid-1998 to present will be maintained for some time, and selected studies will be performed with them. Collaborations with external researchers on the use of the archive are encouraged.

Additionally, the full SEARCH database through the end of operations will continue to be made publically available at <http://www.atmospheric-research.com/public/index.html>. We encourage its continued use by the research community. To date, SEARCH data have been the basis of approximately 270 peer-reviewed scientific publications and have been used to constrain and evaluate local, regional, continental and global-scale atmospheric models, assess atmospheric chemical and physical processes at hourly to decadal time resolution, perform source attribution, evaluate new instrumentation, assess the impact of upcoming regulations, and support investigations of human health impacts of air quality.

The authors are grateful for the long-standing support from Southern Company and EPRI, as well as the many collaborators that have made the SEARCH network a unique experience. We look forward to continued collaborations in the future.

**2IM.40**

**Low-income Single Family Home Air Tightness, Indoor Air Quality and Respiratory Health in Colorado during Fire Season.** PRATEEK SHRESTHA, Shelly Miller, Jamie Humphrey, John Adgate, Elizabeth Carlton, Elisabeth Root, *University of Colorado Boulder*

In this EPA-funded study we are assessing home tightness and characteristics, indoor air quality and respiratory health of residents in low-income communities in the front range across Colorado during the 2016 fire season. In 15 single-family low income homes that have had energy efficiency improvements (sometimes called weatherization) and 15 single-family homes that have not been weatherized we are assessing the homes ability to "protect" residents from fire air pollution, through a combination of direct air sample measurements, questionnaires, lung function testing, household walkthrough, blower door testing. The selected homes will be a subset of larger sample of 250 homes in which direct measurement of air samples is not performed, but all other measures are collected including blower door testing to assess building air tightness during non fire season. All homes are selected in neighborhood pairs (energy efficient and non-energy efficient) and are screened using the income-eligibility requirements of HUD programs. Home infiltration rates are estimated using a model linking weather data and leakage area. The outputs of this work are quantitative data on pollutant levels, housing characteristics and respiratory health. This information is crucial to determine if home tightness impacts health, especially to see whether weatherization activities provide any protection against elevated outdoor pollutant levels during wildfire seasons. Outcomes of this study will provide guidance on efficiency measures that reduces energy use in homes while still providing a healthy indoor environment. Data collection is ongoing and results will be reported for the subset of homes that have been investigated.

**2IM.41**

**Development of a Low-cost Fluorescence Spectrometer for the Analysis of Primary Biological Aerosols.** BENJAMIN E. SWANSON, Donald R. Huffman, J. Alex Huffman, *University of Denver*

Primary biological aerosol particles (PBAP), such as pollen, fungal spores, bacteria and their byproducts, are a ubiquitous presence in the atmosphere and are related to a variety of human health and environmental effects. Most bioparticles contain biological fluorophores which can be detected by utilizing fluorescence spectroscopy, even without the use of fluorescent strains. Previous work has shown that broad categories of bioparticles can be differentiated based on fluorescence fingerprints. We describe a novel, low-cost instrument to acquire both elastic and inelastic (fluorescent) scattering spectra from individual supermicron-size particles in a multi-particle collection on a microscope slide (Huffman et al., 2016). The poster will describe the current state of instrument development, as well as introduce its potential use for analysis of bioaerosols such as pollen and fungal spores.

Huffman, D. R., Swanson, B. E., and Huffman, J. A.: A Wavelength Dispersive Instrument for Characterizing Fluorescence and Scattering Spectra of Individual Aerosol Particles on a Substrate, *Atmos. Meas. Tech. Discuss.*, 2016, 1-21, 2016.

**2IM.42**

**Advancing Field Measurements of Particle Emissions from Brick Kilns.** RYAN THOMPSON, Emily Floess, Cheryl Weyant, Tami Bond, Ellen Baum, Zach Merrin, Paul Francisco, Sameer Maithel, Ananthakrishnan Ravi, Sonal Kumar, Sagar Adhikari, Santosh Guatam, Uma Rajarathnam, Bidya Pradhan, P.S. Praveen, Sujan Shrestha, *Mountain Air Engineering*

Solid fuel (coal and biomass) fired brick kilns contribute a significant fraction of total air pollution in developing regions of the world. However, emissions characterization required to understand health and climate impacts is lacking. Conventional emission measurement methods, such as U.S. EPA methods for stationary sources, are not adequate for brick kilns because of high particle concentrations, large temporal variability in emissions, low exhaust flows, and exclusion of climate relevant emissions such as black carbon.

As part of the Climate and Clean Air Coalition initiative on brick kilns, a dilution sampling method and sampling equipment were developed to meet current needs in climate-relevant emission characterization. The equipment is a portable dilution sampling system that includes filter holders for PM<sub>2.5</sub> gravimetric and composition (organic carbon and elemental carbon) analysis, real-time particle optical scattering and absorption sensors, gas sensors for carbon dioxide, carbon monoxide, and sulfur dioxide, and experimental stack flow measurement devices.

The method was tested on fourteen brick kilns in India, Nepal, and Colombia. The kiln types encompass a large variety of natural draft and forced draft kilns including bull's trench, zig-zag, clamp, tunnel, Hoffman, and Coleman. Fuel types include coal, wood, industrial fuel waste, and agricultural residue. This poster presents methods, equipment, and measurement results. The results are presented as emission factors and emission rates of PM<sub>2.5</sub>, organic carbon, elemental carbon, carbon monoxide, and sulfur dioxide. Emission patterns are illustrated with real-time data.

**2IM.43**

**Performance of Different Particle Wall-loss Correction Methods for Aging Experiments of Alpha-pinene SOA in a Smog Chamber.** Ningxin Wang, Neil Donahue, SPYROS PANDIS, *Carnegie Mellon University*

The interaction of particles with the chamber walls often represents a major complication in the analysis of the results of smog chamber experiments. The uncertainty introduced by the corresponding data corrections increases with the duration of the experiment and is especially significant in chemical aging experiments. A number of particle wall-loss correction methods have been used in experiments focusing on secondary organic aerosol (SOA) yields. These include uses of size-independent first-order loss rate constants, size-dependent corrections, corrections based on the ratio of organics to sulfate in the chamber, etc. While all of these approaches can work well for some types of experiments, they may not be suitable for chemical aging experiments that last several hours and take place under different chamber conditions (e.g., lights are turned on or off).

In this work, we evaluate the performance of several particle wall-loss correction methods with regard to aging experiments of alpha-pinene ozonolysis SOA conducted in the Carnegie Mellon University smog chamber (10 m<sup>3</sup> Teflon chamber). In these experiments the SOA is produced during the dark reaction of alpha-pinene and ozone, and then the products are exposed to OH produced in the chamber by the photolysis of HONO. We show that the size independent and the organic/sulfate ratio approaches often introduce significant errors in aging experiments. The size dependent correction performs better but the corresponding rate constants may change from experiment to experiment and even during an experiment when the conditions change. An approach is proposed for the characterization of these losses in the different phases of the experiment and the corresponding wall loss corrections.

**2IM.44****Measuring the Morphology and Density of Internally Mixed Black Carbon with SP2 and VTDMA: New Insight into the Absorption Enhancement of Black Carbon in the Atmosphere.**

YUXUAN ZHANG, Qiang Zhang, Yafang Cheng, Hang Su, Simonas Kecorius, Zhibin Wang, Zhijun Wu, Min Hu, Tong Zhu, Alfred Wiedensohler, Kebin He, *Tsinghua University*

The morphology and density of black carbon (BC) cores in internally mixed BC (In-BC) particles affect their mixing state and absorption enhancement. In this work, we developed a new method to measure the morphology and effective density of the BC cores of ambient In-BC particles using a single-particle soot photometer (SP2) and a volatility tandem differential mobility analyzer (VTDMA) during the CAREBeijing-2013 campaign from July 8 to 27, 2013 at Xianghe Observatory. This new measurement system can select size-resolved ambient In-BC particles and measure the mobility diameter and mass of the In-BC cores. The morphology and effective density of the ambient In-BC cores are then calculated. For the In-BC cores in the atmosphere, changes in their dynamic shape factor and effective density can be characterized as a function of the aging process measured by SP2 and VTDMA. During an intensive field study, the ambient In-BC cores had an average shape factor of  $\sim 1.2$  and an average density of  $\sim 1.2 \text{ g cm}^{-3}$ , indicating that ambient In-BC cores have a near-spherical shape with an internal void of  $\sim 30\%$ . From the measured morphology and density, the average shell/core ratio and absorption enhancement of ambient BC were estimated to be 2.1-2.7 and 1.6-1.9, respectively, for In-BC particles with sizes of 200-350 nm. When the In-BC cores were assumed to have a void-free BC sphere with a density of  $1.8 \text{ g cm}^{-3}$ , the shell/core ratio and absorption enhancement were overestimated by  $\sim 13\%$  and  $\sim 17\%$ , respectively. The new approach developed in this work improves the calculations of the mixing state and optical properties of ambient In-BC particles by quantifying the changes in the morphology and density of ambient In-BC cores during aging.

**2IM.45****Feasibility Test of Cellulose Filter for Collection of Sulfuric Acid Mist.** CHUFAN ZHOU, Chih-Hsiang Chien, Alexandros Theodore, Chang-Yu Wu, Yu-Mei Hsu, Brian Birky, *University of Florida*

As a known human carcinogen listed by the National Toxicology Program (NTP), exposure to strong inorganic acid mists containing sulfuric acid has been the subject of various occupational health studies. OSHA Method ID-113 and NIOSH Method 7908 instruct the use of MCE filter and quartz fiber or PTFE filter for sampling sulfuric acid mist. The advantages of these filters include extremely good chemical resistance and high collection efficiency although they suffer from fragility, high pressure drop and high cost. Cellulose filter, which is inexpensive and has excellent tensile strength, may be a viable alternative, but its chemical resistance and recovery of sulfuric acid have not been investigated yet.

To avail a low-cost personal sampler for inorganic acid mist, cellulose filter was selected as the collection medium, and its feasibility toward sulfuric acid sampling was investigated. Intact 37 mm filters were observed after they were impregnated by 50 – 500  $\mu\text{g}$  of sulfuric acid for seven days. More than 95% recovery was achieved for these impregnated filters. Mass penetration during eight-hour sampling tests remained stable from 0.36% – 0.74%. These results demonstrate the feasibility and reliability of cellulose filters for collecting sulfuric acid mists.

As sulfur dioxide commonly co-exists with sulfuric acid in industrial settings and its analysis procedure may yield positive interference of sulfuric acid, a mixture of sulfuric acid aerosol generated by a Collison nebulizer and sulfur dioxide gas from a cylinder was tested to assess if the presence of sulfur dioxide gas would affect the collection of sulfuric acid mist on cellulose filters. The results of which will be presented in the conference.

**2NM.1****Rapid Green Assembly of Antimicrobial Nanobunches.**JEONG HOON BYEON, *Yeungnam University*

Antimicrobial nanobunches with different amounts of chitosan-capped Ag were prepared by continuous gas-liquid green route under ultrasound irradiation. Spark-produced aerosol Cu nanoparticles were directly injected into an ultrasound Ag(I)-chitosan reaction cell for efficient hydrosolization of the Cu particles and the subsequent incorporation of Ag and chitosan on Cu. Subsequently, electrospraying was used to form of chitosan-capped Cu-Ag nanobunch coatings. The time required for reducing the bacterial proliferation to 50% dropped to ~1 h at a nanobunch concentration of  $10 \mu\text{g mL}^{-1}$  from the 2.0 min Ag(I) reaction time, and was further decreased to ~0.5 h by increasing the concentration of the nanobunches to  $90 \mu\text{g mL}^{-1}$ . The nanobunches were directly coated onto the substrate using an electrospray device to fabricate transparent films and composite fibers. The antimicrobial activity of the composite carbon fibers was then evaluated via the disc diffusion method.

**2NM.2****Aerosol-assisted Fabrication of Stable Perovskite Solar Cells at Ambient Conditions.**SHALINEE KAVADIYA, Su Huang, Pratim Biswas, *Washington University in St. Louis*

Perovskite solar cells have shown to be a promising photovoltaic technology in the market, due to the rapid rise in their efficiency and low processing costs. Despite their high efficiency, the instability of perovskite material is a serious obstacle to their commercialization. Perovskites readily decompose in the presence of moisture. Thus, most of the studies are performed in a controlled humidity environment. Recent studies have focused on improving their stability by encapsulating the cell or incorporating a hydrophobic material into the perovskite layer. However, solar cell fabrication still occurs in very low humidity conditions. Our previous work reported a method to improve the stability at ambient condition by adding tetraethyl orthosilicate (TEOS) into perovskite, which prevents moisture attack on the perovskite by reacting with water and forming a blocking layer of  $\text{SiO}_2$ .

In this work, a technique was developed to enhance the stability without any additives using electro-hydro atomization (electrospray) to deposit the perovskite ( $\text{CH}_3\text{NH}_3\text{PbI}_3$ ) material. The electrospray is an established technique for generating aerosols by liquid atomization using an electric field, which has also been used for thin film fabrication<sup>1</sup>. Herein, the electrospray was used to deposit perovskite thin films for solar cells. Electrospray provides a uniform film morphology compared to the conventional spin coating technique, resulting in high cell efficiency. Effects of various process parameters such as substrate-to-nozzle distance, flow rate and precursor concentration on the thin film morphology, and the solar cell efficiency were explored. The cells were fabricated and tested under ambient humidity conditions (30-55%). Furthermore, the stability of the devices was tested by exposing them to air for extended periods of time up to 600 hours. The perovskite solar cells had efficiencies as high as 11%. Mechanistic reasons for the enhanced stability will be elucidated.

## Reference:

1. Kavadiya et al., *Nanoscale*, 2016, 8, 1868-1872.

**2NM.3**

**Fabrication of High-performance Multiscale Composite Cathode of Solid Oxide Fuel Cell (SOFC) via Aerosol-based Spray Deposition Methods.** SUNG SOO SHIN, Jeong Hun Kim, Ho Sung Noh, Guangmin Lee, Ji-Won Son, Hyoungchul Kim, Mansoo Choi, *Seoul National University*

In the solid oxide fuel cell (SOFC), oxygen ion transfer rate at the boundary of electrolyte and electrode is one of the most important factors at the reaction of oxygen exchange. In this study, to enhance the oxygen ion transfer ability, we fabricated multiscale composite structure cathode of SOFC via aerosol-based spray deposition methods. Aerosol process has advantages of thin film fabrication and morphology control. And also, it is easy to fabricate porous multi-layer structure cathode with simple process. First, thin (under 1 micro-meter) and uniform Lanthanum strontium cobaltite (LSC) layer with under 100 nm size nanoparticles was fabricated by electrospray deposition of LSC sol. For investigation of the morphology change of the sol, we examine the effect of variables such as applied voltage, nozzle tip-to-substrate distance, flow rate of the solution and diameter of the nozzle tip. Then, thick (~ 10 micro-meter) and uniform cathode layer was fabricated by polymer-assisted nanospray deposition (PA-NSD) method using the mixture consists of LSC powder (particle size of 400 ~ 500 nm), ethyl alcohol and polyvinylpyrrolidone (PVP) dispersant. To increase the overall thickness of cathode and fabricate the porous cathode structure, particle size of the LSC powder and the weight ratio of the PVP and LSC were concerned. As a result, electrochemical performance of the full cell with the multiscale composite structure cathode is much increased than the same full cell without the electrosprayed LSC sol layer because of the ability enhancement of oxygen ion transfer by LSC nanoparticles at the boundary of the electrolyte and electrode.

**2NM.6**

**Effect of Fuel Composition on Monomer Size in an Inverted Hydrocarbon Flame.** JUSTIN DAVIS, Yifei Guan, Igor Novosselov, *University of Washington*

The effect of hydrocarbon fuel composition on soot monomer size is investigated. Though the size of ultrafine particulate matter from combustion is known to vary, the effect fuel composition has on the carbon monomer size has not been reported. The knowledge of monomer size is an important parameter for aerosol agglomeration studies, health exposure studies, material synthesis, and other applications. An inverted flame reactor (IFR) is used for the experimental study on monomer size dependence of fuel composition. The diffusion flame in the IFR provides unique conditions to study soot growth, including the laminar nature of the flame and a long residence time to promote the formation of carbon soot particles. Four gaseous fuel are used: methane, propane, ethylene and acetylene. Volumetric flow rates of the fuel and air are varied to achieve similar flow patterns, with long residence times enabling soot formation for all four fuels. The soot formed in the experiments is measured using an SEM and ImageJ software. The results show monomer diameters ranging from 20nm to 80 nm: with methane producing the smallest monomer size, followed by propane, ethylene, and acetylene. A chemical reaction network (CRN), consisting of a hydrocarbon pyrolysis (fuel rich) region, followed by a diffusion flame front (stoichiometric) region, and a recirculation pathway, was constructed based on CFD simulations. The CRN is used to gain insight into the formation mechanism of carbon soot monomers using a hydrogen abstraction  $C_2H_2$  addition (HACA) mechanism. Monomer volume was found to be proportional to  $C_2H_2$  mole fraction inside the hydrocarbon pyrolysis region for the fuels tested.

**2NM.7**

**Three-dimensional, Crumpled Graphene Oxide-based Nanocomposite Membranes for Water Treatments.** Yi Jiang, WEI-NING WANG, Di Liu, Yao Nie, Wenlu Li, Jiewei Wu, Fuzhong Zhang, Pratim Biswas, John Fortner, *Virginia Commonwealth University*

Multifunctional, crumpled graphene oxide (CGO) porous nanocomposites are synthesized and assembled as reactive membranes via aerosol routes for advanced water treatments. The crumpled 3D nanostructures are highly aggregation and compression-resistant and allow for the incorporation of other, multifunctional particles inside the 3D, composite structure, such as TiO<sub>2</sub> and Ag nanoparticles in this work. The nanocomposites not only allow high water flux via vertically tortuous nano-channels, outperforming comparable commercial ultrafiltration membranes, but also demonstrate excellent separation efficiencies for model organic and biological foulants. The 3D CGO-based nanocomposite structures have great potential as a platform material for next generation water treatment and separation technologies.

**2UA.1**

**Investigation of Wintertime Aerosol Chemistry Using Single Particle Mass Spectrometry.** RYAN COOK, Matthew Gansch, Katheryn Kolesar, Kerri Pratt, *University of Michigan*

Atmospheric aerosols are known to have negative human health impacts and thus are regulated by the Clean Air Act. Most aerosol measurements have focused on summertime; however, wintertime air quality is often influenced by different aerosol sources. In particular, few studies have investigated wintertime air quality in the urban Midwestern US environment, which is expected to be influenced by both local and long-range transported particles. During February-March 2016, size-resolved chemical composition of individual atmospheric particles ranging from 0.1-1.5 microns in diameter was measured in real-time using an aerosol time-of-flight mass spectrometer (ATOFMS) in Ann Arbor, Michigan. Chemically-resolved particle number concentrations were obtained through coupling with a scanning mobility particle sizer and an aerodynamic particle sizer. The main particle types identified were primarily biomass burning from residential heating and organic carbon-elemental carbon particles from vehicular emissions. Many particles were internally mixed with sulfate, nitrate, and ammonium, evidence of atmospheric aging processes. Contributions from mineral dust, metal-rich particles, and road salt were also observed. These results will be useful in improving our understanding and prediction of air quality in wintertime urban environments.

**2UA.2**

**Investigation of Intra-City Variation of Organic Aerosol Concentration and Composition through a Mobile/Satellite Sites Sampling Platform.** PEISHI GU, Zhongju Li, Qing Ye, Naomi Zimmerman, Albert A. Presto, Allen Robinson, *Carnegie Mellon University*

Intra-city variation (1~10 km) of organic aerosol (OA) concentration and composition may be strongly influenced by near-by sources. Various physical and chemical processes may take place and modify the primary emission substantially and make spatial differences of organic aerosol significant within a small region. However, little is known about this process so far; most effort has been made to study the inter-city variation of OA. In this study starting from 2016 summer in Pittsburgh, PA, we will utilize aerosol mass spectrometry (AMS) in organic aerosol measurement on a mobile sampling platform. A second AMS will be deployed at a central urban background location. Instruments will also be deployed to measure NO<sub>x</sub>, PM<sub>2.5</sub> mass and number concentration, and black carbon. Case studies of driving within selected 1 km-by-1 km blocks as well as through a pre-designed route will be conducted in a span of approximately one year. Special interest of source impacts include local traffic and restaurants. We will try to observe the physical and chemical advancement of the fresh emission and try to answer which process governs the changes in organic aerosol composition. This proposed poster will mainly deliver the experimental design and preliminary results from the results accomplished by the date of the conference.

**2UA.3**

**Atmospheric Modeling of Cyclic Volatile Methyl Siloxanes.** NATHAN JANECEK, Charles Stanier, *University of Iowa*

Cyclic siloxanes are common chemicals in personal care products, especially antiperspirants. These are volatile chemicals that are released into the atmosphere by personal care product use. Since people are the emission source, highest concentrations are found in urban and indoor locations. In the atmosphere, cyclic siloxanes are oxidized by hydroxyl radicals (OH) forming oxidation products that can form aerosol species. The oxidation products have largely been unexplored, and production of nanoparticles could have important environmental and health consequences. In this work, we use the Community Multiscale Air Quality (CMAQ) atmospheric chemistry transport model to simulate gas phase cyclic siloxane behavior over North America. The model has been modified to include the most common cyclic siloxanes (D4, D5, and D6) and their OH oxidation products, emissions and seasonally varying boundary conditions calculated using measurement ratios accounting for differential oxidative aging, and wet and dry deposition for the cyclic siloxane species. This work represents the highest resolution modeling to date, and for the first time expected concentrations and the spatial distribution of the oxidation products, which can likely form particles, are reported. Using the model, seasonal concentration trends are explored by simulating January, April, July, and October months. Modeling results show urban parent cyclic siloxane seasonal concentrations are not sensitive to seasonally varying OH concentrations, and instead are associated with chemical transport. Conversely, rural parent cyclic siloxane concentrations, and both rural and urban oxidation products, show sensitivity to seasonally varying OH concentrations. Model results were evaluated to published spring cyclic siloxane measurements with calculated fractional bias values of -0.41, -0.033, -0.90, and fractional error values of 0.95, 0.66, 0.98 for D4, D5, and D6 respectively. While these error metrics remain high, they improve over coarser resolution models previously published at hemispheric scale.

## 2UA.4

**Scaling-up Urban Infrastructure Change: Carbon, Air Quality, and Health Co-Benefits of Urban-Industrial Efficiency & Symbiosis in 640 Chinese Cities.** Anu Ramaswami, Kang Kang Tong, Andrew Fang, RAJ LAL, Ajay Nagpure, Yang Li, Yuajun Yu, Daqian Jiang, Armistead G. Russell, Lei Shi, Marian Chertow, Yangjun Wang, Shuxiao Wang, *Georgia Institute of Technology*

Novel urban-industrial efficiency and symbiosis impacts on energy-use, particulate matter, and global greenhouse gas emissions (GHGs) are assessed using a multi-scalar urban infrastructure systems model. We apply the model to a new dataset covering 637 Chinese cities, providing predominantly city-scale data on co-location and energy-use in key industries, residential and commercial buildings, and district energy systems. We model: a) Reutilization and cascading of industrial waste heat with commercial-residential district energy systems at the city-scale; b) Exchange of construction materials across cement, steel and power sectors at the provincial-scale; c) Energy-efficient buildings, power-plants and industries, and associated electricity savings, at the scale of grid-regions. Aggregated across the nation, these interventions mitigate 15% of city-total CO<sub>2</sub> emissions annually, achievable with present-day technologies, modest industrial efficiency goals (yielding 9% reductions), and practical estimates of select energy- and material-exchange symbiosis potentials (contributing 4.5% and 1.5%, respectively). Waste heat from 16 of the largest energy-using industries in China was sufficient to displace fossil fuel requirements for heating-cooling in all commercial and residential buildings in 53% of the Chinese cities and, further, generate steam for industrial use. Reductions in fossil-fuel use yielded reductions in PM<sub>2.5</sub> emissions and ambient PM<sub>2.5</sub> concentrations (from <1% to 73%), depending on the city, yielding estimates of avoided pollution-related deaths >35,000 annually across all cities. These results show that sectoral efficiencies combined with cross-sectoral material-energy exchange in cities can be a powerful, but presently under-utilized, pathway for reducing PM<sub>2.5</sub> levels and improving public health.

## 2UA.6

**A Hybrid Sampling Network to Investigate Intracity Spatiotemporal Variation of Multiple Pollutants.** HUGH LI, Peishi Gu, Qing Ye, Naomi Zimmerman, R. Subramanian, Ellis Shipley Robinson, Joshua Apte, Allen Robinson, Albert A. Presto, *Carnegie Mellon University*

Long-term exposure to particulate matter (PM) is the major contributor to air pollution related death in 21st century. Intracity exposure patterns can be more complex than intercity ones because of local traffic, land use, and industrial facilities. We use a hybrid sampling network to characterize spatiotemporal variations of multiple pollutants in Pittsburgh, PA. This network makes the first attempt to incorporate a mobile sampling platform, supersite, and distributed sampling together to investigate a wide range of pollutants (CO, NO, NO<sub>2</sub>, VOCs, O<sub>3</sub>, PM<sub>2.5</sub> mass and composition, and ultrafine particles). In this project, we will use the detailed multi-pollutant measurements to characterize how potentially modifiable factors, including emission sources and urban form, affect spatiotemporal patterns. The key question to answer is how exposure-relevant patterns of air pollution in space and time relate to the spatial distribution of emissions sources within each region.

## 2UA.7

**Characterization of Traffic Emissions Exposure Metrics in the Dorm Room Inhalation to Vehicle Emissions (DRIVE) Study.** JENNIFER L. MOUTINHO, Donghai Liang, Karoline Johnson, Rachel Golan, Chandresh Ladva, Roby Greenwald, Rodney J. Weber, Stefanie Ebel Sarnat, Vishal Verma, Dean Jones, Jeremy Sarnat, Armistead G. Russell, *Georgia Institute of Technology*

Detailed measurements and dispersion modeling was conducted to develop more accurate integrated or biologically-relevant metrics to assess exposure to potentially high pollutant levels of primary traffic emissions. A 13-week intensive sampling campaign was conducted at six ambient and two indoor monitoring sites surrounding the busiest highway segment in the US with the study area focusing on the Georgia Institute of Technology campus. Fifty-four college students living in dorms near (20 m) or far (1.4 km) from the highway were recruited for personal exposure monitor sampling and biomonitoring, which included saliva and blood sampling. Traffic-related contaminant indicators selected to capture the heterogeneity of primary traffic emissions were measured at each site, including particle mass and number, elemental and organic carbon, nitrogen oxides, and carbon monoxide. Dispersion models, RLINE and AERMOD, were used to develop spatial concentration fields at a 250m resolution over the Atlanta area and a 25 m resolution over the area of primary exposures. Initial RLINE results were biased, due either to errors in the emissions or the model. Analysis suggests that both may be important, depending upon species. Both the measurement observations and dispersion modeling results show that the highway has a substantial impact on primary traffic pollutant (particularly elemental carbon and carbon monoxide) concentrations and capture the prominent spatial gradients across the Georgia Tech campus, though the gradients were highly species dependent. Results were further used to develop an overall indicator of exposure to traffic related emissions for use in health assessments. In addition to quantifying a multipollutant traffic exposure indicator, metabolic response was evaluated by finding elevated levels of specific metabolites in plasma samples. These results were used to identify which exposure metrics are most predictive of biologically-relevant responses to primary traffic exposures that could be used for large panel-based epidemiologic studies.

## 2UA.8

**Near-Road Spatial Distribution of Ultrafine Particles and Black Carbon across the Los Angeles Metropolitan Area.** ARIAN SAFFARI, Sina Hasheminassab, Farimah Shirmohammadi, Dongbin Wang, Mohammad Sowlat, Roel Vermeulen, Gerard Hoek, Rena Jones, Debra Silverman, Constantinos Sioutas, *University of Southern California*

Roadways are known as the major source of ultrafine and black carbon (BC) particulate emissions in southern California. To enhance our understanding of the small-scale spatial distribution of these parameters in the vicinity of major roadways, short-term measurements of BC and ultrafine particle (UFP) number concentration were carried out at nearly 200 locations across the Los Angeles metropolitan area, spanning from the county of Los Angeles in the west, to the counties of Riverside and Orange in the east and south of the basin. For each study location, 4 spots with different distances from the roadway (less than 50 meters, between 50 and 150 meters and more than 150 meters downwind, in addition to one spot upwind) were selected and monitored, using a mobile monitoring platform equipped with Discmini and micro aethalometer instruments. Measurements were performed for 30 minutes at each site, between 9am and 4pm, to avoid traffic spikes of the morning and afternoon rush hours. To correct the measurements for temporal variations across different sites, all concentrations were normalized by simultaneous measurements at a background stationary site, located sufficiently far from major roadways. Concentrations of BC and UFPs indicated a significant “within-site” spatial variability, with higher levels in the immediate vicinity of the freeway (i.e. less than 50 meters of distance) compared to the regions more than 150 meters from the edge of the freeway. Extent of “between-site” variability of BC and UFP concentrations, however, was proportional to the diversity of emission sources in each region. Specifically, the Port of Long Beach and the airport regions exhibited highest spatial variability compared to the rest of the basin. These measurements, along with air quality predicting variables such as traffic density and meteorological conditions, will be used for development of future land use regression models in the Los Angeles area.

**2UA.9**

**Measurement of Emissions and Air Quality Near a Major Refinery.** Henry Wallace, Nancy Sanchez, Courtney L. Herring, Timothy M. VanReken, James Flynn, Matthew H. Erickson, Barry Lefer, ROBERT GRIFFIN, *Rice University*

During the Benzene and other Toxics Exposure (BEETEX) Study during February 2015, we made stationary measurements of trace gases and particulate matter using a mobile air quality laboratory (MAQL). The site was located 50 m south of a large refinery along the notoriously polluted Houston Ship Channel. Being proximate to the largest petrochemical refining complex and the second busiest port in the United States, neighborhoods in the area are impacted by a variety of emissions. The location and time of the campaign were ideal for observations of primary emissions. Observations of non-refractory submicron particulate matter were made with a High-Resolution Time-of-Flight Aerosol Mass Spectrometer, of particle-bound polycyclic aromatic hydrocarbons (PAH) with a photoelectric aerosol sensor (PAS), and of volatile organic compounds with a Proton Transfer Reaction Mass Spectrometer. In addition, the MAQL has the capability to measure photochemically relevant trace gases and meteorological parameters.

This work presents our results and analyses of this data set. First, we compare PAH measurements estimated using analysis of ion fragments from the HR-ToF-AMS to those made with the PAS. Second, we perform principle component analysis of particulate organics, nitrate, sulfate, ammonium, and PAH and gas-phase compounds including VOCs, nitrogen oxides, total reactive nitrogen, sulfur dioxide, carbon monoxide, and ozone. We present a five-factor solution that explains 69.4% of the variance and identifies sources influencing the site. Factors affecting the composition of the site are vehicle emissions, tank and oil line emissions, primary emissions of particulate sulfate, nitrate and ammonium, diel variability and industrial solvent use. Finally, we present a three-factor solution (hydrocarbon-like, less oxidized, and more oxidized organic aerosol for positive matrix factorization modeling for the source apportionment of particulate matter, which indicates that hydrocarbon-like OA is the dominant factor at this site.

**2UA.10**

**Highly Time-resolved Urban Aerosol Characteristics during Springtime in Yangtze River Delta, China: Insights from Soot Particle Aerosol Mass Spectrometry.** JUNFENG WANG, Xinlei Ge, Yanfang Chen, Yafei Shen, Qi Zhang, Yele Sun, Jianzhong Xu, Yu Huan, Mindong Chen, *Nanjing University of Information Science and Technology*

In this work, a soot particle – aerosol mass spectrometer was deployed during the spring of 2015 in urban Nanjing, to characterize the submicron aerosols (PM<sub>1</sub>). The SP-AMS enables real-time and fast quantification of refractory black carbon simultaneously with other non-refractory particles. The average PM<sub>1</sub> concentration was found to be 28.2 micro-gram per cubic-meter (~54 % of the PM<sub>2.5</sub> mass), with organics (45 %) as the most abundant component, following by sulfate (19.3 %), nitrate (13.6 %), ammonium (11.1 %), rBC (9.7 %) and chloride (1.3 %). These PM<sub>1</sub> species together can reconstruct ~44 % of the light extinction based on the IMPROVE method. Chemically-resolved mass-based size distributions revealed that small particles especially ultrafine ones (<100 nm vacuum aerodynamic diameter) were dominated by organics and rBC, while large particles had significant contributions from secondary inorganic species. PMF analysis of organic aerosols (OA) yielded four OA subcomponents, including hydrocarbon-like OA (HOA), cooking-related OA (COA), semi-volatile oxygenated OA (SV-OOA), and low-volatility oxygenated OA (LV-OOA). Overall, secondary organic aerosol (SOA) dominated the total OA mass (55.5 %), but primary organic aerosol (POA) can outweigh SOA in early morning and evening due to enhanced human activities. High OA concentrations were often associated with high mass fractions of POA and rBC, indicating the important role of anthropogenic emissions during heavy pollution events. The diurnal cycles of nitrate, chloride and SV-OOA both showed good anti-correlations with air temperatures, suggesting their variations were likely driven by thermodynamic equilibria and gas-to-particle partitioning, meanwhile sulfate and LV-OOA concentrations increased during afternoon, showed no positive correlations with relative humidity, indicating the significant role of photochemical processing rather than aqueous-phase processing for their formations. The bivariate polar-plots show that the SV-OOA was formed locally; the variations of hydrogen-to-carbon (H/C) and oxygen-to-carbon (O/C) ratios further suggest an evolution pathway of SV-OOA to LV-OOA.

**2UA.11**

**An Annual Study of Chemical Composition and Source Apportionment of Ultrafine Particulate Matter (PM<sub>0.1</sub>) in Three Major Cities in California.** JIAN XUE, Wei Xue, Michael Kleeman, *University of California, Davis*

Numerous studies have identified associations between the mass of particles with aerodynamic diameter < 2.5  $\mu\text{m}$  (PM<sub>2.5</sub>) and premature mortality but far less is known about the public health threat associated with smaller particle size fractions within the PM<sub>2.5</sub> metric. One size range of great interest is ultrafine particles (UFPs, PM<sub>0.1</sub>, D<sub>p</sub> < 0.1  $\mu\text{m}$ ) due to the ability of these particles to access to the blood circulation and translocate to different regions of the body, and their apparent toxicity in multiple studies. The present work is the first stage of a framework study to perform a state-of-the-science exposure assessment for UFPs and to determine if UFPs are positively associated with premature death in California.

A sampling network was deployed across 3 polluted California cities for 1 year (2015/2016) to measure the concentration and composition of UFPs. Two stations are located in the San Francisco Bay Area, one station is located in Fresno, and one station is located in Los Angeles. UFPs samples were collected with 3 day averaging times using Micro Orifice Uniform Deposit Impactors (MOUDIs). Two impactors were deployed at each site to support a full range of chemical analysis. The first MOUDI was loaded with aluminum foil substrates prebaked at 550°C for characterization of carbonaceous material. The second MOUDI was loaded with Teflon substrates for characterization of trace elements. The chemical concentrations across the year were input to the Positive Matrix Factorization (PMF) model to identify UFPs source contributions from diesel engines, gasoline engines, brake wear/road dust, rail, residential wood burning, and food cooking. The results reveal interesting trends in the annual variation of UFPs chemical composition, spatial gradients, atmospheric processing, and source contributions. The results will provide a basis for future comparison to exposure estimates produced by regional chemical transport models and evaluation of future control strategies.

**2UA.12**

**Characterization of Criteria Air Pollutants in Beijing during 2014-2015.** HAO GUO, Yungang Wang, Hongliang Zhang, *Louisiana State University*

One year-long criteria air pollutants data collected in Beijing were analyzed in this paper, which can support the research on formation, transport and human health effects of air pollutants. This is the first time to study the spatial and temporal variations of six criteria pollutants in Beijing using hourly observational data from 12 sites between June 2014 and May 2015 released by the Ministry of Environmental Protection (MEP) of China. Beijing is facing tremendous air pollution as the daily averaged PM<sub>2.5</sub> concentrations in all sites exceeding the Chinese Ambient Air Quality Standards (CAAQS) Grade I & II standards (15 and 35  $\mu\text{g}/\text{m}^3$ ). Slightly differences in PM<sub>2.5</sub> and O<sub>3</sub> were observed between sites at the urban and rural areas. Pearson correlation coefficients show that most pollutants are temporally correlated in Beijing except for O<sub>3</sub>. The coefficients of divergence (COD) indicate that PM<sub>2.5</sub> is associated at most sites with only one rural site (Dingling) having observable difference. O<sub>3</sub>-8h also correlates at different sites but with one urban site (Haidianquwanliu) different from others. In addition, an extreme PM<sub>2.5</sub> event (hourly average concentration > 300  $\mu\text{g}/\text{m}^3$  for xxx hours) was examined with the consideration of meteorological conditions. Southerly wind with low speed and high relative humidity allow the accumulation of pollutants while northerly wind with high speed and low relative humidity result in good air quality.

**2UA.13**

**Assessment of Compact, Real-time PM<sub>2.5</sub> and Ultrafine Particle Counting Instrumentation with a Spatially-distributed Network in Pittsburgh, Pennsylvania.** NAOMI ZIMMERMAN, Eric Lipsky, R. Subramanian, Allen Robinson, Albert A. Presto, *Carnegie Mellon University*

It is well-established that exposure to elevated PM<sub>2.5</sub> mass concentrations is associated with negative health outcomes. As such, many regulatory bodies have imposed ambient PM<sub>2.5</sub> standards. However, recent toxicology studies suggest that ultrafine particles (UFPs, diameter < 100 nm), which are not currently regulated, have a higher toxicity compared to larger particles and these particles deposit with the greatest efficiency in the alveolar region, where they may induce oxidative stress.

Concentrations of UFPs and PM<sub>2.5</sub> are expected to exhibit substantial spatial and temporal variability. Accurate characterization of UFP and PM<sub>2.5</sub> gradients in an urban environment requires a network of spatially distributed, high time resolution, compact instrumentation. The Met One Instruments Neighborhood Air Monitor and Aerosol Dynamics Inc. "MAGIC" condensation particle counter (CPC) are two instruments capable of these PM<sub>2.5</sub> and UFP measurements, respectively.

In this study, the performance of the Neighborhood Air Monitor and the "MAGIC" CPC was assessed against a range of co-located reference instruments in an urban near-road environment. The instruments were further evaluated in a spatially distributed network designed to capture urban upwind, urban high traffic, and urban outflow environments. Our preliminary findings show that the "MAGIC" CPC was well correlated with a butanol-based CPC ( $R^2 > 0.85$ ). For PM<sub>2.5</sub>, the Neighborhood Air Monitor was well correlated ( $R^2 > 0.9$ ) with other optical PM<sub>2.5</sub> instruments and the monitor was sensitive to spatial gradients exceeding 2 micro-grams per cubic meter.

**2UA.14**

**Ultrafine Particle Measurements at Schools Next to a Freeway in Las Vegas and in the Greater Salt Lake City Area.** STEVEN G. BROWN, Jennifer DeWinter, Paul Roberts, *Sonoma Technology, Inc*

We report on ultrafine particle (UFP) concentrations at two schools: (1) Hunter High School in West Valley City, Utah (a suburb of Salt Lake City), which is located in an urban center away from major roadways; and (2) Adcock Elementary School in Las Vegas, Nevada, which is 20 m from the U.S. 95 freeway. Data were collected at Hunter in winter 2012, and at Adcock in spring 2013. UFP concentrations were higher at Adcock than at Hunter due to Adcock's proximity to the freeway. At Adcock, the mean hourly value was 11,022 particles/cm<sup>3</sup>; at Hunter, the mean hourly value was 6,755 particles/cm<sup>3</sup>. Both locations showed a strong morning peak in particle concentrations and similar morning peaks in black carbon (BC) concentrations. On roughly 40% of days at Adcock, UFP had a midday peak with no corresponding BC peak, likely due to new particle formation. UFP and BC concentrations were significantly higher at Adcock when wind speeds were low, while at Hunter the UFP concentrations were invariant with wind speed and BC was only slightly lower at higher wind speeds. We attribute this difference to the impact of emissions on U.S. 95 next to Adcock, where concentrations are higher under lower wind speeds regardless of wind direction. BC and UFP had no correlation at Adcock, and a low correlation ( $r = 0.35$ ) at Hunter. Other studies have found that BC and particle count is only correlated with larger particles (greater than 200 nm diameter). Since Adcock is next to U.S. 95 and fresh vehicle emissions, UFP count measurements are likely dominated by particles less than 100 nm in diameter, leading to a low correlation with BC. At Hunter, particles are likely more aged and thus larger, leading to a higher correlation between UFP and BC.

## 2UA.15

**Aerosol Optical Properties Measurements by CAPS Single Scattering Albedo Monitor: Comparisons between Summer and Winter in Beijing, China.** TINGTING HAN, Weiqi Xu, Jian Zhao, Chen Chen, Qingqing Wang, Li Jie, Zifa Wang, Xingang Liu, Yele Sun, *Institute of Atmospheric Physics, Chinese Academy of Science*

We have investigated aerosol optical properties in summer and winter in Beijing using a state-of-the-art cavity attenuated phase shift single scattering albedo monitor (CAPS  $PM_{ssa}$ ) that simultaneously measures airborne particle light extinction and scattering coefficients and thus SSA. Aerosol particle compositions were simultaneously measured by Aerosol Mass Spectrometer, Aerosol Chemical Speciation Monitor, and Aethalometers. Our results showed that the frequency distributions of SSA measured by CAPS  $PM_{ssa}$  overall agree with those derived from the measurements by a CAPS extinction monitor and Aethalometers. However, significant differences were observed during periods with low SSA values in summer and winter. The average ( $\pm\sigma$ ) extinction coefficient ( $b_{ext}$ ) and absorption coefficient ( $b_{ap}$ ) were  $335.9 (\pm 342.5) M m^{-1}$  and  $44.4 (\pm 41.2) M m^{-1}$ , respectively during wintertime, which were approximately twice those observed in summer. In contrast, the average SSA was relatively close, 0.86 and 0.85 in summer and winter respectively. Further analysis showed that the variations in SSA can be approximately parameterized as a function secondary particulate matter or secondary inorganic aerosols during both seasons. Finally, we quantified the contributions of aerosol components to extinction coefficients in the two seasons. Our results showed that the light extinction was dominantly contributed by ammonium sulfate (30%) and secondary organic aerosol (SOA) (22%) in summer. In contrast, SOA (39%) was the largest contributor to light extinction in winter followed by ammonium nitrate (18%).

## 2UA.16

**Response of Aerosol Sources and Properties to Emission Controls: Results from Simultaneous Measurements at Ground level and 260 m in Beijing.** Jian Zhao, Wei Du, Yingjie Zhang, Chen Chen, Weiqi Xu, Qingqing Wang, TINGTING HAN, Zifa Wang, Yele Sun, *Inst. of Atmospheric Physics, Chinese Academy of Sciences*

Strict emission controls were implemented in Beijing and adjacent provinces to ensure good air quality during the period of 20 August – 3 September. Here we conducted synchronous measurements of submicron aerosol ( $PM_{1}$ ) at two different heights, i.e., ground and 260 m on a meteorological tower in urban Beijing from 22 August to 31 September, by using a High-Resolution Aerosol Mass Spectrometer and an Aerosol Chemical Speciation Monitor. Our results showed that organic aerosols (OA) dominated  $PM_{1}$  at both ground and 260 m (54% and 51%, respectively) during the control period, however, secondary inorganic aerosols (SIA = sulfate + nitrate + ammonium) were more significant in  $PM_{1}$  after the control period (51 - 52%). These results suggested a larger impact of emissions controls on reduction of SIA compared with OA. The response of primary and secondary OA to emission controls were further investigated by positive matrix factorization analysis. Our results showed very different responses of POA and SOA to emission controls at different heights. Finally, the sources of aerosol species during the control and uncontrol periods were investigated using FLEXPART and bivariate polar plots.

**2UA.17**

**Semi-Continuous Measurement and Characteristics of Water-Soluble Organic Carbon and Ions of PM<sub>2.5</sub> Aerosol with PILS-TOC-IC in Baengnyeong Island during MAPS-Seoul 2016.** TAEHYOUNG LEE, Seokwon Kang, Kyunghoon Kim, Gyutae Park, Jihee Ban, Dajeong Park, Min-Suk Bae, Mindo Lee, Hyejung Shin, Youngkyo Seo, Jinyoung Choi, Donghee Jung, Seokjun Seo, *Hankuk University of Foreign Studies*

Aerosols have an important effect from scattering and absorbing the solar energy and indirectly by acting as cloud condensation nuclei and also some of the effects of aerosols are reduction in visibility, deterioration of human health, and deposition of pollutants to ecosystems. In various experimental results were showed that organic compounds have an important fraction from 10 to 70% of the total aerosol mass. Organic carbon contains water-soluble organic carbon (WSOC) and water insoluble organic carbon. WSOC are involved in the most unknown liquid-phase chemistry of wet aerosol and clouds. It is also worked as cloud condensation nuclei (CCN). Formation of secondary organic aerosol by chemical reaction of hydrocarbon compounds is a source of main pollution of WSOC compounds. Study of pollution source of WSOC is important method for creation process of secondary organic aerosol that completely has not studied.

Analysis of WSOC is important and need to real-time measurement system for definition of chemical cause and sources. In this study, Particle-into-liquid sampler (PILS) coupled with total organic carbon (TOC) analyser and ion chromatography (PILS-TOC-IC), was used for semi-continuous measurement of WSOC and ionic compounds of PM<sub>2.5</sub> in Baengnyeong-island during MAPS-Seoul 2016. PILS-TOC-IC can provide chemical information about real-time changes from ions composition and concentrations of WSOC and ionic compounds.

**2UA.18**

**Aircraft-based Aerosol Composition Measurements during MAPS-Seoul.** TAEHYUN PARK, Jaebum Lee, Yongjae Lim, Junyoung Ahn, Jinsoo Park, Jinsoo Choi, Jongho Kim, Soobog Park, Taehyoung Lee, *Hankuk University of Foreign Studies*

Aerosols influence climate change directly by scattering and absorption and indirectly by acting as cloud condensation nuclei and also some of the effects of aerosols are reduction in visibility, deterioration of human health, and deposition of pollutants to ecosystems. Urban area is large source of aerosols and aerosol precursors. Aerosol sources are both local and from long-range transport. Long-range transport processed aerosol are often dominant sources of aerosol pollution in Korea. To improve our knowledge of aerosol chemistry, Megacity Air Pollution Studies-Seoul (MAPS-Seoul) of Aircraft-based aerosol measurement took place in and around Seoul, Korea during May and June 2015 and 2016.

MAPS-Seoul campaigns were conducted to study the chemical characterization and processes of pollutants in the Seoul Metropolitan area to regional scales of Korean peninsula. Aerodyne high resolution time of flight aerosol mass spectrometer (HR-ToF-AMS) was deployed on aircraft platforms on-board King Air (Hanseu University). We characterized aerosol chemical properties and mass concentrations of sulfate, nitrate, ammonium and organics in polluted air plumes and investigate the spatial and vertical distribution of the species. The results of studies show that organics is predominant in the Aerosol and a significant fraction of the organics is oxygenated organic aerosol (OOA) at the high altitude. The results of those studies can provide highly-temporal resolved details on the width, depth and spatial distribution of the pollutant plume and aerosol, which are valuable for modeling input parameters for modeling aerosol behavior.

**2UA.19****The Effect of Sound Wall - Vegetation Combination Barriers on Pollution Dispersion from the Freeways.**

DILHARA RANASINGHE, Isis Frausto-Vicencio, Eon Lee, Yifang Zhu, Seyedmorteza Amini, Faraz Enayati Ahangar, Akula Venkatram, Steve Mara, Suzanne Paulson, *University of California, Los Angeles*

The differential exposure to high levels of air pollution near heavily trafficked roadways, compared to other locations, raises serious health concerns in land usage in such locations. A widely considered mitigation strategies for exposure reduction is the optimization of sound walls and roadside vegetation barriers. Physical barriers affect pollutant concentrations around it by blocking initial dispersion, and increasing turbulence and initial mixing of the emitted pollutants. Vegetation can also remove some gaseous pollutants by absorption and particulate matter by deposition. Though it is well established that sound walls, vegetation barriers and combination barriers; that is sound walls together with vegetation barriers, affect the pollution dispersion downwind of roadways, there are many inconsistent results about the dispersion patterns found from different field, tracer, wind tunnel and numerical modeling studies done so far. The complexity of pollutant movement under varying conditions makes accurate prediction of exposure reduction difficult.

An extensive field measurement campaign was conducted to look at the effectiveness of sound wall-vegetation combination barriers as a near-roadway pollutant mitigation strategy. Mobile measurements of several air pollutants were done at two sites near heavily-trafficked freeways in Santa Monica, CA and Sacramento, CA. Measurements were done in two different seasons in Santa Monica; fall, 2015 and winter, 2016. In Sacramento, the measurements were done in summer, 2016. Pollution variation behind the barriers were analyzed together with local meteorology measurements to find general patterns of the pollution dispersion behind combination and vegetation barriers. This study will provide insights into the value and best practices for siting and design of vegetation and combination barriers, to reduce downwind pollution from roadways. The results could provide planners and decision makers with additional tools to evaluate and consider potential near-roadway air pollution mitigation options for existing and future development.

**2UA.20****Particle Emission Properties during DPF Active Regeneration.**

HIROYUKI YAMADA, Satoshi Inomata, Hiroshi Tanimoto, *National Traffic Safety and Environment Laboratory*

Mechanisms involved in increased particle and volatile organic compound (VOC) emissions during active and parked active regeneration of a diesel particulate filter (DPF) were investigated using heavy-duty trucks with and without a urea selective catalytic reduction (SCR) system. Particles emissions increase in the latter part of the regeneration period, and the mechanisms differed at particle sizes above and below 23 nm. Particles with sizes above 23 nm were emitted due to the lower filtering efficiency of the DPF because of the decreasing amount of soot trapped during regeneration. Small particles (below 23 nm) were mainly sulfate or sulfuric acid particles trapped by the catalyst and emitted due to the increased temperature during regeneration. These particle emissions from the SCR system continued for a longer time period because of the higher temperature of the catalyst compared with a non-SCR system. As pointed out by former researchers, these particles seem to be semi-volatile particles, but the volatility was lower than they expected.

**3AC.1**

**Optical Properties of Secondary Organic Aerosol from Cis-3-hexenol and Cis-3-hexenyl Acetate: Effect of Chemical Composition, Humidity and Phase.** REBECCA HARVEY, Adam Bateman, Shashank Jain, Yong Jie Li, Scot Martin, Giuseppe Petrucci, *University of Vermont*

Atmospheric aerosols play an important role in Earth's radiative balance directly, by scattering and absorbing radiation, and indirectly by acting as cloud condensation nuclei (CCN). Recently, the ozonolysis of green leaf volatiles (GLVs) has been found to contribute to secondary organic aerosol (SOA), yet the role these SOA play in the Earth's radiative budget is poorly understood. Herein, we measure optical properties of GLV-derived SOA and report on their role in the direct radiative effect. We also discuss the relationship between SOA optical properties and bulk vs molecular-level chemistry. Specifically, we measured the scattering efficiency, absorption efficiency, particle phase, bulk chemical properties (O:C, H:C) and the molecular-level composition of SOA formed from the ozonolysis of two GLVs; cis-3-hexenol (HXL) and cis-3-hexenyl acetate (CHA). Both GLVs produced SOA that was weakly absorbing, yet CHA-SOA was a more efficient absorber than HXL-SOA, especially at wavelengths shorter than 350 nm. The scatter efficiency of SOA from both systems was wavelength-dependent, with the stronger dependence exhibited by HXL-SOA. Perhaps the most interesting result from this work was that HXL-SOA formed under both dry (10 percent RH) and wet (70 percent RH) conditions had significantly different optical properties, which was not reflected in bulk chemical properties. Instead, we rationalized the differences in optical properties under the two RH regimes using a molecular-level understanding of the role of water in particle formation and particle composition. Ultimately, we have found that SOA derived from GLVs has the potential to affect the Earth's radiative budget, and also that bulk chemical properties may be insufficient to predict SOA optical properties.

**3AC.2**

**Photolysis of Secondary Organic Aerosol Material in the Presence of Volatile Organic Compounds: The Role of Photosensitization.** KURTIS MALECHA, Sergey Nizkorodov, *University of California, Irvine*

Organic compounds trapped inside and on surfaces of atmospheric particles are readily accessible to actinic radiation from the sun. While the gas-phase photochemistry of organic compounds is relatively well understood, the rates and mechanisms of photochemical transformations of organic compounds in particles are poorly known. Recently, the role of photosensitized reactions in aerosol chemistry, where a photosensitizer absorbs light at a given wavelength causes an increase in aerosol mass and diameter, has been discussed in the literature. This presentation will describe our experiments that characterize the photosensitization reactions of secondary organic aerosols (SOA) containing photosensitizers in the condensed-phase and in the presence of various volatile organic compounds (VOCs). We generate a suite of model SOA by oxidation of VOCs in a smog chamber, collect SOA on an inert substrate, irradiate them with near-UV and/or visible radiation in the presence of a selected VOC, and examine the suppression of photoproducts in the gas phase by proton transfer reaction mass spectrometry. Special attention is given to the inferred rate of uptake of a given VOC and the increase in condensed-phase mass.

**3AC.3**

**Modeling Aqueous Organic Aerosol Chemistry: Photosensitizers and the Oxidizing Power of the Aqueous Phase.** V. FAYE MCNEILL, Wanyi Li, William Tsui, Alison Fankhauser, Nabil Khan, Kayane Dingilian, Hai-Lung Dai, Yi Rao, *Columbia University*

Light-absorbing organic species in atmospheric aerosols may act as photosensitizers, directly oxidizing organic species or forming oxidants such as HO<sub>2</sub>. This chemistry may contribute to the formation of secondary organic aerosol (SOA) material, but additional insight into the mechanisms and kinetics of these processes is required so that we may evaluate the relative importance of this pathway. We will present data and insight from laboratory studies of the photosensitizer chemistry of imidazole-2-carboxaldehyde and an analysis of published laboratory data for photosensitized SOA growth using our photochemical box model, GAMMA. GAMMA results demonstrating the potential impact of this chemistry in the environmental context will also be presented.

**3AC.4**

**Chemical Characterization of Organic Aerosol Emitted from Combustion of Indonesian Peat and Biomass.** SRI HAPSARI BUDISULISTIORINI, Matthieu Riva, Michael Williams, Jing Chen, Masayuki Itoh, Haris Gunawan, Jason Surratt, Mikinori Kuwata, *Nanyang Technological University*

Indonesia peatland fires during the 2015 El Niño caused haze pollution over Southeast Asia region. Characterization of organic aerosol (OA) composition within biomass burning emissions is useful for source apportionment of atmospheric aerosols and evaluating environment impacts of haze pollution. Previous studies have investigated chemical composition of Indonesian peat aerosols, however, during wildfires various types of fuel are burned concurrently. We report chemical characterization of OA from biomass burning using peat, partially decomposed litters and soil, leaf, and charcoal fuels collected in Riau and Central Kalimantan provinces, Indonesia. Fuel was ignited under laboratory-controlled conditions and smoke was mixed with particle-free air. The diluted smoke was measured by a Time-of-Flight Aerosol Chemical Speciation Monitor (ToF-ACSM) for chemical composition of non-refractory submicron particulate matter (NR-PM<sub>1</sub>). Filter samples were simultaneously collected during combustion for identification of OA constituents at the molecular level using gas chromatography coupled to electron ionization mass spectrometry (GC/EI-MS) and ultra-performance liquid chromatography interfaced to both a diode array detector and an electrospray ionization high-resolution quadrupole time-of-flight mass spectrometer operated in negative ion mode (UPLC/DAD(-)ESI-HR-Q-TOFMS). NR-PM<sub>1</sub> mass concentrations from peat combustions are larger than other fuels, but all are dominated by OA, accounting for ~99% of total mass. OA mass spectra are not highly oxidized, as indicated by the predominant ion at m/z 43 (mostly C<sub>2</sub>H<sub>3</sub>O<sup>+</sup>) over m/z 44 (mostly CO<sub>2</sub><sup>+</sup>). Interestingly, ratio of biomass burning marker ions, m/z 60 (mostly C<sub>2</sub>H<sub>4</sub>O<sub>2</sub><sup>+</sup>) to m/z 44, is dependent of fuel type, suggesting differences in chemical composition. Concentrations of levoglucosan and other polyol compounds are higher in aerosols from peat combustion compared to other fuels. Moreover, identification of organosulfates might indicate multiphase chemical processes within peat and biomass burning smoke. Nitroaromatics and UPLC-DAD traces reveal the formation of brown carbon (BrC) chromophores from peat and biomass fires.

**3AC.5**

**Aerosol Particle Browning and Production of Semivolatile, Light-Absorbing Species upon Exposure to Gas-Phase Methylglyoxal or Methylamine.** DAVID DE HAAN, Natalie Jimenez, Alexia De Loera, Paola Formenti, Mathieu Cazaunau, Aline Gratien, Jean-François Doussin, *University of San Diego*

Cloud processing causes important changes in aerosol particles. Wet scavenging of water-soluble gases, aqueous-phase oxidation, and other reactions can increase the amount of organic material and cause the particles to absorb light. Oligomer formation during droplet drying can produce semi-solid organic phases that slow the kinetics of subsequent chemical and physical processes within the particle. We report on aerosol chamber experiments with common atmospheric aldehydes (e.g. methylglyoxal), amines (methylamine, glycine), and ammonium salts. Gas-phase species are monitored by high-resolution PTR-MS, while particles and droplets are monitored for size (SMPS, WELAS), optical parameters (CAPS-PMSSA, PILS / UV-vis), physical characteristics (aerosol bounce) and offline speciation (high-resolution LC-ESI-MS of aqueous filter extracts). CAPS data indicates that particle browning upon exposure to methylglyoxal or methylamine gas can occur on a timescale of less than 1 min, and is sensitive to chamber RH. However, SMPS data shows that dried particles exhibit only negligible increases in mass during browning. Furthermore, cloud events in this system trigger post-cloud uptake of volatile imine products and the production of a 2nd-generation semivolatile species that absorbs light at 450 nm. Brown carbon production rates measured in aerosol particles exceed those measured in bulk-phase experiments by at least four orders of magnitude, well in excess of any concentration effects. This suggests that surface reaction processes are dominant in the aqueous-phase atmospheric chemistry of methylglyoxal.

**3AC.6**

**Aqueous Phase Photo-oxidation of Nitroaromatic Compounds in Brown Carbon Aerosol.** RACHEL HEMS, Jonathan Abbatt, *University of Toronto, Canada*

Light absorbing organic aerosols, referred to as brown carbon, are geographically widespread and can have an important climate impact through the absorption of solar radiation. The sources of brown carbon aerosols are thought to be primarily biomass or fossil fuel burning, but with contributions from secondary reactions in aqueous aerosol or cloud droplets, for example reaction of aldehydes and amines. Despite ongoing research in this field, little is known about the chemical composition of brown carbon aerosols, specifically the chromophores responsible for the colour, and their atmospheric transformations. Recent studies, both in the laboratory and the field, have shown that brown carbon aerosols can be bleached of their colour by direct photolysis and photo-oxidation reactions on the timescale of hours to days. However, the photo-oxidation of nitrophenols, coloured compounds often associated with biomass burning organic aerosol, show an enhancement in light absorption before the colour is lost. The mechanism of this colour enhancement and the fate of nitrophenol compounds in aqueous aerosol is investigated in the aqueous phase photo-oxidation of 4-nitrocatechol. Chemical composition is monitored online throughout the reaction with the aerosol-chemical ionization mass spectrometer and light absorption is measured offline with UV/Vis spectroscopy. We studied the kinetics of the reaction and its products to gain a better understanding of brown carbon aerosol aging and the evolution of its light absorptivity. A mechanistic understanding of photo-oxidation of nitroaromatic species can help to better model light absorbing organic aerosol.

**3AP.1****Modelling and Experimental Evaluation of Aerosol Nanoparticle Photoionization in an Applied Electric Field.**

Robert Nishida, ADAM M BOIES, Simone Hochgreb,  
*University of Cambridge, University of Minnesota*

Aerosol nanoparticles are more efficiently charged by direct ultraviolet photoionization than by other charging mechanisms such as diffusion charging. The resulting charged nanoparticles can therefore more easily be manipulated for detection, capture, or control in many aspects of aerosol and materials science.

Aerosol particles emit electrons and become positively charged to multiple charge states if they absorb ultraviolet photons of high enough energy. The emitted electrons ionize gas molecules which, in turn, recombine with particles to reduce their charge level. Mechanisms of particle charge recombination with gaseous ions are well understood, but the photoionization process has limited experimental validation. Experimental studies have typically relied on the measurement of current resulting after photocharging via empirical constants, which serve as a fitting parameters for every change in particle size, light intensity, or flow rate when no change should occur [1,2]. Modelling of the photoionization process has not seen significant improvement in over a decade [3,4].

In this work, a generalized model for particle photocharging and transport is proposed, which includes equations for flow, photocharging, recombination, wall losses and electric field transport. The Fowler-Nordheim equation and photocharging theory is evaluated for the applicability of its experimental constants, including a single empirical constant and a particle work function to account for photoionization. The model is validated using measurements of currents in an experimental photoionization chamber. The device is outfitted with a method for varying the electric field in order to capture ions, reduce recombination, and increase the particle charge state in a continuous flow of aerosol nanoparticles. The variation in electric field allows control the final particle charge state, and thus the total collection of current.

Experimental data is obtained for a range of aerosol particle compositions (e.g. soot, silver), sizes and concentrations. The limitations of the existing theory and models are described in connection with the experimental comparisons. The novel approach of using an electric field to allow control of particle charge states is demonstrated to be useful for a range of photocharging based devices.

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**3AP.2****Finite Element Analysis Simulations on the Photoacoustic Response of Aerosols with Water Coatings.**

JAMES RADNEY, Christopher Zangmeister, *National Institute of Standards and Technology*

The magnitude of absorption enhancement by an absorbing aerosol with a water coating is a topic that has received considerable attention. Mie theory predicts that the absorption cross-section should continuously increase with coating thickness and extinction minus scattering measurements have confirmed this response. However direct absorption-based measurements of this enhancement using a photoacoustic spectrometer have proved elusive at best. In some instances, rapid vaporization of water at the particle/water interface causes ultrasonic nano-explosions that are perceived as an apparent enhancement of the photoacoustic signal; as a result, measured absorption cross-sections are larger than physically explainable by Mie theory. In other instances, the evaporation of surface water reduces the photoacoustic signal by reducing the energy available for thermal relaxation. This array of observations arises because the thermal and acoustic response to light pulses by water-coated aerosol particles depends upon the intensity and duration of the pulse, the type of particle under investigation and the coating thickness. We will present finite element analysis simulation results on the photoacoustic effect in coated aerosols with an emphasis on the heat transfer, fluid flow and pressure (acoustic) wave propagation. Both spherical and aggregated aerosol particles with varying coating thicknesses will be examined in order to better understand the different responses.

**3AP.3**

**Universal Description of Light Scattering by Atmospheric Ice Crystals.** YULI HEINSON, Justin Maughan, Ping Yang, Amit Chakrabarti, Jiachen Ding, Chris Sorensen, *Kansas State University*

Q-space analysis is applied to the scattering phase functions associated with various shapes of ice crystals. The present analysis involves displaying the scattered intensity as a function of  $q$  or  $qR$ , on a log-log scale, where  $q=2k\sin(\theta/2)$  and  $2R$  is the characteristic dimension of the particle. The analysis uncovers common patterns for all ice crystal shapes, patterns which are quite similar to the counterparts found for spheres. Specifically, a  $q$ -independent forward scattering lobe is followed by the Guinier regime which is then followed by a -3 slope regime due to 2D Fraunhofer diffraction, a transition regime, and then a -4 slope regime due to 3D diffraction. An enhanced back scattering regime is sometimes observed. Aggregates of ice crystals show a single power law with an exponent of about -2 along with the diminishing glory in the backward direction. The Rayleigh normalized forward scattering intensity, in which approximately half of the scattered light resides, is found to scale with the internal coupling parameter  $\rho'$  with a power law with an exponent of -2.

**3AP.4**

**Coagulation of Agglomerates with Polydisperse Primary Particles in the Free Molecular Regime.** Eirini Goudeli, Maximilian L. Eggersdorfer, SOTIRIS E. PRATSINIS, *ETH Zurich*

Agglomerate coagulation in the free molecular regime is encountered in the early stage of aerosol formation in both atmospheric and industrial processes. Here ballistic agglomeration of fractal-like particles consisting of polydisperse primary particles (PP) is investigated by discrete element modeling (DEM). The DEM-extracted coagulation rate is compared systematically to that in the literature for spherical (aerosol textbooks) and agglomerate particles consisting of monodisperse PP (*J. Colloid Interface Sci.* 1986, 114:67–81; *Aerosol Sci. Technol.* 2012, 46:1174–1186; *Langmuir* 2015, 31:1320–1327). Increasing the width or polydispersity of the PP size distribution accelerates initially the coagulation rate of agglomerates but delays their attainment of the asymptotic fractal-like structure and self-preserving size distribution without altering these values provided that sufficiently large numbers of PPs are employed. For example, the standard asymptotic mass fractal dimension,  $D_f$  of 1.91 is attained with clusters containing each, on the average, 50 monodisperse PPs and about 900 polydisperse PPs having geometric standard deviation equal to 3. This transition to the fractal regime with increasing agglomerate size is consistent with mass-mobility measurements. Even though the same asymptotic  $D_f$  and mass-mobility exponent,  $D_{fm}$ , are attained regardless of PP polydispersity, the asymptotic prefactors or lacunarities of  $D_f$  and  $D_{fm}$  increase with PP polydispersity. For monodisperse PPs the average agglomerate radius of gyration,  $r_g$ , becomes larger than the mobility radius,  $r_m$  when agglomerates consist of more than 40 PPs. Increasing PP polydispersity increases that number of PPs similarly to the required PPs per agglomerated for attainment of the asymptotic  $D_f$ . Various options for calculation of that PP number as a function of PP polydispersity are compared.

**3AP.5****Wind Tunnel Experiment of Bacillus Spores Resuspension.**

JING QIAN, Babak Nasr, Matthew Brown, Meilu He, Morgan Minyard, Andrea R. Ferro, Goodarz Ahmadi, Suresh Dhaniyala, *Clarkson University*

Quantitative understanding is lacking for accurately modeling real-world outdoor biological particle resuspension processes. This experimental study quantifies particle resuspension for a range of substrates and particle types in a wind tunnel designed and fabricated to operate at high flowrates and variable humidity. The detachment of particles is determined as a function of shear velocity for each set of conditions. This presentation will describe the experimental methodology on spore preparation, deposition, resuspension and detection. Initial results include resuspension rate vs shear velocity for the detachment of Bacillus spores as compared with glass spheres and PSL particles from glass and stainless steel substrates under various flowrates and two different RH conditions. Approved for public release, distribution is unlimited.

**3AP.6****Aircraft Measurements Intercomparison during**

**GoAmazon2014/5.** FAN MEI, Micael Cecchini, Jian Wang, John Shilling, Jason Tomlinson, Jennifer Comstock, John Hubbe, Mikhail Pekour, Luiz Machado, Manfred Wendisch, Martin Zoeger, Bernadett Weinzierl, Scot Martin, Beat Schmid, *Pacific Northwest National Laboratory*

Currently, the indirect effects of atmospheric aerosols remain the most uncertain components in forcing of climate change over the industrial period (IPCC, 2013). This large uncertainty is partially a result of our incomplete understanding of the ability of particles to form cloud droplets under atmospherically relevant supersaturations. One objective of the US Department of Energy (DOE) Green Ocean Amazon Project (GoAmazon2014/5) is to understand the influence of the emission from Manaus, a tropical megacity, on aerosol size, concentration, and chemical composition, and their impact on cloud condensation nuclei (CCN) spectrum.

The GoAmazon2014/5 study was an international campaign with the collaboration efforts from US, Brazil and Germany. During the intensive operation period, in the dry season (Sep. 1 – Oct. 10, 2014), aerosol concentration, size distributions, and CCN spectra, both under pristine conditions and inside the Manaus plume, were characterized in-situ from the DOE Gulfstream-1 (G-1) research aircraft and German HALO aircraft during 4 coordinated flights on Sep. 9, Sep. 16, Sep 21 and Oct. 1, 2014. During those four flights, aerosol number concentrations and CCN concentrations at two supersaturations (0.25% and 0.5%) were measured by condensation particle counters (CPCs) and a DMT dual column CCN counter onboard both G-1 and HALO. Aerosol size distribution was also measured by a Fast Integrated Mobility Spectrometer (FIMS) aboard the G-1 and is compared with the size distribution from Ultra High Sensitivity Aerosol Spectrometer – Airborne (UHSAS-A, DMT), which were deployed both on the G-1 and the HALO. Good agreement between the aerosol properties measured from the two aircraft has been achieved. The vertical profiles of aerosol size distribution and CCN spectrum will be discussed.

**3HR.1****Are We Done with Respiratory Deposition and Dosimetry of Inhaled Particles?** CHONG KIM, *USEPA*

Deposition of inhaled particles and subsequent dose estimation in the respiratory airways is an essential information needed for assessing potential health hazard of airborne pollutant particles on the one hand and therapeutic efficacy of drug aerosols on the other hand. Over several decades tremendous efforts have been made to obtain accurate dose of inhaled aerosols utilizing in vivo and in vitro experiments, mathematical analyses and computer modeling. As a result, a large amount of data has been accumulated that can be tapped into for estimating dose of inhaled aerosols under various inhalation or exposure conditions. In addition, well-documented mathematical models are widely available for use that provide means of estimating dose in a very specific and detailed manner. This gives us a sense of accomplishment and to a degree puts us into complacency despite the fact that the current knowledge is based on discrete experimental data of a small number of mainly healthy adult subjects and models built with highly ideal lung morphology, both of which are far from adequate for providing answers to challenging real world questions. Dose estimation process requires at least three critical inputs from physicochemical characteristics of aerosol particles, inhalation pattern and lung morphology. Although advancement of technology has introduced some new aerosol monitoring instruments, experimental method, particularly in vivo has not been much progressed. Mathematical models are still based on idealized simple lung structure, limiting the scope of analysis and predictability. This presentation will discuss the current status of aerosol lung dosimetry, needs for improvement and expansion of data base, and methodologic approaches that may be employed for further studies. This is an abstract of a proposed presentation and does not necessarily reflect EPA policy.

**3HR.2****A Novel Device for Cell Exposure at the Air-Liquid Interface.** Mika Ihalainen, Pasi, I Jalava, Kari Kuuspallo, Maija-Riitta Hirvonen, JORMA JOKINIEMI, *University of Eastern Finland, Kuopio, Finland*

Inhalation exposure is the main route causing health effects by the air pollutants. Air-liquid interface (ALI) in-vitro exposure mimics most realistically real life conditions. In ALI devices it is crucial to know the dose for the cells accurately. The dose from inhaled particles is determined by particle size and concentration at the air-liquid interface. The most important natural deposition mechanisms at the air-liquid interface are interception, impaction, gravitational settling and diffusion. However, diffusion is strongly dependent on particle size and thus dose determination becomes difficult. Also deposition by diffusion is very inefficient for particles larger than about 10 nm. Hence it is not possible to get high enough dose for toxicological studies by diffusion in most applications. Deposition by thermophoresis does not depend much on particle size up to several hundred nanometers. Thus from various initial size distributions it is fairly easy to determine the deposited amount of particles by thermophoresis.

We have designed a novel ALI device where it is easy to control flow rates, temperature and relative humidity. Deposition of various nanoparticles has been determined by collecting particles on foils for subsequent microscopic analysis. The aerosols were characterized with the scanning mobility particle sizer (SMPS) prior the ALI device. A model describing the deposition of the ALI device was constructed and validated with the experimental results. The results show that the online data (SMPS) estimated quite well the size distribution of the deposited particles (SEM).

Our ALI device shows several advantages compared to existing commercial devices as high deposition efficiency, uniform deposition over the whole cell area, reliable determination of the exposure dosage and possibilities to select parameters without compromising the well-being and viability of the target cells. So far the ALI device has been used to expose cells with silver and zinc oxide nanoparticles and wood smoke.

**3HR.3**

**Source Apportionment of the Redox Activity of Urban Quasi-ultrafine Particles (PM<sub>0.49</sub>) in Thessaloniki Following the Increased Biomass Burning due to the Economic Crisis in Greece.** Georgios Argyropoulos, Athanasios Besis, Dimitra Voutsas, Constantini Samara, Mohammad Sowlat, SINA HASHEMINASSAB, Constantinos Sioutas, *Aristotle University of Thessaloniki*

The goal of this study was to explore the sources driving the oxidative potential of ambient quasi-ultrafine particulate matter (PM<sub>0.49</sub>, particles with an aerodynamic diameter below 0.49 micro-meter) in the city of Thessaloniki, Greece's second largest city and one of the most polluted cities of European Union (EU). Twenty 48-hr PM<sub>0.49</sub> samples were collected in one urban traffic (UT) site and one urban background (UB) site in two separate seasons (i.e., cold and warm). The chemical composition and the oxidative potential (measured by the dithiothreitol (DTT) assay) of the collected particles were subsequently measured. Two different approaches were employed to link the measured redox activity of PM<sub>0.49</sub> with specific sources: (a) Principal Component Analysis of the chemical components of PM<sub>0.49</sub> followed by Multilinear Regression analysis of the measured redox activity on factor tracers (PCA-MLR), and (b) Robotic Chemical Mass Balance receptor modelling of the ambient PM<sub>0.49</sub> mass followed by MLR of the redox activity on the determined source contributions (RCMB-MLR). In the urban traffic (UT) and urban background (UB) sites, DTT activity was highly correlated with EC and levoglucosan, respectively. This suggests that biomass burning (represented by levoglucosan) is the main driver of the DTT redox activity in the urban background (UB) site, while DTT redox activity of the PM<sub>0.49</sub> particles is mostly driven by vehicular emissions (as represented by EC) in the urban traffic (UT) site. In addition, both per-mass and per-volume DTT redox activity of the PM<sub>0.49</sub> particles were found to be substantially higher in the urban background (UB) site in the cold season. This finding underscores the increase in PM toxicity with the shift from traditional oil burning to biomass burning for residential heating, a result of the dramatic rise in the price of fuel oil following the economic crisis in Greece.

**3HR.4**

**Single Living yEast PM<sub>2.5</sub> Toxicity Sensor (SLEPTor) System.** Kai Wei, Minghao Qiu, Rongfei Zhang, Liantong Zhou, Ting Zhang, Chunxiong Luo, MAOSHENG YAO, *Peking University*

Air pollution has become one of major environmental challenges facing mankind in this century. However, current atmospheric toxicity studies are mostly offline with low sensitivity and poor understanding of biological responses. Here, we proposed an online analysis system dubbed as SLEPTor (Single Living yEast PM<sub>2.5</sub> Toxicity Sensor) by integrating automated air sampling, microfluidics, GFP-tagged *Saccharomyces cerevisiae* yeast sensor as well as multiplexing automated fluorescence imaging system that allows us to study various protein responses of biological cells in vivo. In testing the SLEPTor, 63 yeast proteins were screened simultaneously here for their responses to both man-made ROS and also Beijing air samples. For the man-made, MRS3, MRS4, BSD2 and ZRC1 proteins were detected in increased abundances, among which the BSD2 expression, related to oxidative stress, was more pronounced, followed by MRS4 (for DNA repair) with a peak expression 20 min later. In contrast, HSP60 (oxidative stress), SSA1 (DNA repair) and MSB1 (MAPK pathway) proteins were observed to have elevated expressions visualized with time-lapsed movies when challenged with Beijing air samples 100 min later. Using the SLEPTor developed, we have observed sequential protein expressions for oxidative stress and DNA repair on the protein level in a single living cell. The same experiments were repeated twice using the SLEPTor and further confirmed by a spectra method. Among the proteins, SSA1 was shown to be sensitive to ambient air. The developed technology pioneers a new arena for investigating atmospheric health in an interactive manner with a large range of different functional proteins involved

**3HR.5**

**Toxicogenomic Profiling to Assess the Biological Effects upon Exposure to Isoprene-Derived Secondary Organic Aerosol (SOA) in Human Lung Cells.** YING-HSUAN LIN, Maiko Arashiro, Kenneth Sexton, Avram Gold, Ilona Jaspers, Rebecca Fry, Jason Surratt, *University of North Carolina at Chapel Hill*

Secondary organic aerosols (SOA) derived from isoprene photooxidation represent a substantial organic aerosol mass fraction in atmospheric fine particulate matter (PM<sub>2.5</sub>). The formation processes of isoprene SOA are largely influenced by anthropogenic emissions through multiphase chemistry. Considering the occurrence and abundance of isoprene SOA in the troposphere, it is crucial to understand the health effects induced by inhalation exposure to mitigate its potential impact on public health. In this study, we assessed the toxicogenomic effects in response to isoprene SOA exposure in human airway epithelial cells (BEAS-2B) through a direct air-liquid interface exposure. Pathway-focused gene expression profiling was performed using Qiagen Human Oxidative Stress Plus RT<sup>2</sup> Profiler PCR Array and NanoString nCounter<sup>®</sup> Human Inflammation v2 Panel, which include 84 oxidative stress and 249 inflammation human genes, respectively. Our results show that the expression levels of 31 genes were significantly altered (fold change > 1.5, p < 0.05) upon isoprene SOA exposure under non-cytotoxic conditions. Gene-set analysis for functional enrichment and induced network modules identify the nuclear factor (erythroid-derived 2)-like 2 (Nrf2) mediated signaling pathway as a predominant defense mechanism for cell survival. Various molecular functions, transcription factors, and biological pathways are also found to be enriched, including glutathione metabolism for detoxification, as well as the Toll-like receptor cascade for inflammatory signaling. Together with detailed characterization of SOA constituents, our findings highlight the importance of linking PM<sub>2.5</sub> source, composition, early biological responses and potential health outcomes.

**3HR.6**

**Aerosol Based Gold Nanoparticles Delivery to Brain: A Non-Invasive Approach to Cross Blood Brain Barrier.** RAMESH RALIYA, Debajit Saha, Tandeep Chadha, Baranidharan Raman, Pratim Biswas, *Washington University in St. Louis*

There is significant interest in the translocation of very small nanoparticles to the brain; with relevance in the field of nanotoxicology and nanomedicine. An emerging field of nanomedicine involves the use of gold nanoparticles both as a diagnostic and/or therapeutic agent. While nanoparticle drug delivery has been used for translocation to a variety of organs, the delivery to the brain has not been extensively validated due to the blood-brain barrier. Conventional approaches such as intravenous injection and intranasal exposure suffer from low efficiency and off target delivery of the particles. To address these challenges, in the present investigation 5 nm gold nanoparticles were synthesized by a novel technique. These were then aerosolized using electro-hydro atomization. Studies involving nanoparticle exposure, accumulation, and bio-interactions were done with locusts (*Schistocerca americana*), whose olfactory system is functionally and architecturally very similar to the mammalian olfactory system.

In this work, our first goal was to quantify uptake and translocation of custom-designed nanoparticles to the brain through the olfactory sensory pathway. Insect antenna, sensory appendage at the periphery of the olfactory pathway, was exposed to the gold nanoparticles by using electrospray aerosol technique. Transport and accumulation of gold nanoparticles in the olfactory pathway were studied by fluorescence microscopy, transmission electron microscopy, and quantitatively by inductively coupled plasma mass spectroscopy. As a result of aerosol exposure to locust antenna, gold nanoparticles were observed to translocate to the brain in an hour. Quantitatively, gold was detected in the range of 5 and 19  $\mu\text{g}$  from the exposed locusts' brains during the exposure period of 1 and 6 hours.

Our second goal was to identify the interactions of the translocated nanoparticles with the brain physiology. To achieve this goal, electrophysiological changes in the olfactory neurons due to nanoparticle interactions were studied by multi-electrode extracellular recording technique. We found that principle neurons in the antennal lobe (similar to the olfactory bulb in vertebrates) did not show any significant changes in their passive or active firing properties due to interactions with the gold nanoparticles that were transported to the brain through antennal exposure.

Overall, our findings suggest that by combining electrospray aerosol technique and custom-designed minimally-interactive gold nanoparticles, pharmacokinetically significant amount of nanoscale drug (or drug loaded in such nanoscale carrier) could potentially be delivered to the brain. To the best of our knowledge, this is the first holistic report for the aerosol

delivery of gold nanoparticles and study of its interactions with the brain.

### 3IM.2

#### **Measurement of Dust Dispersivity by Shadowgraphy**

**Method—Direct Image Particle Analysis (DIPA).** Seungkoo Kang, SHENG-CHIEH CHEN, Wing-Tak Lai, David Y. H. Pui, *University of Minnesota*

For measuring the size distribution of resuspended dust particles by dust dispersers, real-time sampling instruments are normally used. However, different instruments usually reported different size distributions for the same dust stream and most likely it was due to the different measurement principles of the instruments. Besides, the occurrence of particle transport loss during the sampling by the instruments can also alter the size distributions, especially, for the dust particles larger than 1.0 micro-meter. In this study, the noninvasive shadowgraph imaging technique was applied to measure the dust size distribution at the area of interest to avoid sampling errors caused by the transport loss. Besides, the 2-D images taken for the resuspended dusts were expected to directly have better and clearer morphology information than the embodied equilibrium optical or dynamic diameter by the real-time instruments. With the 8 and 29 Mpixel CCD camera equipped with a high magnification lens, monodisperse PSL particles of 1.0, 2.0, 4.0, 17.0, 26.0 micro-meter were first used to demonstrate the sizing accuracy of the measurement system. Then the validated system was applied to the size distribution measurements of polydisperse ISO 12103-1 A2 fine dusts from different dust dispersers, including ISO light duty injector and ISO heavy duty injector. This newly developed system was able to measure dusts as large as 500 micro-meter which was unlikely by the conventional optical particle counter and aerodynamic particle sizer. It was also observed the changes in size distribution of the A2 dusts generated by the ISO injectors operated at different mass feeding rates and supply pressures indicating one should consider the effect of the operation condition for determining the size distribution of dusts.

**3IM.3**

**Optimizing a Photoacoustic Soot Sensor for the Measurement of Ultra-low Soot Concentrations in Exhaust from Combustion Engines.** MICHAEL ARNDT, Wolfgang Schindler, Herbert Reingruber, Klaus Harms, Stefan Riedler, *AVL List GmbH*

Photoacoustic soot sensors are capable of measuring very low concentrations of soot by using the light absorption of the black carbon in order to generate an acoustical signal. In real engine exhaust the chemical composition of the gas can influence the precision of the measurement by changing the acoustic properties of the gas.

This effect can be reduced by proper dilution of the sample, but in many applications this might not be desirable. Conducting a zeroing with filtered exhaust eliminates most disturbances caused by cross-sensitivities and acoustical effects. However, this method adds complexity to the application and only yields perfect results when the exhaust composition stays constant.

In order to overcome these issues a novel method for real-time compensation of the mentioned distortions was developed. It makes use of the fact that changes in the sonic speed manifest as a shift in the resonance frequency of the photoacoustic resonator system. The laser light source is modulated at the characteristic resonance frequency of the cell in order to obtain best signal amplification. The modulation frequency of the laser gets adjusted in real-time in order to keep the system at the resonance maximum. This is done by analyzing the phase angle of the standing acoustical wave. If the signal intensity is not high enough to generate a clean signal, an additional acoustical wave at a different frequency is induced by an internal loudspeaker. This additional signal is analyzed in parallel to the main signal. Thereby a correction of the modulation frequency is calculated in real-time. The processed measurement signal only consists of the main frequency, any other acoustical waves are removed by synchronous demodulation.

The accuracy of the recent version of a widely used photoacoustic instrument, the AVL Micro Soot Sensor plus, could be improved significantly by applying this method.

**3IM.4**

**Study of the Truncation Issue in the Cavity Attenuation Phase Shift PMSSA Monitor using Two Novel Approaches.** FENGSHAN LIU, David Snelling, Kevin Thomson, Gregory Smallwood, *National Research Council Canada*

To monitor black carbon (BC) mass concentrations from emission sources and in the atmosphere, it is desirable to have the real-time measurement capability. The recently developed cavity attenuated phase shift particulate matter single scattering albedo (CAPS PMSSA) monitor has shown good performance for real-time aerosol optical properties and black carbon mass concentration measurements. The scattered light by particles in the sampling glass tube of CAPS PMSSA is measured by an integrating sphere. However, similar to an integrating nephelometer, the scattering component of the measurement also suffers the truncation error due to the loss of scattered light in the forward and backward directions. Such loss can be significant if the particles scatter radiation predominately in the forward directions, which is the case for fairly large BC mass-fractal aggregates. It is therefore important to develop correction algorithms to quantify the truncation error for the purpose of improving the accuracy of CAPS PMSSA.

The theories developed so far in the aerosol science community to deal with the truncation issues have been based on simple considerations of the nephelometer geometry and the scattering phase function of spherical particles from the Mie theory. Such simplified models are unable to account for non-spherical shape of aerosol particles, such as BC particles, the interactions among aerosol particles in the sampling tube, as well as to the effect of the boundary condition at the inner surface of the sampling tube. To overcome the difficulties of these simplified models and to more accurately estimate the truncation error of the CAPS PMSSA monitor, this study proposed two novel approaches: one is based on solving the radiative transfer equation (RTE) and the other is based on a ray-tracing (RT) algorithm with detailed treatment of boundary conditions at the glass tube.

Numerical calculations of the scattering loss were conducted for different particle sizes characterized by the asymmetry parameter of the scattering phase function using the geometrical dimensions of the typical Aerodyne CAPS PMSSA at 660 nm. The two approaches developed in this study predicted larger scattering loss than the simplified theoretical estimate in the literature. Results of the two approaches were compared and their advantages and disadvantages were also discussed.

**3IM.5**

**Measuring Light Absorption with Filter-based Instruments: Correction Schemes for Filter Artifacts.** APOORVA PANDEY, Yu Yang, Rajan Chakrabarty, *Washington University in St Louis*

Several filter-based instruments, such as the aethalometer, particle soot absorption photometer and UV-vis spectrophotometer, are commonly used for measuring aerosol light absorption. These techniques involve the estimation of Beer-Lambert light attenuation through a filter sample, and subsequently calculating an absorption coefficient. The conversion of attenuation coefficient to absorption coefficient is subject to several measurement artifacts. Multiple scattering of light by the filter substrate causes an increase in the optical path, leading to an increase in light absorption by aerosol deposits with respect to their absorption as free particles. Further, with increasing loading of absorbing aerosols, the proportion of the scattered light absorbed by the particles increases, effectively decreasing the optical path. In contrast, high loading of highly scattering aerosols results in an increase in the optical path. The net discrepancy between filter-based and non-contact measurements of aerosol absorption coefficients depend upon the type of filter substrate, and the amount and optical nature of aerosol deposits.

In this work, we provide correction factors for filter based absorption coefficient measurements for Black Carbon (BC) and light absorbing Organic Carbon (LAOC). A natural gas fueled Bunsen burner was used to generate BC particles and peat combustion was used to generate LAOC containing organic material. Aerosol samples were collected on Teflon and glass fiber filters. Simultaneously their real-time absorption and scattering coefficients were measured using multi-wavelength Photoacoustic Spectrometers with integrated nephelometers at 375, 405, 532, 671 and 1047 nm wavelengths. A high-resolution UV-vis spectrophotometer equipped with an integrating sphere was used to measure transmittance spectra for blank and sample filters. The calculated attenuation coefficients were compared with the corresponding real-time absorption coefficients, to extract the multiple scattering and loading correction factors. A ray-tracing inversion approach, was used to estimate a scattering factor from transmittance and reflectance measurements on the filters. The correction schemes employed wavelength-dependent attenuation and aerosol single scattering albedo as parameters.

**3IM.6**

**A New Concept for Aerosol Satellite Remote Sensing in the Twilight Zone.** HANS MOOSMULLER, Michealene Iaukealum, Jeffrey LaCombe, Eric Wang, *Desert Research Institute*

Satellite remote sensing of atmospheric aerosols is important for understanding the effects of aerosols on radiative forcing and climate change, visibility, and air quality. Most satellite instruments used for this purpose are flown on polar, sun-synchronous orbits with typical mid-day overpass times. Examples include NASA's Terra and Aqua satellites with overpass times of 10:30 in a descending node for Terra and 13:30 in an ascending node for Aqua. Aerosol characterization over the ocean takes advantage of a fairly dark background lightened by aerosol scattering. Measurements over land surfaces are much more difficult, especially for high and variable surface albedos including snow and ice and desert surfaces. These difficulties are due to the inherent brightness of the surface that makes detection of aerosol scattering challenging.

Here, we propose a satellite flying in a polar, sun-synchronous, dawn-dusk orbit enabling observation of the twilight zone where the earth surface is several orders of magnitude darker than during mid-day, because it doesn't receive any direct solar illumination. On the other hand, aerosols in the atmosphere may still be illuminated, depending on their altitude, distance from the dawn-dusk line, and surface topography. The illumination-observation geometry is fairly unique with a  $\sim 90^\circ$  scattering angle between the near horizontal solar illumination and the nadir-looking observation. This will result in unique polarization observations as p-polarized light will not be observed for spherical scatterers and will indicate depolarization by non-spherical scatterers.

We propose to utilize this concept for the sensitive satellite characterization of atmospheric aerosols with a multi-spectral camera imaging the twilight zone. Initial development will include stratospheric balloon-borne imaging during sunset and sunrise in conjunction with vertical in-situ aerosol characterization during ascent and co-located AERONET observations, analysis of data from geostationary satellite imagers, and working toward development of a dawn-dusk orbiting CubeSat.

**3IM.11**

**In-Situ Characterization of Aerosol Nanoparticles at Close-to-Ambient Concentrations by Small Angle X-Ray Scattering (SAXS).** PAULUS S. BAUER, Heinz Amenitsch, Paul M. Winkler, *Universitaet Wien, Vienna, Austria*

In-situ characterization of aerosol nanoparticles is a challenging task in aerosol science. Common aerosol analyzers such as differential mobility analyzers usually extract the particles from their original environment for analysis. Thereby, nanoparticles can get modified or get lost e.g. by wall collisions inside the instrument, which can affect the measured size distribution and concentration. Thus, there is an essential demand for an in-situ measurement technique. Small-angle X-ray scattering (SAXS), commonly used in material science or in biochemical process analysis, can fill this gap. It is capable of measuring in-situ particle size distribution in the nanometer range if the scattering contrast between nanoparticles and gas molecules is sufficiently large. SAXS has already been applied in nucleation studies with extremely high nanoparticle concentrations of  $\sim 10^{12}$  /cc and carrier gas pressures  $\sim 2$  kPa. (Laksmono et al. (2011), *Phys. Chem. Chem. Phys.*, 13, 5855)

Here we report first experiments on nanoparticle characterization by SAXS at concentrations of about  $10^6$  /cc. To provide a representative environment for aerosols a flow tube was operated at ambient pressure. The experiments were conducted at the Elettra synchrotron near Trieste, Italy, due to the available high beam intensity and the experience on aerosol studies in flow tubes (Jungnikl et al. (2011), *Aerosol Sci. Technol.*, 45, 805). We analyzed high molecular weight tungsten oxide particles having a high scattering contrast compared to the air background. For direct comparison of the SAXS data to conventional aerosol measurements a Differential Mobility Particle Sizer (DMPS) and a Condensation Particle Counter (CPC) were run in parallel. Results show that SAXS can be used to obtain in-situ size information of nanoparticles at close-to-ambient concentrations.

**3NM.1**

**Observation of Incipient Particle Formation during Flame Synthesis by Tandem Differential Mobility Analysis-Mass Spectrometry (DMA-MS).** YANG WANG, Juha Kangasluoma, Michel Attoui, Jiayi Fang, Heikki Junninen, Markku Kulmala, Tuukka Petäjä, Pratim Biswas, *Washington University in St Louis*

Flame synthesis of nanoparticles is widely used to produce a range of nanomaterials. Unfortunately, the incipient cluster formation by nucleation and vapor condensation is not well understood (Wang et al, 2014). This gap in our knowledge of incipient particle formation is caused by limitations in instruments, where, during measurements, the high diffusivity of sub 3 nm particles significantly affects resolution and transport loss. This work used a high resolution differential mobility analyzer (DMA) and an atmospheric pressure interface-mass spectrometer (APi-TOF) to observe incipient cluster formation during flame synthesis. By tandemly applying these two instruments, differential mobility analysis-mass spectrometry (DMA-MS) measured the size and mass of the incipient particles simultaneously, and the effective density of the sub 3 nm particles was estimated. The sub 3 nm clusters generated during the synthesis of  $\text{SiO}_2$  and  $\text{TiO}_2$  have effective densities of  $1.42 \text{ g/cm}^3$  and  $1.75 \text{ g/cm}^3$ , respectively, meaning that they were less dense than the  $\text{SiO}_2$  and  $\text{TiO}_2$  bulk crystals, possibly because these particles were in an amorphous state. The APi-TOF further provided the chemical compositions of the detected clusters based on highly accurate masses and isotope distributions. Measurements in a blank flame detected a large number of sub 3 nm particles generated from chemical ionization reactions, and determined that nitrate ions dominated in the negative ions. The blank flame-generated ions played an important role during particle synthesis, since the APi-TOF observed the appearance of nitrate ions in clusters containing silicon or titanium (such as  $\text{Si}_2\text{H}_6\text{NO}_{10}^-$  and  $\text{TiN}_2\text{O}_{10}^-$ ). As precursor feed rate increased, particles with larger mass and sizes were formed due to coagulation and vapor condensation. The unchanged particle effective density implied that the particle formation pathway in flames was not a function of precursor feed rates.

Wang, Y. et al., (2014). *J. Aerosol Sci.*, 71, 52-64.

**3NM.2**

**Characterization of Particle Release from Nanotechnology-enabled Clothing Products.** LEONARDO CALDERÓN, Letao Yang, Jin Young Shin, Kibum Lee, Gediminas Mainelis, Rutgers, The State University of New Jersey

The textile industry has been using nanotechnology over 30 years, including the addition of manufactured nanoparticles into clothing items. While studies have shown that nanomaterials have potentially negative effects on human health, new nanotechnology-enabled products continue to enter the market without fully understanding the particle properties to which consumers may be exposed during product use.

This research evaluated potential consumer exposure to nanoparticles via inhalation. Particle release was measured during simulated clothing wear. Metal concentrations, morphology of emitted particles as well as effects of washing on particle release have also been examined.

Eighteen nanotechnology clothing items, including those with incorporated silver nanoparticles, were selected due to their hydrophobicity and antibacterial characteristics. A test system was built to create friction between the rotating clothing samples and felt abrader wheels. Scanning Mobility Particle Sizer (SMPS) and Aerodynamic Particle Sizer (APS) determined size distribution and concentration of the particles emitted, new and washed. Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) examined the shape and agglomeration of particles, either captured from airborne state using an electrostatic precipitator or shredded into a liquid medium. Inductively coupled plasma mass spectrometry (ICP-MS) was performed to detect metals.

We observed that all products released nanoparticles due to friction and abrasion. Over a 50 minute period, a new product NSF18 emitted  $7 \times 10^7$  particles ranging in electrical mobility diameter from 4.45 to 168.5 nm, and its Ag content was  $5 \times 10^6$  micro-gram/kg. After washing, its particle emissions were to  $8 \times 10^7$  over 50 min and Ag content was  $4 \times 10^6$  micro-gram/kg. A brand new product NSF12 emitted  $2 \times 10^5$  particles over 50 min ranging in electrical mobility diameter from 523 nm to 19.80 micro-meter and its Ag content was  $4 \times 10^7$  micro-gram/kg. After washing, its particle emissions were to  $9 \times 10^4$  over 50 min and Ag content was  $1 \times 10^9$  micro-gram/kg. Generally, washing decreased particle emissions.

**3NM.3**

**Multi-directional 3D Assembly with Charged Nano-aerosol.** YONGJUN BAE, Hyesung Cho, Mansoo Choi, Seoul National University

Even though a host of nanotechnologies has been developed, the approach to assemble the nanoparticles into the proper structure networks remains largely elusive. In this research, we present a method to fabricate the multi-furcated nanoparticle assemblies via aerosol technology. We successfully demonstrate the position control of charged particles (in terms of the growth direction) as a function of the electric field influenced by the hole pattern arrangement on the silicon substrate. Based on the effects of the alignment angles and distances between patterns, we designed diverse types of hole arrangement for guiding charged nanoparticles to the three dimensional and multi-directional assembly. Electrostatic calculations show the electrical trap limiting the movement of charged particles around the hole and inducing the multi-directional structure by electric field superposition. In accordance with the growth time, interconnections between neighboring structures were precisely controlled and electrical characteristics were measured to check the growth state and the formation of the electric network. As an application, multi-furcated bridge structures connecting the separated electrodes were prepared by copper nanoparticle assembly and applied to the metal oxide semiconductor gas sensor showing the enhanced sensitivity ( $S = 1.6$  at CO 100 ppm) compared to nanoparticle film shaped gas sensor ( $S = 0.5$  at CO 100 ppm).

**3NM.4****Apparel Selection for the International Space Station Based on the Emission of Airborne Particles and Lint.**

LEONARDO CALDERÓN, Marit Meyer, Gediminas Mainelis, Rutgers, The State University of New Jersey

The NASA Life Support Systems Project meticulously selects resources, materials, and equipment to create a safe and healthy environment for the astronauts on the International Space Station (ISS). The ISS air revitalization system removes carbon dioxide and airborne particles. Historical data shows that lint created due to friction of onboard materials, including astronauts' clothing, is one of the largest sources of airborne debris. Filter cleaning is labor and time intensive, thus minimizing lint production from clothing would be beneficial.

The objective of this work was to characterize several types of apparel in terms of produced particles and lint and recommend suitable candidates for the use onboard of ISS. We also investigated whether the new or washed fabrics were different in their "production" of lint.

Fabrics from six manufacturers were examined, including the fabrics currently used on the ISS. A zero particle background test chamber was built, where fabric wear was simulated using a rotational abrader with felt wheels. Scanning Mobility Particle Sizer and Aerodynamic Particle Sizer determined size distribution and concentration of the particles emitted for different abrasion times, new and washed clothing. Lint left on the abraders and chamber walls was collected and weighed.

All tested products produced particles and lint. Among those, F1A fabric showed a peak particle concentration of 1000 #/cm<sup>3</sup> at the lowest measured size of 14.1 nm. F1B fabric showed a peak value of 100 #/cm<sup>3</sup> in the 20 nm bin and decreasing concentrations of larger particles. Typically, for all products, concentrations of particles >523 nm were lower than 10 particles/cm<sup>3</sup>. The recovered lint mass did not vary significantly between the products; however material composition and frequency of wash impacted the magnitude of lint and particle release. This work was part of the Intravehicular Activity Clothing Study sponsored by NASA's Advanced Exploration Systems Program.

**3NM.5****Development of an Analytical Methodology for Measurement of Aerosol Debris Generated from Sanding of CNT Composite Materials.** TRACI LERSCH, Kristin Bunker, Gary Casuccio, Jonathan Kang, Lorenzo Cena, RJ Lee Group, Inc.

Carbon nanotubes (CNTs) are being used in a wide range of commercial products due to their inherent properties. Bulk CNTs are incorporated in commercial products ranging from rechargeable batteries, home care products, automotive parts, and epoxy resins used in sporting goods to spacecraft. Evaluating the life cycle of products containing CNTs and potential release of CNTs from a product to the environment is of interest to the scientific community. To this end, researchers at NIOSH have been evaluating the potential for release of 'free' CNTs and debris containing exposed CNT protrusions in composite materials. In this study, composite materials containing 0.15-3% CNT by weight were sanded with fine and coarse sandpaper in a chamber while aerosol samples were collected using filter-based methods and a thermophoretic sampler. Bulk samples of the debris were also collected from within the chamber. Sample analysis was complicated because traditional electron microscopy preparation techniques involving dissolution of the filter resulted in liberation of the CNTs contained in the composite debris. Therefore, an analytical methodology was developed involving the analysis of the thermophoretic samples focusing on the release of ultra-fine free CNTs and the analysis of the debris collected on the as-received filters. The specific methodology consisted of using a combination of computer controlled scanning electron microscopy (CCSEM) followed by manual evaluation in a high resolution SEM/STEM. During off-line review, the CCSEM images were examined for CNT protrusions. The sample was then placed in a high resolution SEM/STEM and particles of interest were relocated and scrutinized to distinguish CNT protrusions from plastic protrusions. Preliminary results show that free CNTs were not detected and that approximately 20% of the composite particles contained exposed CNT protrusions, with an average number of CNT protrusions of 3-5 per composite particle. The length and width of the CNTs were also documented.

**3NM.6**

**Nanoparticle Detection in Environmentally Relevant Matrices Using DMA-ICP-MS.** CHRISTINE LOZA, Charlie Chan, Mark Ellefson, Sue Wolf, Brian Mader, *3M Company*

Engineered nanoparticles frequently are used as additives to consumer products to enhance product properties. Understanding the environmental fate and impact of engineered nanoparticles relies on the ability to characterize them at relatively low levels in complex media, which often contains additional naturally occurring nanoparticles. We present the application of a recently developed hyphenated technique combining electrospray aerosol generation, particle size selection using differential mobility analysis (DMA), and elemental analysis using inductively coupled plasma mass spectrometry (ICP-MS) to characterize gold and silver nanoparticles in environmentally relevant water samples including ground water, industrial wastewater, and ecotoxicology test media. The method is capable of detecting nanoparticles of 20-100 nm diameter at part-per-billion (ppb) levels in environmentally relevant aqueous solutions. Following instrument characterization, the DMA-ICP-MS was used to assess the fate of gold nanoparticles in a solution containing *daphnia magna*. Insights into dose verifications obtained by DMA-ICP-MS will be discussed as well as the method's performance and the advantages of the hyphenated DMA-ICP-MS over single-particle ICP-MS.

**3UA.1**

**Chemical Compositions of Atmospheric Submicron Aerosol during New Particle Formation and Growth Events in Beijing.** XIAOXIAO LI, Runlong Cai, Dongsen Yang, Yueyun Fu, Jiming Hao, Jun Zheng, Jingkun Jiang, *Tsinghua University*

Rapid growth of newly formed particles increases atmospheric CCN concentration and fine particulate matter burden. Characterizing submicron aerosol helps to reveal whether new particle formation events (NPF) also leads to significant change in their chemical compositions. We carried out a field campaign in Beijing during the spring of 2016. An aerosol chemical speciation monitor (ACSM) and an aethalometer with a PM<sub>1</sub> impactor at its inlet were used to characterize non-refractory submicron aerosol and submicron black carbon. A DEG SMPS and a PSD were used to measure aerosol size distribution from 1 nanometer to 10 micrometers. A chemical ionization high-resolution time-of-flight mass spectrometer equipped with a corona ionization source was used to measure sulfuric acid and its dimer. A proton-transfer-reaction mass spectrometer was used to monitor organic species. During one month's measurement, 11 new particle formation events were observed. Monthly average mass concentration of submicron aerosol was 38 micrograms per cubic meter. Growth rate of each NPF event was estimated. Submicron aerosol chemical compositions and their variations during NPF events were examined. Possible correlations with the growth of newly formed particles were discussed.

## 3UA.2

**The “Parade Blue”: Effects of Short-term Emission Control on Aerosol Chemistry.** HAIYAN LI, Qiang Zhang, Fengkui Duan, Bo Zheng, Kebin He, *Tsinghua University*

The strict control on emissions implemented in Beijing, China, during the 2015 China Victory Day Parade (V-day Parade) to commemorate the 70<sup>th</sup> Anniversary of Victory in World War II, provided a good opportunity to investigate the relationship between emission sources and aerosol chemistry in a heavily polluted megacity. From August 11 to September 3, 2015, an Aerosol Chemical Speciation Monitor was deployed in urban Beijing, together with other collocated instruments, for the real-time measurement of submicron aerosol. The average PM<sub>1</sub> mass concentration was 11.3 ( $\pm$  6.7) microgram per cubic meter during the parade, 63.5% lower than that before the parade. Different from the relatively smaller decrease of organics (53%), secondary inorganic aerosols (sulfate, nitrate and ammonium) showed significant reductions of 65%–78% during the parade. According to the positive matrix factorization results, primary organic aerosol (POA) from traffic and cooking emissions decreased by 41.5% during the parade, whereas secondary organic aerosol (SOA) presented a much greater reduction (59%). The net effectiveness of emission control was investigated further under comparable weather conditions before and during the parade. By excluding the effects of meteorological parameters, the total PM<sub>1</sub> mass was reduced by 52%–57% because of the emission controls. Although the mass concentrations of aerosol species were reduced substantially, the PM<sub>1</sub> bulk composition was similar before and during the control period as a consequence of synergetic control of various precursors. The emission restrictions also suppressed the secondary formation processes of sulfate and nitrate, indicated by their substantially reduced oxidation ratios during the event. The study also explored the influence of emission controls on the evolution of organic aerosol using the mass ratios of SOA/POA and oxygen-to-carbon ratios. The results showed that for northwesterly airflows, emission restrictions during the V-day Parade also reduced the oxidation degree of organic aerosol.

## 3UA.3

**Vertical Profiles of Air Pollutants in Urban Boundary Layer: Results from the Measurements on Beijing 325m Meteorological Tower in Severe Haze Episodes.** QINGQING WANG, Weiqi Xu, Wei Du, Chen Chen, Tingting Han, Dongsheng Ji, Zifa Wang, Yele Sun, *Inst. of Atmospheric Physics, Chinese Academy of Sciences*

The formation of severe haze episodes interacts closely with urban boundary layer (UBL), however, it is a great challenge for air quality models to precisely predict these events on the basis of known parameterization. One reason is the lack of understanding of the vertical evolution mechanisms of air pollutants within UBL. Thus, studying vertical distributions of air pollutants is essential to help elucidate the mechanisms of haze formation in megacity in China, and realize precise forecast of serious haze incidents. Here, vertical profiles of air pollution were measured with a container equipped on Beijing 325 m meteorological tower between ground level and 260m using Cavity Attenuated Phase Shift Particulate Matter extinction monitor (CAPS-PMext), CAPS-NO<sub>2</sub> monitor, and Aethalometer. Submicron aerosol chemical species were synchronously measured in real-time at ground level and 260m with Aerodyne Aerosol Mass Spectrometer and Aerosol Chemical Speciation Monitor, respectively. Meteorological variables and lidar measurements were also obtained to help explain vertical evolution mechanisms of air pollutants. Vertical profiles of air pollutants were classified into four categories: (1) Well mixed. It usually happened when mixed-layer height or stable UBL height was higher than the pod slipping height, and no temperature inversion appeared; (2) Higher at the ground level. It usually happened when the local ground emission accumulated fast. Such pollutants vertical profile usually appeared in Beijing due to its strong emission capacity; (3) Higher at the 260m. It usually caused by the enhanced pollutants transport at the high altitude; (4) Significant transition at a certain height. It usually occurred when the UBL height was below the observation height of the slipping pod.

## 3UA.4

**Characterization of Particle Number Size Distributions at Ground Level and 260 m on a Meteorological Tower in Beijing.** Wei Du, Jian Zhao, Yingjie Zhang, YELE SUN, *Inst. of Atmospheric Physics, Chinese Academy of Sciences*

Despite extensive studies in characterization of the particle number size distributions at ground level in Beijing, real-time characterization above the urban canopy has never been performed to date. Here we conducted the first simultaneous real-time measurements of size-resolved particle number concentrations at two heights, i.e., ground and 260 m, at the same location in urban Beijing from August 22, 2015 to October 1, 2015 using two Scanning Mobility Particle Sizers (SMPS). Our results showed that the temporal variations of volume concentrations were similar between ground level and 260 m, while the number size distributions were significantly different. The number concentrations of accumulation mode particles (100 – 400 nm) at 260 m were higher than those at ground level ( $r^2 = 0.85$ , slope = 1.17), those outside this size range were lower at higher heights. Detailed analysis suggests that the number differences at the two heights strongly depended on particle size. For example, higher number concentrations at smaller sizes were observed at ground level due to cooking emissions. New particle growth events (NPE) were occasionally observed throughout the study. The average growth rate (GR) was  $3.6 \text{ nm h}^{-1}$  at 260 m and  $3.2 \text{ nm h}^{-1}$  at ground level, respectively. Positive matrix factorization was also performed on size-resolved number concentrations and the sources of particle numbers at two different heights were compared and discussed.

## 3UA.6

**Spatial Variation of PM<sub>2.5</sub> Chemical Composition in Roadside, Urban, and Suburban Environments in Hong Kong: Quantifying Source Contribution of Urban Traffic.** JIAN ZHEN YU, X. H. Hilda Huang, *Hong Kong University of Science & Technology*

Hong Kong is one of the most densely populated metropolitan cities in the world, with over 7 million people living on a land area of 1104 km<sup>2</sup>. A monitoring network of PM<sub>2.5</sub> chemical composition consisting of one roadside, four urban sites and one regional background site has been in operation since 2011, collecting filters on a schedule of one 24 h-sample every six days. Data from this monitoring network provides opportunities to investigate relative impact of local (esp. urban traffic) vs. region sources and certain secondary processes in urban local scale.

A clear PM<sub>2.5</sub> spatial gradient was noted from regional background to urban and to roadside environments, with a mass increment in annual average PM<sub>2.5</sub> of 3.0 and 10.8  $\mu\text{g m}^{-3}$ , respectively, in comparison with the regional background site (2014 annual average at 23.1  $\mu\text{g m}^{-3}$ ). The chemical speciation data reveal organic matter (OM) and elemental carbon (EC) as the main contributors (70-85%), nitrate and ammonium making minor contributions (12-23%) to the mass increments. The concentration contrasts between urban and regional background sites were 6.15 vs 7.88  $\mu\text{g m}^{-3}$  for OM, 1.29 vs 2.39 for EC, 0.52 vs 1.14 for nitrate, and 2.85 vs 3.17 for ammonium in 2014. The mass increments of all the four species could be rationalized to derive from either direct emission or secondary products of vehicular exhaust (e.g., nitrate from NO<sub>x</sub> oxidation). This analysis allows us to estimate that the urban traffic accounted for ~10% of PM<sub>2.5</sub> at urban sites and ~30% at the roadside site. On the other hand, sulfate concentrations are comparable among different sites, producing a small variation range (8.45-8.66  $\mu\text{g m}^{-3}$ ) in the site annual average concentration. Additional species that show spatially uniform concentrations include K<sup>+</sup> and Pb. The lack of spatial variability suggests that they are derived from regional sources and thereby well mixed when reaching Hong Kong.

**4AC.1****Rethinking the Concept of pH in Atmospheric Particles.**

MICHAEL BATTAGLIA JR., Christopher Hennigan,  
*University of Maryland, Baltimore County*

The purpose of this study was to compare the acidic conditions inferred from bulk particle distributions with the acidic conditions within individual particles. Specifically, we characterized on an individual particle level the combination of particle size and environmental conditions (T, RH) where a bulk definition of pH may be applied. We find a range of limiting conditions – both particle size and RH – where the scale of individual particles is too small to apply the bulk definition of pH. Such limitations do not exist when aerosol distributions are aggregated, as is typically the approach in using bulk aerosol measurements as inputs into thermodynamic equilibrium models. Using measured values of aerosol water content and thermodynamic equilibrium models, the  $H^+$  and  $OH^-$  per particle were calculated for monodisperse aerosol size distributions. As a function of particle diameter, for all particles 0-2.5 microns in diameter, pH values from 0-3 were prohibited on the basis of requiring fractional ( $<1$ )  $OH^-$  ions per particle. The smallest critical diameter calculated is 0.20 micron, required for pH 7 at 90% RH; no particles smaller than this diameter would meet the bulk definition of pH. As a function of RH, the smallest critical RH value calculated is 62.4%, required for pH 7 and a 250 nm particle diameter. Individual particles at RH levels below this critical value do not contain enough water to apply the bulk definition of pH. These results suggest that the bulk aggregation of particles during sampling leads to a dominating effect of large particles. In the future it may be necessary to develop and utilize a different particle acidity measurement scale, rather than aerosol pH, to characterize the critical factor driving atmospheric processes that are known to be affected by acidity.

**4AC.2**

**In Situ Observations of Organic Molecules at the Gas-Aerosol Interface.** V. FAYE MCNEILL, Yajing Wu, Wanyi Li, Bolei Xu, Xia Li, Hannah Wang, Hai-Lung Dai, Yi Rao,  
*Columbia University*

Organic molecules at the gas-particle interface of atmospheric aerosols can determine the heterogeneous chemistry and climate properties of the aerosol. However, probing the chemistry of the particle surface in situ has proven challenging, given a lack of suitable surface-sensitive analytical techniques. We employed a surface-sensitive technique, Second Harmonic Scattering (SHS), to successfully observe organic molecules at the gas-particle interface of laboratory-generated aerosols. As an example, we directly detected trans-4-[4-(dibutylamino)styryl]-1-methylpyridinium iodide (DiA4) at the gas-particle interface of laboratory generated submicron aerosols with the SHS technique, and employed it as a probe molecule to investigate the presence of other organic species at the gas-aerosol interface.

**4AC.3**

**Formation of Reactive Oxygen Species by Secondary Organic Aerosols in Water.** MANABU SHIRAIWA, Haijie Tong, Andrea Arangio, Thomas Berkemeier, William Brune, Pascale Lakey, Ulrich Poeschl, Joanna Socorro, *MPIC*

Reactive oxygen species (ROS) exist widely in the atmospheric environment. They play multifunctional roles in atmospheric chemistry, influencing formation and chemical aging of organic aerosols and adverse health effects of particulate matter in air pollution. However, little is known on abundance of ROS within atmospheric aerosol particles.

We detect and quantify ROS and related free radicals in ambient particles and laboratory-generated secondary organic aerosols (SOA). Ambient particles have been sampled with a 24 h time resolution using a rotatory multi-stage cascade impactor in Mainz, Germany. SOA were formed by oxidation of monoterpenes, isoprene, and naphthalene in a 2 m long quartz flow tube reactor and the Potential Aerosol Mass (PAM) chamber. The collected particles were analyzed using a continuous wave Electron Paramagnetic Resonance (CW-EPR) spectrometer. We found that ambient particles with diameter of 100 - 300 nm contain substantial amount of organic radicals with concentrations on the order of  $1e10 - 1e12$  spin/ $\mu\text{g}$  of particles. We show that ambient and laboratory-generated SOA form substantial amounts of ROS including  $\text{H}_2\text{O}_2$ , OH, superoxide, and other organic radicals upon interaction with liquid water. Formation of OH radicals can be explained by the decomposition of organic hydroperoxides. The molar OH yield from SOA is enhanced in the presence of  $\text{Fe}^{2+}$  ions due to Fenton-like reactions. Our findings imply that the chemical reactivity and aging of SOA particles is strongly enhanced upon interaction with water and iron. In cloud droplets under dark conditions, SOA decomposition can compete with the classical  $\text{H}_2\text{O}_2$  Fenton reaction as the source of OH radicals. Also in the human respiratory tract, the inhalation and deposition of SOA particles may lead to a substantial release of ROS, which may contribute to oxidative stress and play an important role in the adverse health effects of atmospheric aerosols.

**4AC.4**

**The Role of Aerosol Water in Secondary Organic Aerosol Formation from Volatile Organic Compounds.** JENNIFER FAUST, Jenny Wong, Alex K. Y. Lee, Jonathan Abbatt, *University of Toronto, Canada*

Aerosol droplets present a unique aqueous reaction medium in the atmosphere because of their small volume and high concentrations of both inorganic and organic solutes. Secondary organic aerosol (SOA) can form when volatile organic compounds (VOCs) are oxidized to yield semivolatile species, which then condense onto atmospheric seed particles and partition into the aqueous phase according to physical solubility. Most commonly, dissolution is driven by processes like hydration; other reactions within the condensed phase also enhance overall uptake.

Here we report SOA yields from the oxidation of isoprene, toluene, and alpha-pinene on deliquesced and effloresced ammonium sulfate seeds within a room-temperature oxidation flow tube held at 70% relative humidity. In the case of isoprene photooxidation by OH, we find a strong 60% enhancement in SOA formation on deliquesced relative to effloresced seeds. Particle acidity does not affect SOA yield from isoprene but does generate more highly oxidized products with greater molecular weights, likely due to acid-catalyzed reactions and oligomerization. Both toluene photooxidation by OH and alpha-pinene oxidation by ozone exhibit weak enhancements in SOA yield on wet relative to dry ammonium sulfate seeds. Preliminary results further suggest that SOA formation from alpha-pinene ozonolysis is initially driven by condensation of extremely low volatility organic compounds (ELVOCs), in contrast to the isoprene and toluene systems, which are dominated by semivolatile species. Overall, we conclude that particle-phase water mediates SOA formation in the atmosphere, but the extent of its influence varies widely among VOC precursors.

**4AC.5****Measuring pH of Atmospheric Aerosol Particle Microenvironments Using a Raman Microspectroscopic Method.**

REBECCA CRAIG, Andrew Ault, *University of Michigan*

Assessing the pH of atmospheric aerosol particles is of great interest, due to the impact of acidic particles on the environment and human health. Many atmospheric particle phase chemical processes are dependent on acidity, such as secondary organic aerosol formation and gas-particle partitioning. As aerosol chemical composition determines hygroscopicity and contributes to cloud condensation nuclei activity, the pH of a particle can impact composition, cloud droplet nucleation and, ultimately, climate forcing. Traditional methods of estimating aerosol pH through indirect measurement or assumptions often disagree with thermodynamic model predictions of particle acidity. Raman microspectroscopy was recently used to develop a method to determine the acidity of individual particles generated from H<sub>2</sub>SO<sub>4</sub>/MgSO<sub>4</sub> standard solutions. The method utilized sulfate and bisulfate concentrations determined from  $\nu(\text{SO}_4^-)$  and  $\nu(\text{HSO}_4^-)$ , the acid dissociation constant, and activity coefficients from extended Debye-Hückel calculations to determine [H<sup>+</sup>] and pH. This spectroscopic method will be expanded and applied to study more complex systems and various aerosol particle microenvironments in order to improve fundamental understanding of pH and ion behavior in high ionic strength atmospheric particles.

**4AC.6**

**Fine Particle pH.** RODNEY J. WEBER, Hongyu Guo, Aikaterini Bougiatioti, Nikolaos Mihalopoulos, Athanasios Nenes, *Georgia Institute of Technology*

pH is a critical aerosol property that impacts many atmospheric processes, including isoprene secondary organic aerosol formation, mineral dust and redox metal mobilization and has been linked to direct adverse health effects. pH also affects acidic gas-particle phase partitioning, with nitric acid-nitrate a common example. Based on data from field studies in widely differing locations, through thermodynamic modeling we assess particle pH and nitrate partitioning in the southeastern US summer, northeastern US winter, western US summer and eastern Mediterranean. Thermodynamics predicts nitrate formation when pH ranges between 2 and 3 for moderate ambient temperatures. At all sites fine particle pH ranged between approximately 0 and 3 and various levels of nitrate were observed. In the southeast summer, pH has remained consistently below 2 despite a 70 percent decrease in sulfate in the past 15 years. Thus, little nitrate is expected and confirmed by historical data, counter to widespread views based on sulfate trends that particles will be neutralized and nitrate displace sulfate to become a significant component of PM<sub>2.5</sub>. Lower temperatures shift nitric acid partition to slightly lower pHs and account for the substantial nitrate levels often observed in winter in the northeast, despite similar sulfate and pH levels as those of the southeastern summer. In California pH tends to be more often in the 2 to 3 range, resulting in frequent high levels of nitrate aerosol, whereas in the eastern Mediterranean pH at the higher end of the range is seen in biomass burning plumes, leading to nitrate, in part due to the presence of potassium. In all cases, the aerosol is never near neutral, as often assumed or inferred from ion balances or molar ratios. A better understanding of the implications of a consistent highly acidic aerosol on geochemical cycles, aerosol-health linkages and aerosol atmospheric processing is needed.

**4AC.7****Formation of Organic Nitrogen in Aqueous Nanodroplets.**CHRIS STANGL, Murray Johnston, *University of Delaware*

Recent ambient measurements of nanoparticle composition during summertime new particle formation (NPF) events in the eastern United States have found that a significant amount of nitrogen-containing compounds exist in the particle phase that are unassociated with sulfate neutralization, nitrate partitioning or organonitrate formation. A potential source of these compounds is thought to be nitrogen-containing organic species such as imines, which can be formed by aqueous processing of carbonyl-containing compounds in the presence of ammonia. In the work to be presented, aqueous processing of water-soluble carbonyls relevant to the location of study was simulated in the laboratory by partially drying internally-mixed nanodroplets containing ammonium sulfate and various carbonyls (glyoxal, methylglyoxal, glycolaldehyde). Off-line molecular composition analysis with high resolution mass spectrometry showed the presence of many imine-derived organo-nitrogen species in the particle phase. On-line elemental composition measurements with the nano aerosol mass spectrometer (NAMS) confirmed the presence of organic nitrogen. N:C ratios attributed to the organic fraction of the particles showed agreement between both techniques, and alluded that such systems may have the potential to explain organic nitrogen observed in ambient nanoparticles. Our results suggest that aqueous chemistry may significantly impact nanoparticle composition and growth during NPF in locations where emissions of water-soluble organic gases are high, such as the eastern United States.

**4AP.1****Common Model Assumptions Increase Uncertainties in Describing Atmospheric New Particle Formation.** TINJA OLENIUS, Jan Julin, Ilona Riipinen, *Stockholm University*

In climate and air quality models, new particle formation (NPF) from condensable vapors is incorporated by feeding in the particle formation rate at a size around a few nanometers. Traditionally, the formation rate has been obtained from parameterizations based on the classical nucleation theory or observations, both of which involve semi-empirical corrections or scaling factors in order to produce formation rates of a realistic order of magnitude. To improve the understanding of NPF and its effects on climate, modeling studies have now started to replace the scaled approaches by results from quantum mechanics -based molecular modeling or well-controlled chamber experiments that have recently become available.

However, even when using state-of-the-art particle formation rates, incorporating the rates in a climate model involves making certain assumptions or approximations. These assumptions arise from the interface between the molecular-level scheme that describes the initial formation process, i.e. the formation rate, and the aerosol dynamics model that simulates the particle growth to larger sizes. We investigate the uncertainties related to the model interface with a detailed sub-10 nm particle dynamics model that allows simultaneous dynamical modeling of both the initial formation process and the early growth steps. Preliminary results suggest that incorporating the formation rates as is done in conventional aerosol dynamics models may result in uncertainties of factors of at least ca. 2-10 in the concentrations of nanometer-sized particles. These uncertainties may be significant in the interpretation of modeling data and predictions of secondary aerosol concentrations.

## 4AP.2

**Quantitative Particle Sizing in the Cluster-particle Transition Region during new Particle Formation.**

DOMINIK STOLZENBURG, Katrianne Lehtipalo, Robert Wagner, Paul M. Winkler, *University of Vienna*

New particle formation and subsequent nanoparticle growth is frequently observed in the atmosphere (Kulmala et al. (2004), *J. Aerosol Sci.* 35, 143-176). The dynamics of the aerosol population determines the impact of new particle formation on the global budget of cloud condensation nuclei (Weber et al. (1997), *J. Geophys. Res.* 102, 4375). However, high particle losses and low detection efficiencies have limited the precision of size-distribution measurements in the critical sub-10nm range.

Here we present the first results from a newly developed Differential Mobility Analyser – train (DMA-train) operating six DMAs together with six ultrafine nanoparticle detectors in parallel. The DMA-train was used to track new particle formation events in the CLOUD chamber at CERN (Duplissy et al. (2016), *J. Geophys. Res. Atmos.*, 121, and references therein) during a 12-week intensive campaign in fall 2015. While a particle size magnifier operated in scanning-mode (Airmodus A11) was used to measure the very initial growth, and a fast-scanning nanoSMPS (TSI 3938) monitored the size-distributions from about 5 nm onwards, a gap was left in the crucial 2-5nm size range, where clusters become aerosol particles. Intercomparison of the three instruments shows, that the DMA-train perfectly fills the gap, due to its excellent counting statistics achieved by measuring fixed particle sizes in distinct channels.

With this unprecedented array of instruments, the quantification of both neutral and charged particle growth from 1 to 60 nm in the presence of highly oxidised biogenic vapours, sulphuric acid and ammonia becomes possible. We will present the most detailed and precise particle growth rate measurements so far obtained in CLOUD. We are now at a stage where we can perform quantitative growth law-analysis (Rao and McMurry (1989), *Aerosol Sci. Tech.* 11:2, 120-132) and compare nanoparticle evolution to model simulations over the full size range.

## 4AP.3

**Enhanced Growth Rates of Nanodroplets in the Free Molecular Regime.**

YENSIL PARK, Shinobu Tanimura,

Barbara Wyslouzil, *The Ohio State University*

When Pathak et al. [*Aerosol Sci. Technol.*, 2013, 47:1310-1324] studied the growth rates of nonane and D<sub>2</sub>O nanodroplets in the free molecular regime ( $Kn > 10$ ) using a supersonic nozzle, they found that neither the droplet temperature nor the growth rates matched the experimental values if they assumed the condensation coefficient ( $q_c$ ) and evaporation coefficient ( $q_e$ ) in the Hertz-Knudsen growth law were both equal to 1. Rather, to match the experiments they had to set  $q_e < 1$  with  $q_c = 1$ . To confirm that this result was not due to uncertainties associated with the properties of supercooled water, we analyzed similar experiments for n-propanol under conditions where the alcohol is not supercooled with respect to the solid phase [Park et al., *Aerosol Sci. Technol.*, 2016, accepted]. We again found that when  $q_c = q_e = 1$ , mass and energy balances yield theoretical temperatures and droplet growth rates that lie below the experimentally determined values. Much better agreement between theory and experiment is possible by setting  $(q_c, q_e) = (1, 0.6)$  or  $(q_c, q_e) = (1.3, 1)$ . Retardation of evaporation is difficult to justify during rapid condensation, whereas a value of  $q_c > 1$  is consistent with the enhancement of the condensation rate by long-range attractive interactions. Since long range van der Waals interactions are known to enhance the coagulation of nanoparticles, it is reasonable to expect that they can also play a role in condensation.

**4AP.4****Scaling Laws for Packing Density of Fractal Aggregates.**

PAI LIU, William Heinson, Rajan Chakrabarty, *Washington University in St Louis*

Fractal aggregates in nature grow with a scaling dimensionality less than the spatial dimension. This results in their packing density ( $\theta_f$ )—defined as actual volume occupied by solid subunits constituting an aggregate relative to total aggregate volume—decreasing with increasing size  $R_{g/a}$  (aggregate radius of gyration normalized by average radius of monomers (repeating subunits)). Fundamental questions remain regarding the scaling laws and physical mechanisms controlling the evolution of  $\theta_f$ , especially after the onset of gelation. This is in part because of experimental challenges owing to the effects of gravity and thermal fluctuations on the formation and structural stability of aggregates in the large  $R_{g/a}$  limit. Here, we experimentally map the scaling of  $\theta_f$  for aggregates—made of non-repulsive monomers—across five orders of magnitude of  $R_{g/a}$ . Our experiments reveal three successive growth regimes, namely diffusion-limited cluster aggregation (DLCA) of monomers, percolation of aggregates, and DLCA of percolates, with distinct cross-over points occurring at  $R_{g/a} \approx 4$  and  $1 \times 10^3$ . Corresponding to these regimes, we show  $\theta_f$  to decrease in distinct power-law exponents of -1.3, -0.5, and -1.3, respectively. Our work, besides demonstrating the experimental realization of stable aggregation in very large  $R_{g/a}$  limit, redefines the currently held scaling law for  $\theta_f$  of rigid aggregates, and has implications for synthesis of materials with superlative properties and accurate estimation of climate forcing by carbonaceous aerosols.

**4AP.5****Particle Resuspension from Substrates: Analysis of Time-Dependence on Removal Rates.**

BABAK NASR, Jing Qian, Meilu He, Jana Kesavan, Minyard Morgan, Andrea R. Ferro, Goodarz Ahmadi, Suresh Dhaniyala, *Clarkson University*

Airflow-driven particle resuspension from surfaces plays an important role in indoor and outdoor air quality. The characteristics of particle removal from a substrate depend on particle size and morphology, substrate roughness, relative humidity, and flow field near the wall. The influence of these factors on the particle resuspension rates has been considered to varying extents in existing models. The current models, however, do not account for the effect of time on particle resuspension. In most resuspension processes, particles experience unsteady or intermittent airflow, and it is critical to consider time-dependence of particle removal. In this study, a semi-empirical model is described for time-dependent particle removal from surfaces exposed to turbulent flow. The model is derived based on a combination of experimental data reported in literature and those obtained in our lab. The model predictions are tested for a case of particle removal with a pulsed-jet impinging flow. For this case, firstly, computational fluid dynamics (CFD) simulations are used to obtain near-wall flow characteristics and then our semi-empirical model of time-dependent particle removal characteristics is used to predict the spatial characteristics of particle removal over a substrate. The removal characteristics are then compared to experimental results. In our presentation, we will describe the model development approach and the experimental procedure to validate the developed model.

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**4AP.6**

**Uncertainties in Particle Wall Loss Correction during Secondary Organic Aerosol Formation in Chamber Experiments.** RENEE MCVAY, Theodora Nah, Jeffrey R. Pierce, John Seinfeld, Nga Lee Ng, *California Institute of Technology*

Particle wall deposition must be accounted for when determining secondary organic aerosol (SOA) yields during laboratory chamber experiments. However, a number of different particle wall loss correction methods exist, adding uncertainty to this correction. Furthermore, the use of high concentrations of seed particles has been suggested as a way to minimize the effects of vapor wall loss. Use of high seed particle concentrations complicates the particle wall loss correction, as coagulation will need to be accounted for. We present experiments and model simulations showing how particle wall loss rates change with different seed concentrations and size distributions and demonstrate how coagulation can be accounted for. We furthermore present alpha-pinene ozonolysis experiments using differing seed concentrations and size distributions. We apply four different particle wall loss correction methods to these experiments to quantify the uncertainty in this correction. This study demonstrates the importance of properly accounting for particle wall loss, especially when comparing SOA yields measured in different chambers using different particle wall loss correction methods.

**4AP.7**

**Effect of Translational and Rotational Brownian Motions on the Drift Velocity of Non-Spherical Aerosol Particles.** CHARLES HAGWOOD, George Mulholland, *National Institute of Standards and Technology, Gaithersburg*

A one dimensional model (Mulholland et al., accepted for publication in the *J. Aerosol Science*) for the effect of the rotation rate on the drift velocity of a nanorod in the free molecular regime was previously studied over the parameter range from fast rotation to slow rotation relative to the linear aerosol relaxation time. In this case the dependence of the friction coefficient on the orientation was proscribed as a trigonometric function of the product of the rotation velocity and the time. In reality, the rotation of the nanorod is driven by rotational Brownian motion. In the current study, we assume a Langevin equation (Ornstein-Uhlenbeck process) for the rotational dynamics. Because the friction tensor for translational motion will depend on the particle's orientation, the stochastic differential equation describing the translational velocity is coupled with the rotational Langevin equation. We solve this pair of equations numerically using the Ermak-Buckholz numerical integration scheme. The numerical integration is challenging since the time step must on the one hand be small enough to resolve the change in the orientation angle. On the other hand, it must be at least a factor of ten longer than both the translation aerosol relaxation time and the Brownian rotation time scale to obtain an average value of the drift velocity relevant to a measured drift velocity. A second solution method based on the analysis of the conditional probability distribution for the translational velocity distribution given the orientation distribution function was also used. This approach results in a Feynman-Kacs path integral. The results for these two methods will be compared. The results of Langevin approach will also be compared with the previously published results for the one dimensional model.

**4CO.1**

**Secondary Organic Aerosol Formation in Biomass-Burning Plumes: Theoretical Analysis of Lab Studies.** Qijing Bian, Shantanu Jathar, John Kodros, Kelley Barsanti, Lindsay Hatch, Andrew May, SONIA KREIDENWEIS, Jeffrey R. Pierce, *Colorado State University*

Secondary organic aerosol (SOA) has been shown to form from biomass-burning emissions in laboratory and field studies. However, there is significant variability between individual studies, which could be due to differences in fuels, fire conditions, dilution, and/or conditions of laboratory studies. This talk will focus on important processes affecting SOA formation in laboratory chamber studies. In smog-chamber studies, vapor wall losses have been demonstrated to be an important factor that suppresses traditional secondary organic aerosol (SOA) formation; however, impacts of vapor wall losses on the production of biomass-burning SOA have not yet been investigated. We use an aerosol microphysics model of that accounts for size, volatility, and chemistry to estimate the influence of the vapor wall loss on the SOA formation observed during the FLAME-III chamber studies. Our simulations show that the mean OA enhancement is 1.8 throughout the experiments when considering vapor wall loss, which roughly matches the mean observed enhancement during FLAME-III. On the other hand, the mean OA enhancement increases to over 3 when wall loss is turned off, which implies that the vapor wall losses are suppressing SOA formation. These results are generally robust across the parameter uncertainties (wall-loss and mass-transfer coefficients, and chemistry assumptions).

**4CO.2**

**Fast Secondary Aerosol Formation in Biomass Burning Plumes in Southern Africa.** VILLE VAKKARI, Johan Paul Beukes, Kerneels Jaars, Miroslav Josipovic, Andrew D. Venter, Pieter G. van Zyl, *Finnish Meteorological Institute, Helsinki, Finland*

Biomass burning (BB) is one of the largest sources of reactive trace gases and fine particles in the Earth's atmosphere. However, there is large uncertainty in the climate effect of the BB emissions, mostly because of the reactive species co-emitted with black carbon (BC) particles. We investigated the temporal evolution of BB smoke in southern Africa utilizing continuous in-situ aerosol measurements at Welgegund, South Africa (26.57S, 26.94E, 1480 m above sea level) from 20 May 2010 to 31 December 2014. Of the measurements performed at Welgegund ([welgegund.org](http://welgegund.org)), we used aerosol particle number size distribution, carbon monoxide (CO), BC with a MAAP, local wind and solar radiation. Submicron particulate mass (PM<sub>1</sub>) was estimated from the number size distribution; the ratio of excess BC to excess CO was used to characterize the flaming to smoldering ratio of the fire.

During the nearly five year period we were able to identify 118 BB plumes. For 83 plumes the location of the fire could be identified from MODIS burnt area and/or SEVIRI fire radiative power observations. For these episodes – a total of 250 hours of in-plume sampling – we could estimate the plume age. We observed fast secondary aerosol formation in nearly all plumes transported under daylight conditions: in smoldering cases up to a factor of 4 increase in excess PM<sub>1</sub> to excess CO ratio occurred in less than 5 hours. Only the flaming-dominated BB plumes did not exhibit significant secondary aerosol formation during daytime. In night-time plumes the secondary aerosol formation was much slower and during very calm nights a decrease in the excess PM<sub>1</sub> to excess CO ratio was frequently observed. In conclusion, our observations indicate that secondary aerosol formation in BB plumes depends strongly on both the emission (flaming vs. smoldering fire) and the oxidizing capacity of the atmosphere during plume transport.

**4CO.3**

**Evolution of Organic Aerosol (OA) Composition Emitted from Residential Coal Combustion.** WEI ZHOU, Haixia Ren, Mo Xue, Jiming Hao, Jingkun Jiang, *Tsinghua University*

In the absence of particulate matter (PM) control devices, residential coal combustion contributes significantly to ambient PM pollution, black carbon (BC) emissions, and PM health effects. Characterizing PM emissions from residential coal combustion with high time resolution is beneficial for developing control policies and evaluating the environmental impact of PM emissions. This study reported the evolution of organic aerosol (OA) composition formed during complete residential coal combustion processes, i.e., from fire start to fire extinction.

A residential coal combustion system includes a clean air supply system, a typical Chinese stove, a chamber collection system, and a dilution system were used for residential coal combustion experiments. A thermal desorption aerosol gas chromatograph and an aerosol chemical speciation monitor (ACSM) were used to in-situ measure OA composition. Three commonly used coal types were tested, i.e., bituminous, anthracite, and semi-coke coals.

In total, the chemical composition of major organic species are non-aromatic hydrocarbons, carboxylic acids and aromatic compounds. The emission of organic particles showed distinct characteristics in terms of four stages, i.e., the heating and ignition stage, fiercely combustion stage, stable combustion stage, and ember combustion stage. Non-aromatic hydrocarbons and aromatic compounds are the dominant compounds of organics, with the fraction of these two components more than 90%. While carboxylic acids dominated the organics during fiercely combustion stage and stable combustion stage, two complete combustion stages. During these two stages, a significant ion peak of  $m/z$  73 from organic acids were observed in ACSM, while this ion peak was previously considered the characteristic fragment ion of levoglucosan and used in source apportionment to identify biomass burning OA. Our results will improve our understanding of potential pollution control measures for residential coal combustion and source apportionment for ambient OA.

**4CO.4**

**Photochemical Production of Secondary Organic Aerosol from a Non-road Diesel Engine: Influence of an Alternative Fuel and Emissions Control Systems.** SHANTANU JATHAR, Beth Friedman, Abril Galang, Patrick Brophy, Delphine Farmer, John Volckens, *Colorado State University*

Non-road diesels account for about a quarter of the nitrogen oxides and primary aerosol emissions from mobile sources in the United States. While a lot is understood about primary emissions, very little work has been done to characterize the atmospheric formation and evolution of secondary organic aerosol (SOA) from tailpipe emissions of non-road diesels. Further, little is understood about how SOA responds to the use of alternative fuels and emissions control systems. To address this gap, in the Summer of 2015, we performed photochemistry experiments on diluted emissions from a 4.5 L John Deere diesel engine using a potential aerosol mass (PAM) reactor. Aerosol size, mass and composition were measured using a scanning mobility particle sizer, photoacoustic extinctions, and high-resolution aerosol mass spectrometer (HR-AMS). After 1.5 days of simulated atmospheric aging, production of SOA dominated primary aerosol emissions by an order of magnitude. Efficient combustion at higher engine loads and removal of SOA precursors and particle emissions by emissions control systems (oxidation catalyst and particle filter respectively), significantly reduced emission factors for POA (factor of 10-50) and production factors for SOA (factor of 10). The only exception was that the SOA production was nearly identical for idle loads regardless of the use of emissions control systems. We hypothesize (and validate using carbon monoxide measurements) that at idle loads the oxidation catalyst temperatures were too low to oxidize/remove any of the SOA precursors. Elemental analysis of the HR-AMS data shows a more oxygenated OA at idle than higher loads. Statistically, the use of soy-based biodiesel (B100) produced slightly lower POA emissions but nearly identical SOA levels as diesel. Work is under way to perform a positive matrix factorization using the HR-AMS data and understand compositional differences in OA produced across engine loads, fuels and use of emissions control systems.

**4CO.5****Secondary Organic Aerosol Forming Potential from Emerging Light-Duty Gasoline Direct Injection Vehicles.**

PATRICK ROTH, Diep Vu, Jiacheng Yang, Tyler Berte, Thomas D. Durbin, Georgios Karavalakis, Akua Asa-Awuku, *University of California, Riverside*

Vehicle emissions are an important source of VOCs, NO<sub>x</sub>, CO, and PM, which can contribute to SOA and ozone formation. Previous work has characterized the physical and chemical properties of aged emissions from vehicles operating over realistic driving conditions. However, these studies focused on older technology vehicles, such as Port Fuel Injection (PFI) vehicles, with less attention on newer technology gasoline direct injection (GDI) vehicles.

GDI technology has become the preferred standard to PFI engines in the US and European markets due to its increased specific output and improved fuel economy. However, GDI vehicles will have difficulty meeting the 3 mg/mile LEVIII PM Standard (2017) due to increased PM emissions; whereas PFI vehicles generally emit below 1 mg/mile. As a result, manufacturers may begin electing to utilize gasoline particulate filters (GPF) to meet the LEVIII PM Standard.

For this study, the SOA forming potential from the emissions generated from five GDI vehicles (one with GPF filter) were investigated over the LA-92 driving cycle in triplicate. The exhaust was collected in CE-CERT's 30m<sup>3</sup> Mobile Atmospheric Chamber (MACH). The emissions were then photochemically aged and real-time particle and gaseous phase measurements were analyzed.

As the gaseous emissions aged and condensed, the fractal, primary particles (BC) quickly transitioned to more dense, spherical particles. The change in composition and morphology impacts both volatility and hygroscopicity measurements. Aged emission masses were found to exceed the primary masses with varying ratios of inorganic ammonium nitrate and secondary organic material (HR-TOF AMS). The vehicle equipped with the GPF filter displayed a considerable decrease in primary PM along with differences in the physical and chemical compositions of aged aerosols. The data generated from this work will aid manufacturers and regulatory agencies understand the impacts of the increasing market share of GDI engines.

**4CO.6****Phase-partitioned PAHs in Gasoline Direct Injection Engine Exhaust Sampled with an Integrated Organic Gas and Particle Sampler.**

NAOMI ZIMMERMAN, Pallavi Pant, Cheol-Heon Jeong, Khaled Rais, Juana Delgado-Saborit, James S. Wallace, Jeff Brook, Greg J. Evans, Krystal G. Pollitt, *University of Toronto*

Given the projected increase in gasoline direct injection (GDI) market share over the next several years, there is a pressing need for a detailed characterization of GDI emissions, particularly of exhaust constituents that are potentially attributable to negative health outcomes, such as polycyclic aromatic hydrocarbons (PAHs). In this study, the polycyclic aromatic hydrocarbons (PAHs) in the engine exhaust particulate matter (PM) were sampled using an integrated organic gas and particle sampler (IOGAPS) XAD-coated annular denuder and quantified using GC-MS analysis (Agilent GC-6890N plus MSD-5973N). The test vehicle was a 2013 Ford Focus 2.0L engine connected to an engine dynamometer and diluted with an ejector dilutor system (Dekati, dilution ratio = 20). Three configurations (1: denuder + sorbent impregnated filters (SIFs), 2: upstream Zefluor filter + denuder + SIFs, and 3: standard filter pack + SIFs) were used to collect GDI exhaust samples at cold start and highway cruise operating conditions. GDI engine exhaust PAH concentrations were approximately 10 times higher during cold start than highway cruise. At highway cruise, pyrene and fluoranthene were the dominant PAHs in the undenuded filter pack; downstream of the denuder benzo(a)anthracene was the dominant PAH and the bulk of the pyrene and fluoranthene was removed. As it has been previously shown that adverse biological responses to GDI engine exhaust exposure may be specific to the particle phase, understanding the partitioning characteristics of PAHs may help elucidate specific PAHs contributing to this effect.

**4CO.7****Secondary Aerosol Formation Potential of Gasoline Vehicle Exhaust Under On-road and Laboratory Conditions.**

PAULI SIMONEN, Joni Kalliokoski, Panu Karjalainen, Miikka Dal Maso, Topi Rönkkö, Sanna Saarikoski, Hilkka Timonen, Matthew Bloss, Athanasios Dimaratos, Leonidas Ntziachristos, Jorma Keskinen, *Tampere University of Technology*

Light-duty vehicles emit both primary particles and precursor gases that can form secondary particle mass as a result of atmospheric oxidation. The potential of vehicle exhaust to produce secondary mass has been studied in laboratories using large smog chambers and fast oxidation flow reactors. However, the composition of exhaust emissions in real-world driving may significantly differ from those of laboratory driving cycles.

To probe the difference of real-world and laboratory observations, we performed measurements of the secondary mass formation potential of two modern gasoline vehicles. Real-world driving emissions were obtained by vehicle chase measurements, and they were compared to the measurements conducted on a chassis dynamometer for the same vehicles.

The emissions were measured with two ELPs (Electrical low pressure impactors): one measuring the primary emission and the other measuring the emission aged in TSAR (TUT Secondary Aerosol Reactor), a fast-response oxidation flow tube in which the sample is exposed to ozone and OH radicals. The chemical composition of particles before and after the oxidation flow reactor was measured by an SP-AMS; primary emission particle number concentration was measured using a CPC and a PSM-CPC combination. Gas-phase emissions were measured with CO<sub>2</sub> and NO<sub>x</sub> analyzers. In addition, a PEMS system was deployed during the chase measurements to measure raw exhaust CO<sub>2</sub>, NO<sub>x</sub> and CO concentrations.

In this work, we present the results of on-road secondary aerosol formation potential of light-duty gasoline vehicles, and compare the on-road and laboratory results. Especial attention is paid to chemical composition of secondary aerosol, as well as, total secondary particle formation potential in terms of mass.

**4HR.1****Association of Ambient Fine Particulate Air Pollution (PM<sub>2.5</sub>) with Cardiopulmonary Morbidity in Jeddah, Saudi Arabia.**

HAIDER KHWAJA, Shedrack R Nayebare, Omar S. Aburizaiza, Azhar Siddique, David Carpenter, Jahan Zeb, Abdullah J Aburizaiza, Cristian Pantea, Mirza M. Hussain, *Wadsworth Center, University at Albany*

The associations of exposure to air pollution and adverse human health effects have been demonstrated in many epidemiological studies. Though fine particulate air pollution (PM<sub>2.5</sub>) is a major environmental problem of concern in Saudi Arabia, there has been no research on the health effects of exposure to PM<sub>2.5</sub>. We have investigated the cardiovascular (CVDs) and respiratory diseases (RDs) risk associated with daily exposure to PM<sub>2.5</sub> and black carbon (BC) in Jeddah, Saudi Arabia. Daily PM<sub>2.5</sub> sampling at 3 sites in Jeddah was carried out for 6 weeks per quarter during April 2013 – February 2014 with simultaneous collection of hospital data on cardiopulmonary morbidity. Annual mean for PM<sub>2.5</sub> and BC was 41.7 and 2.1 µg/m<sup>3</sup>, respectively. The relative risk for cardiopulmonary morbidity was determined using a generalized linear time-series model. Risk for RDs was found to be highest at lags 0 – 1 and moving average 2 – 3 (MA<sub>2-3</sub>) for all patient categories. People below 30 years were disproportionately affected by RDs with age-group (0 – 14) years being the most vulnerable. RDs risk ranged from 3.3 – 17.8% for exposures to PM<sub>2.5</sub>, 15 – 72% with individual lags, and up to 150% with moving averages for exposures to BC. The risk for CVD was highest in age-groups above 30 years with high CVDs risk mostly observed at lags 2 – 6 and MA<sub>2-7</sub>. CVDs risk ranged from 2.3 to 17.8% for exposures to PM<sub>2.5</sub> and 18 – 58% for exposures to BC. In general, exposure to PM<sub>2.5</sub> significantly increased cardiopulmonary morbidity risk across all age-groups. This highlights the severe damage on human health attributable to PM<sub>2.5</sub> air pollution and suggests an urgent need for an abatement strategy for air pollution in Saudi Arabia.

**4HR.2**

**Air Pollution Exposures among Pregnant Women in a United States - Mexico Border Town.** KIRSTEN KOEHLER, Jairus Pulczinski, Misti Levy-Zamora, Johnson Natalie, Ana Rule, Josias Zietsman, *Johns Hopkins School of Public Health*

Traffic-related air pollution (TRAP) has been implicated in negative health effects including asthma, cardiovascular disease, and cancer. Early life represents a unique window of susceptibility to air pollution as exposures in utero can result in altered physiological responses that can continue into adulthood. Prenatal exposures to heavy metals and polycyclic aromatic hydrocarbons (PAHs), components of TRAP, have been linked to reduced lung function, cognitive impairment, low birth weight, and increased asthma susceptibility. Furthermore, towns located on the United States – Mexico border are substantially impacted by TRAP because of their proximity to heavy traffic at the border crossings and due to diesel trucks that do not meet the United States emissions standards. This study examined exposure to TRAP in 20 pregnant mothers (third trimester) in Hidalgo County, TX, a region with the highest childhood asthma prevalence in Texas. Personal exposures to PM<sub>2.5</sub> mass, black carbon (a marker of exposure to TRAP), and airborne PAHs were monitored in three 24-hour periods occurring at two-week intervals. Pollution measures were paired with a GPS to evaluate the impact of different microenvironments on exposure. Exposures to PM<sub>2.5</sub> mass were highly variable both within- and between-person. Daily average exposures to PM<sub>2.5</sub> mass ranged from 5 to 150 ug/m<sup>3</sup> and short-term exposures for some participants exceeded 3000 ug/m<sup>3</sup> during some activities. Exposures to TRAP were highly variable among this susceptible population of women. The 24-hour average personal exposures often exceeded the ambient air quality 24-hour PM<sub>2.5</sub> standard set by the United States Environmental Protection Agency.

**4HR.3**

**Chemical Composition, Environmental Impact and Health Implication of Primary and Secondary Emissions of Gases and Particles from Residential Wood Burning.** IMAD EL HADDAD, Giulia Stefanelli, Deepika Bhattu, Jun Zhou, Giancarlo Ciarelli, Emily Bruns, Peter Zotter, Thomas Nussbaumer, Amelie Bertrand, Nicolas Marchand, Brice Temime-Roussel, Sebnem Aksoyoglu, Jay Slowik, Urs Baltensperger, Andre Prévôt, Josef Dommen, *Paul Scherrer Institute*

Organic gases undergoing conversion to form secondary organic aerosol (SOA) during atmospheric aging are largely unidentified. SOA dominates the atmospheric organic aerosol burden and this knowledge gap contributes to uncertainties in aerosol effects on climate and human health. Here, we use high-resolution mass spectrometry and perform a set of smog chamber and flow tube experiments to quantify primary and aged gaseous and particulate emissions from residential wood combustion, a major source of pollution particularly in regions with cooler climate. SOA oxidative potential is assessed using an online reactive oxygen species analyzer. Four types of residential stoves, two pellet burners and an industrial boiler were run under different burning conditions. The main parameters affecting emission strength and composition are identified and the major gaseous precursors responsible for SOA formation are determined. SOA is mainly formed through the oxidation of non-traditional precursors, including phenolic compounds from lignin pyrolysis and aromatic hydrocarbons from incomplete combustion. Based on laboratory data, regional air quality models are updated to better assess the impact of wood combustion on emissions and SOA formation in Europe during winter.

**4HR.4**

**Biological Effects of Human and Murine Lung Cells Exposed to Combustion Aerosols at the Air/Liquid-Interface: Investigation of Wood Combustion-, Ship- and Car Engine-Emissions.** RALF ZIMMERMANN, Gunnar Dittmar, Tamara Kanashova, Jeroen Buters, Sebastian Öder, Hanns Paur, Sonja Mühlhopt, Marco Dilger, Carsten Weiss, Horst Harndorf, Benjamin Stengel, Karsten Hiller, Sean Sapcariu, Kelly BeruBe, Tobias Krebs, Thorsten Streibel, Erwin Karg, Martin Sklorz, Jürgen Orasche, Johannes Passig, Suchi Smita, Maija-Riitta Hirvonen, Olli Sipppula, Jorma Jokiniemi, et al., *Helmholtz Zentrum München and Rostock University*

Combustion aerosol-emissions are highly health-relevant. The Virtual Helmholtz Institute HICE ([www.hice-vi.eu](http://www.hice-vi.eu)) studies physical-chemical properties of combustion emissions in conjunction with their biological effects on lung cells. In this context human lung cells are exposed to diluted combustion exhaust-fumes at the air-liquid interface (ALI). The ALI-exposure technology allows a realistic aerosol-exposure of lung cells. After exposure, biological responses of the lung cells are analysed. Up to now emissions of wood combustion compliances (wood log-stove and pellet-burner), a ship-diesel engine (operated with heavy fuel oil (HFO) or refined diesel fuel (DF)) and a car engine (operated with gasoline or ethanol (E85)) were investigated and are discussed in the contribution. Human alveolar basal epithelial cells (A549, BEAS2B and primary cells) and murine macrophages (RAW) were ALI-exposed to the freshly-emitted diluted combustion aerosols. The cellular effects were then characterized, including a comprehensive multi-omics molecular biological-effect characterisation on transcriptome, proteome and metabolome level (Oeder et al., *PLoS one*, 2015). The cellular response-strengths of the combustion aerosols were observed at comparable aerosol deposition doses. The following order of biological effect-strength was observed: A relatively mild effect was detected for the diluted wood combustion- and car-emissions (with ethanol-fuel emissions being slightly more reactive than gasoline-fuel emissions). Counter-intuitively the biological effects-strengths for log-wood and pellet burner emissions were very similar. The ship diesel engine-emissions, however, induced the most intense biological responses. Surprisingly the HFO-emissions showed lower biological effect strengths than the supposedly cleaner DF, although the HFO-emissions contained much higher concentrations of known toxic compounds (transition metals, organic toxicants). The obtained holistic physical-chemical and molecular biological results demonstrate the complexity of PM-induced biological effects. The activation-pattern (i.e. different induced molecular pathways) and the activation-strength vary considerably for the investigated aerosol sources, suggesting large differences in relative toxicity and mechanisms for aerosol-induced health effects of combustion-emissions from different sources.

**4HR.5**

**Premature Mortality in China Due to Exposure of Outdoor Fine Airborne Particulate Matter: Source Contributions and Responses to Concentration Reductions.** Jianlin Hu, Hongliang Zhang, QI YING, *Texas A&M University*

Exposure to high concentrations of airborne fine particulate matter (PM<sub>2.5</sub>) significantly increases the mortality of cardiovascular and pulmonary diseases in China. Previous assessments of excess mortality ( $\Delta$ Mort) due to PM<sub>2.5</sub> exposure were based on coarse resolution chemical transport modeling simulations and relatively old emission inventory data, thus might lead to underestimation of the severity. Sources that contribute to  $\Delta$ Mort have not been quantified. We determined the spatial distribution of  $\Delta$ Mort due to adult (>30 years old) ischemic heart disease (IHD), cerebrovascular disease (CEV), chronic obstructive pulmonary disease (COPD) and lung cancer (LC) at 36-km resolution for 2013 from predicted annual-average surface PM<sub>2.5</sub> concentrations using source-oriented Community Multiscale Air Quality (CMAQ) model along with an ensemble of four regional and global emission inventories. Observation data fusing was applied to provide additional correction of the biases in PM<sub>2.5</sub> concentrations from the ensemble. Source contributions to  $\Delta$ Mort were determined based on total  $\Delta$ Mort and fractional source contributions to PM<sub>2.5</sub>.  $\Delta$ Mort due to COPD, LC, IHD and CEV are 0.329, 0.148, 0.239 and 0.953 million, respectively, leading to a total  $\Delta$ Mort of 1.669 million. Industrial and residential sources were the two leading sources, contributing to 0.508 (30.5%) and 0.366 (21.9%) mp, respectively. Secondary ammonium ion from agriculture, secondary organic aerosol and aerosols from power generation were responsible for 0.204, 0.179 and 0.172 mp of  $\Delta$ Mort, respectively. Contribution of transportation to  $\Delta$ Mort was relatively small, only accounting for 0.096 mp, which is slightly higher than contributions of open burning (0.082 mp) and windblown dust (0.054 mp). Decreasing rate excess mortality per unit reduction of PM<sub>2.5</sub> is expected to be slow at high PM loading experienced in most part of China and PM<sub>2.5</sub> concentrations need to be greatly reduced before health benefit of emission control becomes evident.

**4HR.6**

**Effect of Inhalable Exposures on Cytokine Levels in Workers in Northern Colorado Dairies.** KIMBERLY ANDERSON, Joshua Schaeffer, John Mehaffy, Mary Bradford, Jessy Tryon, Amanda VanDyke, Stephen Reynolds, T. Renee Anthony, Darrah Sleeth, Christian L'Orange, John Volckens, *Colorado State University*

Exposure to bioaerosols is associated with a multitude of adverse health effects (asthma, chronic bronchitis, wheeze and cough). The Personal Inhalable High-Flow Sampling Head (PHISH) sampler is a new low-cost, disposable inhalable sampler that operates at 10 L/min. This study evaluated worker exposures to dust and endotoxin in dairy parlors using PHISH, 37-mm CFC, and Button samplers. Inflammation of the upper respiratory system was evaluated by evaluating cytokine levels in nasal lavage. Personal air monitoring was conducted over three work shifts and on the workers' day off to quantify inhalable dust and endotoxin. Samples were analyzed gravimetrically and compared between the PHISH, CFC, and Button. Post-shift nasal lavage fluids were assessed for interleukin 1-beta, 6, 8 and 10 (IL-1 beta, IL-6, IL-8, and IL-10), TNF-alpha, and IFN-gamma. Total endotoxin concentrations for the PHISH sampler were 12 times higher than those measured in the CFC sampler. Differences in cytokine levels were identified by gender and smoking status. In general, women had lower baseline cytokine levels compared to men, and a more substantial increase in cytokine levels after one day of exposure. Current smokers had higher baseline levels of TNF-alpha, IL-1-beta, and IL-10. Levels of IL-1, IL-6, and IL-8 decreased with increasing number of days worked. Levels of TNF-alpha and IFN-gamma increased slightly with increased number of days worked. No significant differences were seen in cytokine expression or in pulmonary function between new workers (<1 year) compared to participants who have worked for longer than one year. Preliminary data analysis suggests that baseline cytokine level, gender, smoking status, season, and dairy have an effect on cytokine levels. The PHISH mass concentration and total endotoxin units had slightly stronger correlations between most cytokine levels compared to the CFC mass concentration and endotoxin levels.

**4HR.7**

**Characterization of Aerosol Filtration Properties of Neonatal Human Nasal Airways.** SCOTT TAVERNINI, Michelle L. Noga, Andrew R. Martin, Warren H. Finlay, *University of Alberta*

Delivery of medicinal aerosols to newborns is an essential tool for the treatment of infant respiratory ailments; yet the deposition of particles traversing the nasal passage of neonatal infants remains poorly quantified. Delivery of pharmaceutical aerosols via the nasal passage is necessitated by the fact that infants less than about six months of age are obligatory nasal breathers, thus the filtration properties of the nasal passage are important. Additionally, it has been suggested that environmental pollution in the form of particulate matter is associated with increased infant mortality, further motivating the present study. Nasal deposition has been investigated previously for infants 3-18 months old; the present study addresses the 0-3 month age range and whether current correlations can be used to predict nasal deposition in this younger population. Airway replicas of eight infants have been rapid prototyped from computed tomography (CT) scan data. Aerosol of jojoba oil generated by a 6-jet collision nebulizer is passed through two paths, one including an airway model, the other a blank sampling line, under varying flow conditions. Comparing the aerosol distribution measured by an electrostatic low pressure impactor (ELPI) after passing each path gives the fraction of aerosol particles, classified by aerodynamic diameter, which deposit in the nasal passageway. Deposition data as a function of Reynolds and Stokes number is examined.

**4IM.1**

**Chemical Analysis of Various Laboratory-Generated Particles by Using a Newly Developed Single Particle Mass Spectrometer.** HEE-JOO CHO, Donggeun Lee, Kihong Park, *Gwangju Institute of Science and Technology, Gwangju, Korea*

Atmospheric aerosols are very important on atmospheric chemistry, global climate, air quality, and adverse health effects. Most of these atmospheric processes are closely related with individual particle size, chemical composition and mixing state. However, it is very challenging to determine single particle chemical composition in real time due to its small mass and complex mixing state. Single particle aerosol mass spectrometry (SPMS), which commonly uses laser for evaporation and ionization of individual particles, can be considered as a useful tool to determine chemical constituents of single particles in real time. It can detect not only non-refractory components, but also refractory constituents. In this study, a new SPMS was developed to analyze chemical composition and mixing state of single particles produced from various sources. The SPMS consist of two high vacuum chambers that are separated by a skimmer with 3 mm inner diameter, and each chamber is pumped down by two turbo molecular pumps. An orifice (with inner diameter of 100 micro-meter) and aerodynamic lens were newly designed to transport 90-1100 nm particles with high efficiency. The Nd:YAG laser with a 266 nm wavelength and a frequency of 20 Hz was used for particle ionization to achieve high hitting efficiency. Also, a triggering system by using a scattering laser was developed to detect particles at low concentration. Single particle mass spectra for particles from biomass burning, coal combustion, bubble bursting from seawater, and re-suspended particles from collected road dust were compared. Clustering of various types of particles is being performed.

**4IM.2**

**Intercomparison of Capture and Standard Vaporizers in the Aerodyne Aerosol Mass Spectrometer (AMS).** WEIWEI HU, Pedro Campuzano-Jost, Douglas Day, Philip Croteau, Manjula Canagaratna, John Jayne, Jose-Luis Jimenez, *CIRES, University of Colorado, Boulder*

Aerosol mass spectrometers (AMS) and Aerosol Chemical Speciation Monitors (ACSM) commercialized by Aerodyne Research Inc. are used widely to measure the mass concentrations and size distributions of non-refractory species in submicron-particles. With the “standard” vaporizer that is installed in all commercial instruments to date, the quantification of ambient aerosol mass concentration requires the use of a collection efficiency (CE) for correcting the loss of particles due to bounce on the vaporizer. However, CE depends on aerosol phase and chemical composition, and thus can vary with location, air mass, and season of sampling, and typically contributes the most uncertainty to the quantification of aerosol mass. To address this limitation, a new “capture” vaporizer has been designed to reduce or eliminate particle bounce and thus the CE correction.

To test the performance of the capture vaporizer, two AMS instruments, one with the standard vaporizer and one with the capture vaporizer were operated side by side in the lab and multiple field studies. In four ambient or flow reactor datasets, good agreement was observed between the time series of mass concentration of the main species between the capture (without use of CE) and standard vaporizers (with the composition-dependent CE correction from Middlebrook et al., AS&T 2012), verifying that CE~1 in the capture vaporizer. However, compared to the standard vaporizer, the observed mass spectra were shifted to smaller fragments with the capture vaporizer, suggesting additional thermal decomposition arising from the increased residence time and surface collisions of the molecules in the vaporizer. The additional decomposition is also consistent with the observed longer particle vaporization times which lead to artificially broadened particle size distribution measurements. The impact of the size distribution broadening is significant for lab studies using monodisperse particles, but less important for field studies since ambient distributions are typically quite broad. The influence of vaporizer temperature on fragment pattern and the shape of the size distributions was also investigated.

**4IM.3**

**Development of an Online Extractive Electrospray Ionization Time of Flight Mass Spectrometer (EESI-TOF): Application to Atmospheric Aerosol.** FELIPE LOPEZ-HILFIKER, Veronika Pospisilova, Josef Dommen, Andre Prévôt, Urs Baltensperger, Tofwerk, Jay Slowik, *Paul Scherrer Institute*

Thermal desorption of aerosol components for analysis is typical in most online aerosol sampling instruments (e.g. AMS, ATOFMS, SPLAT, PALMS, TAG, FIGAERO). Thermal desorption leads to decomposition even at low temperatures (<100 C) significantly changing measured aerosol composition and properties, hindering mechanism development and source apportionment efforts.

We describe the development of an online extractive electrospray time-of-flight mass spectrometer (EESI-TOF) for fast molecular analysis of aerosol organics without heating induced fragmentation. This instrument couples an EESI inlet, recently developed at PSI to a high-resolution time of flight mass spectrometer. Briefly, the extractive electrospray instrument operating principle involves the collision of atmospheric aerosol with charged electrospray droplets. The soluble components are extracted into the electrospray droplet, and as the solvent from the electrospray evaporates, ion ejection results in gas phase ions formed from the extracted aerosol. Therefore aerosol are ionized rapidly, and transferred into the gas phase without any need for sample heating.

The EESI-TOF provides rapid response (1Hz) measurements of highly oxidized organic species and oligomers with individual compound detection limits as low as 1 ng m<sup>-3</sup> in 5 seconds, allowing for the simultaneous retrieval of molecular compositions for hundreds of compounds that comprise organic aerosol at high time resolution. Online analysis of SOA from the reaction of  $\alpha$ -pinene and ozone at in a flow tube and simulation chamber results in prompt formation of over 500 individual molecules (150 to 500+ Th) which are detected by the EESI-TOF with excellent signal to noise even for oligomeric species.

We present the detailed characterization of the EESI-TOF instrument and its application to atmospheric aerosol, both from chambers and ambient measurements. We discuss the instrument performance in the context of current aerosol measurement shortfalls, and potential applications of the instrument to the chemical speciation of organic aerosol at atmospherically relevant conditions.

**4IM.4**

**Deployment of a PM2.5-capable Aerosol Chemical Speciation Monitor in Nanjing, China.** Yunjiang Zhang, Lili Tang, PHILIP CROTEAU, Hongliang Zhang, Ping Chen, Wen Xu, Leah Williams, Manjula Canagaratna, John Jayne, Douglas Worsnop, *NUIST / JSEM, China*

Aerosol Mass Spectrometers (AMS) and Aerosol Chemical Speciation Monitors (ACSM) measure the chemical composition of non-refractory PM1. However, in locations where there are a significant number of particles with diameters between 1 and 2.5 microns, AMS and ACSM systems measure lower mass concentrations than PM2.5 monitoring instruments and are unable to provide information about the chemical composition of these particles. In order to address this issue, modifications have been made to the sampling inlet, aerodynamic focusing lens, and particle vaporizer used in both AMS and ACSM systems to allow them to quantitatively measure non-refractory PM2.5. In order to test these modifications with ambient aerosol we deployed a PM2.5-capable ACSM at the Jiangsu Environmental Monitoring Center in Nanjing, China during October and November, 2015 along with a PM1 ACSM and other PM2.5 monitoring instruments including a Monitor for AeRosols and Gases in Ambient air (MARGA), 7-Wavelength Aethalometer, semi-continuous OC-EC, Tapered Element Oscillating Microbalance (TEOM), and PM1 and PM2.5 Beta Attenuation Monitors (BAM). During the deployment, the PM2.5 mass ranged from 6 to 250 micro-g/m<sup>3</sup> and the average PM1 to PM2.5 ratio was about 0.5. Here we present an overview of the PM2.5 system for ACSM and AMS and the results of this intercomparison which demonstrate good agreement between the PM2.5 ACSM and the other PM2.5 monitoring instruments for both mass and chemical composition.

**4IM.5****Quantitative Off-line Particulate Matter Composition Analysis with Thermal Desorption Mass Spectrometry.**

XIAOLIANG WANG, Gustavo Riggio, Xufei Yang, Laxmi Narasimha Yatavelli, L.W. Antony Chen, Judith Chow, John Watson, *Desert Research Institute*

On-line aerosol mass spectrometry has provided insights into atmospheric aerosol formation, sources, and transformation processes. However, wide deployment of on-line mass spectrometers is impractical due to cost, maintenance, and expertise requirements. Integrated filter samples are being collected in aerosol speciation networks with wide spatial and temporal coverage and a decades-long sample archive. A thermal desorption-mass spectrometry (TD-MS) method has been developed to quantify major constituents of particulate matter on quartz-fiber filters from these networks. A particle-laden filter punch is heated at predefined temperature steps in a pure helium atmosphere. Species evolve at different temperatures depending on their volatility and thermal stability, and the products of this evolution are separated and quantified by an electron-impact ionization mass selective detector (MSD). Chemical standards are used to establish calibration relations that include fragmentation patterns along with transfer, ionization, and detection efficiencies. TD-MS also provides an estimate of the ratios of oxygen (O), hydrogen (H), and nitrogen (N) to carbon (C), i.e., O/C, H/C, and N/C, and therefore the ratio of organic matter to organic carbon. With reasonable assumptions about oxidation states, this TD-MS approach has demonstrated quantification of particulate sulfate, nitrate, ammonium, and organic carbon mass concentrations in a single analysis. Comparison with other methods for ambient samples shows that the differences are within +/-5%.

**4IM.6****A Collision Cross Section versus Mass Two-Dimensional Space for Characterization of Atmospheric Organic**

**Aerosol.** XUAN ZHANG, Jordan Krechmer, Stephan Graf, Wen Xu, Michael Cubison, Michael Groessl, John Jayne, Jose-Luis Jimenez, Douglas Worsnop, Manjula Canagaratna, *Aerodyne Research, Inc.*

A new metric is introduced for representing the molecular signature of atmospheric organic aerosols, the collision cross section, a quantity that is related to the structure and geometry of organic molecules and is derived from ion mobility measurements. By combination with the molecular mass, a two-dimensional collision cross section–mass space is developed to facilitate the comprehensive investigation of the complex organic aerosol mixture. A unique distribution pattern of chemical classes, characterized by functional groups including amine, alcohol, carbonyl, carboxylic acid, ester, and organic sulfate, is developed on the 2-D space. Species of the same chemical class, despite variations in the molecular structures, tend to situate as a narrow band on the space and follow a unique trend line. Reactions involving changes in functionalization and fragmentation can be represented by the intrinsic directionalities along or across these trend lines, thus allowing for the interpretation of mechanisms associated with the formation and evolution of atmospheric organic aerosol. The characteristics of trend lines for a variety of functionalities that are commonly present in ambient aerosols can be predicted by the core model simulations, which provide a useful tool to identify the chemical class to which an unknown species belongs on the space. Within the band produced by each chemical class on the space, molecular structural assignment can be achieved by utilizing collision induced dissociation as well as by comparing the measured collision cross sections in the context of those obtained via molecular dynamics simulations.

**4IM.7**

**On-line and Hyphenated Photoionization Mass Spectrometric Techniques for Gas and Particulate Phase Analysis: Investigation of Wood Combustion-, Ship- and Car Engine-Emissions.** Hendryk Czech, RALF ZIMMERMANN, Olli Sippula, Benjamin Stengel, Anne Ulbrich, Toni Miersch, Jürgen Orasche, Heikki Lamberg, Martin Sklorz, Thorsten Streibel, Horst Harndorf, Jorma Jokiniemi, *University of Rostock*

Anthropogenic emissions from combustion sources are known to cause severe effects on human health. Furthermore, emitted greenhouse gases and particulate emission as well as secondary particles from gas-to-particle conversion affect the radiative forcing of the Earth. The Virtual Helmholtz Institute HICE ([www.hice-vi.eu](http://www.hice-vi.eu)) together with the Joint Mass Spectrometry Center Rostock-Munich investigates the molecular aerosol composition of combustion processes with relevance on a global scale, such as emissions from marine engines, automobile engines and different types of wood stoves, with mass spectrometric techniques in the field and laboratory test benches. The overall scope of this study is to integrate biological responses from cell exposure experiments and chemical/physical properties of the combustion aerosol. On-line single-photon ionization (SPI) and resonance-enhanced multiphoton ionization (REMPI) time-of-flight mass spectrometry (TOFMS) was applied to analyze the composition of volatile to semi-volatile organic compounds (VOC/SVOC) in real-time for dynamic combustion processes. Striking changes in organic molecular composition could be observed for batchwise log wood combustion through burning phases, accelerations during driving cycles and high-speeds of automobiles and load changes of a marine engine. Moreover, fine particulate matter from these combustion processes were collected on quartz fiber filters and analyzed by a thermal-optical carbon analyzer hyphenated to a SPI/REMPI-TOFMS (Diab et al. 2015, *Atm. Meas. Techn.*). The ImproveA temperature protocol defines four thermal steps of organic carbon (OC1 – OC4) for which the organic molecular composition was investigated. OC1 and OC2 (room temperature to 280°C) can be regarded as thermodesorption step with evaporating compounds, whereas in OC3 and OC4 (280°C to 580°C) pyrolysis dominates, leading to thermal fragment of low-volatile organic compounds (LVOC). With this approach, the influence of fuel switching from high-sulfur heavy fuel oil to low-sulfur diesel fuel on particulate organic emissions from a marine engine and wood stove emissions under different operating conditions were examined.

**4UA.1**

**Real-time Measurements of PM<sub>2.5</sub>, Black Carbon, Sound and Traffic Dynamics Near a Major Highway.** SIVARAMAN BALACHANDRAN, Corey Jonathan, Ann Dillner, Farzan Oroumijeh, Hui Ren, Harika Tadepally, *University of Cincinnati*

The Port of Cincinnati moved 49,930,467 tons of goods in 2014, making it the 13th largest (as well as the largest inland) port in the US. Concomitant with this growth in the port has been an increase in freight traffic. The highest volume of traffic in Cincinnati is on I-75 near Exit 3, where the daily traffic exceeds over 185,000 vehicles per day, with approximately 20% of this traffic being comprised of heavy duty trucks. The Southwest Ohio Air Quality Agency (SWOQA) also has a near roadway (NR) monitoring site adjacent to I-75 approximately ¼ of a mile from Exit 3. Therefore, this location provides an ideal field laboratory to measure traffic, air pollution and sound, leading to a greater understanding of air pollution concentrations and traffic state during daily congested periods as well as intermittent incidents.

Traffic dynamics data will be gathered by using an Electronically Scanning Radar (ESR) (Delphi ESR 2.5). This allows for data gathering to evaluate microscopic traffic models, including individual vehicle classification, speed, location and acceleration. Real-time PM<sub>2.5</sub> will be measured using portable DustTrak PM<sub>2.5</sub> monitor (TSI), which can concurrently measure continuous PM<sub>2.5</sub> and time-integrated Teflon filter-based samples. Real-time black carbon (BC) will be measured using microAethalometers (AE51, Aethlabs). 24-hour Teflon filter samples will be analyzed for organic and elemental carbon using Fourier Transform Infrared Spectroscopy (FT-IR) and for metals using x-ray fluorescence. In addition to the NR site, the portable air quality monitors will also be co-located at the Chemical Speciation Trends (CSN) site located on Taft Rd. in central Cincinnati (TAFT), allowing for evaluation of the portable monitors and the FT-IR method. Sound measurements and traffic dynamics data will be used to statistically model PM<sub>2.5</sub> and BC concentrations. The first phase of data gathering will be undertaken in the summer of 2016.

## 4UA.2

**Characterizing the Near-road Submicron Aerosols Near a North Carolina Interstate Freeway: Summer Vs. Winter Observations.** PROVAT SAHA, Andrey Khlystov, Andrew Grieshop, *North Carolina State University*

Motor vehicles are a dominant source of primary and secondary submicron particulate matter (PM) in urban areas. There are steep gradients in concentrations of primary gas- and particle-phase species, including black carbon (BC), organic aerosols (OA) and other species within 10s to 100s of meters from the roadway. Here, we present a comprehensive near-road submicron aerosol characterization effort from summer and winter field campaigns at a site near Interstate 40, outside Durham, North Carolina. Month-long measurement campaigns were performed in summer 2015 and winter 2016 and involved detailed measurements at: (i) a fixed near-road site located within 10 m from highway, (ii) an upwind background site, and (iii) during downwind transects on a minor roadway perpendicular to highway when wind directions were favorable. Measurements include submicron aerosol chemical composition, size distributions, and volatility using a multi-tube thermodenuder (TD), black carbon, NO<sub>x</sub>, meteorological conditions and traffic data. A van is equipped for transects measurement with various aerosols and gaseous instruments and a multi-tube TD and consecutively sample at different distances (15, 50, 100, 150, 220 m) downwind of the highway and repeated several times a day. Preliminary results show strong seasonal and diurnal differences in spatial distribution of traffic-sourced pollutants. Strong signature of vehicles emission was observed within 100-150 m from highway edge with significantly higher concentration at morning. Less-sharp near-road gradients are observed in winter in many species. Particle volatility measurements show that traffic-sourced ultrafine particles evaporate at lower temperatures than background aerosol in both seasons. Transect measurements of particle evaporation show that this behavior evolves with downwind transport. The observed spatial patterns appear to be moderated by temperature, winds, mixing height, traffic. Detailed observations from summer and winter campaigns will be presented.

## 4UA.3

**Comprehensive Characterization of Vehicle Emissions in Ft. McHenry Tunnel.** ANDREY KHLYSTOV, David Campbell, Mark McDaniel, Chiranjivi Bhattarai, *Desert Research Institute*

Vehicular traffic emits large quantities of gaseous and particulate air pollutants, affecting air quality and human health. To mitigate the negative effects of traffic, several controls have been introduced in recent years to reduce emissions from both heavy-duty (HD) and light-duty (LD) vehicles. We will present results of a mobile source emission study aimed to investigate real life effectiveness of emission controls and to update profiles of traffic-emitted air pollutants. The study was conducted during two one-week-long campaigns, one in winter (February 2015) and one in summer (August 2015), in the Ft. McHenry tunnel in Baltimore, MD, USA. The tunnel passes under the Baltimore Harbor and carries traffic of Interstate 95, the main highway on the East Coast of the U.S. It is a four-bore 2.2 km tunnel, with two lanes per bore. HD vehicles are limited to the right-hand bore, while LD vehicles are allowed in all bores. The posted speed limit is 55 mph. The daily traffic volume is approximately 127,000 vehicles per day. The sampling was conducted at the exit of each eastbound bore and in the east ventilation building that supplies air to the eastbound bores. We will present fleet-averaged fuel-based emission factors (EFs) for criteria and non-criteria gaseous and particulate pollutants measured during this study, including: carbon monoxide and oxides of nitrogen, PM<sub>2.5</sub>, organic and elemental carbon, volatile organic compounds, carbonyls, gas- and particle-phase polycyclic aromatic hydrocarbons, alkanes and cycloalkanes, alkenes, hopanes, steranes, and nitro-PAHs. The dependence of EFs on fleet composition, fuels, and ambient conditions will be evaluated. The effect of temperature on evaporative emissions, as derived from winter and summer measurements, will also be discussed.

## 4UA.4

**High-time resolution VOC and Speciated Total Emissions for Diesel and Gasoline Vehicles: Implications for Future Fleet Emissions and Pollutant Formation.** GREG DROZD, Yunliang Zhao, Rawad Saleh, Georges Saliba, Bruce Frodin, Hector Maldonado, Satya Sardar, Allen Robinson, Allen H. Goldstein, *University of California, Berkeley*

Over the past two decades vehicle emissions standards in the United States have been dramatically tightened with the goal of reducing urban air pollution. Secondary organic aerosol (SOA) is the dominant contributor to urban organic aerosol, but controversy remains regarding the contributions of different types of vehicles to this SOA. Recent studies suggest increased non-methane hydrocarbon (NMHC) potency for SOA formation in lower emission standards vehicles. Speciation and time-resolved measurements during drive cycles for vehicular NMHC emissions are critical for effectively predicting not only SOA production, but also ozone formation and levels of air toxics. Experiments were conducted at the California Air Resources Board Haagen-Smit Laboratory to investigate pollutant emissions for Tier 0 (T0) and low, ultra-low, super ultra-low, and partial zero emission vehicles (LEV, ULEV, SULEV, PZEV). Tailpipe emissions were comprehensively characterized over a wide range of volatilities, from VOCs to LVOCs. Time-resolved measurements of VOCs using a proton-transfer-reaction mass spectrometer reveal the importance of emissions during the first 30 seconds after engine start and hard acceleration. IVOCs and SVOCs were sampled with sorbent tubes and characterized using thermal desorption two dimensional gas-chromatography-mass-spectrometry with electron impact (2D-GC-EI-MS) and vacuum-ultraviolet (2D-GC-VUV-MS) ionization. 2D-GC-EI-MS data reveal isomer distributions for alkyl benzenes that are drive-cycle dependent. 2D-GC-VUV-MS analysis of diesel exhaust IVOCs showed they are dominated by cyclic, branched compounds. A diesel vehicle with a particulate filter and selective catalytic reduction showed near elimination of IVOC emissions. Primary organic aerosol collected on quartz filters analyzed using 2D-GC-VUV-MS clearly show that gasoline and diesel particles were dominated by motor oil. These tests show that more than 200 miles of hot stabilized driving are typically required to equal cold start emissions. VOC emissions profiles, particularly for the BTEX compounds, show differences from the neat fuel composition, with implications for fuel-based emissions inventories.

## 4UA.5

**SOA Formation from Tailpipe Emissions from On-road Gasoline Vehicles.** YUNLIANG ZHAO, Rawad Saleh, Georges Saliba, Greg Drozd, Hector Maldonado, Satya Sardar, Bruce Frodin, Allen H. Goldstein, Allen Robinson, *Carnegie Mellon University*

On-road gasoline vehicles have been indicated as a major source of SOA in urban areas, but our understanding of SOA formation from tailpipe emissions is poorly constrained. Results from recent chamber experiments with dilute tailpipe emissions from gasoline vehicles have shown that only a small fraction of measured SOA can be explained by light aromatic compounds (C6-C9). Understanding what cause(s) the large discrepancies between measured and predicted SOA from tailpipe emissions is critical to determining the contribution of gasoline vehicles to atmospheric PM, improving the performance of atmospheric models, and making effective emission control policies. To determine the cause(s), we have performed a comprehensive study to characterize primary emissions and investigate SOA formation from tailpipe emissions from on-road, in-use light-duty gasoline vehicles. We have comprehensively characterized primary emitted hydrocarbons, corresponding to the saturation concentration range of C2-C36 n-alkanes. These quantified hydrocarbons include three important classes of SOA precursors, single-ring aromatic compounds, intermediate-volatility organic compounds and semi-volatile organic compounds. SOA formation from dilute exhaust was measured through smog chamber experiments. The mass balance between measured and predicted SOA is achieved by including light single-ring aromatic compounds, intermediate volatility organic compounds and semi-volatile organic compounds and accounting for the effects of NO<sub>x</sub> levels on SOA formation. This mass balance indicates that light single-ring aromatic compounds, intermediate volatility organic compounds and semi-volatile organic compounds all are important precursor classes. The contribution of light-duty gasoline vehicles to SOA production from on-road vehicles is updated based on these new findings.

**4UA.6**

**On-road, Near-road, and Urban Background Measurements of Traffic-related Pollutants in Metropolitan Toronto, Canada.** CHEOL-HEON JEONG, Jon M. Wang, Nathan Hiker, Kerolyn Shairsingh, Dennis Herod, Tony Munoz, Greg J. Evans, *SOCAAR, University of Toronto*

Traffic emissions represent a major local source of air pollution in urban areas and are strongly associated with adverse health impacts. The concentrations of traffic-related pollutants (e.g. ultrafine particles (UFP), black carbon (BC), nitrogen oxides (NO<sub>x</sub>), and carbon monoxide (CO)) can vary spatially with distance from roadways, through atmospheric processes that can depend on meteorological conditions. Due to the strong spatial variability of the traffic-related pollutants, on-road and near-road measurements are needed to evaluate and monitor the exposure of populations living or spending time near major roadways to elevated pollution levels.

A near roadway monitoring pilot study was conducted at two near-road and two urban background sites in Toronto, with a view towards creating additional near-road monitoring stations across Canada. Toronto's near-road stations are located within 20 m of major roadways. These monitoring stations were equipped with instrumentation for measuring traffic-related pollutants at high time resolutions (1 Hz, in most cases). The differences in traffic-related pollutants between urban background and near-road environments were evaluated by comparing the pollutant concentrations measured at these monitoring stations. The influence of meteorological parameters on the spatial variability was investigated. In addition to data from the four near-road network stations, NO<sub>x</sub> measurements at currently available air quality monitoring stations operated by the Ontario Ministry of the Environment and Climate Change were analyzed in order to provide better spatial resolution data and examine the suitability of the current monitoring stations for near-road measurements. Lastly, on-road measurements of traffic-related pollutants using a mobile laboratory were conducted during the summer of 2015 in the Greater Toronto area. This study provided traffic-related pollutant concentrations measured while driving on major roadways and near-road residential areas. The spatial extent of the elevated concentrations between on-road and near-road will be discussed.

**4UA.7**

**Impact of Meteorology Datasets on Near Roadway Dispersion Model Estimates.** Fatema Parvez, KRISTINA WAGSTROM, *University of Connecticut*

More than 19% of the United States population lives near high traffic roadways where they are exposed to elevated near road pollutant concentrations. Vehicular emissions are one of the primary sources of air pollution in cities and associated with elevated morbidity and mortality rates in individuals living near roadways. Currently available near-roadway dispersion models use meteorological data from local weather stations, potentially limiting their implementation due to the unavailability of data in many areas. In order to overcome this limitation, process-based meteorological estimates from models such as the Weather Research and Forecasting (WRF) model are used as a substitute. This raises the question of how model estimates vary between process-based meteorological estimates and station data.

In this study we employ a Gaussian plume dispersion model, R-LINE, to simulate near road concentrations using both station data and Weather Research and Forecasting model (WRF) estimates. R-LINE simulates the dispersion from line sources by numerically integrating point source emissions along multiple road configurations. We evaluate the seasonal and diurnal variability of roadway dispersion for both of the meteorological input datasets and compare the model estimates. As we found fairly substantial differences in model estimates for the two input datasets, we also explore R-LINE's sensitivity to different meteorological parameters in both stable and unstable atmospheric conditions for multiple locations in Connecticut. This study illustrates and quantifies how R-LINE's estimates vary based on the use of different sources of meteorological inputs.

**5AC.1****Dependence of Water Transport Kinetics, Reactive Uptake Coefficients and Effective Volatility of Semi-Volatile Organic Components on Organic Aerosol Viscosity.**

JONATHAN P. REID, Frances Marshall, Young-Chul Song, Stephen Ingram, Allen E. Haddrell, David Topping, Jacqueline Hamilton, *University of Bristol*

The prevalence of secondary organic aerosol (SOA) in the atmosphere is well established, with chemical components spanning wide ranges in volatility, functionality, molecular weight and hygroscopicity. Departures from equilibrium behaviour have been observed in phase state and gas-particle partitioning of volatile and semi-volatile components, with anticipated impacts on ambient particle mass concentrations, ice nucleation efficiency, oxidation kinetics and optical properties. Improvements to predictions of non-equilibrium behaviour in ambient aerosol are dependent on refined representations of the microphysical properties and processes that aerosol undergo. In particular, the relationship between the viscosity of an aerosol particle and the diffusivity of species within the particle has been the focus of much recent work.

We will report direct measurements of the diffusion constants of water and semi-volatile organic compounds (SVOCs) in surrogates of atmospheric organic aerosol, examining the correlation of these mass transport coefficients with direct and independent measurements of particle viscosity. Briefly, single aerosol particles are trapped in either optical traps or an electrodynamic balance and the time-dependent response of particle size to changes in relative humidity and temperature examined to explore the mass transfer kinetics. Parallel measurements examine the coalescence of pairs of aerosol particles with the timescale for relaxation in shape allowing the determination of particle viscosity. In particular, we will discuss the correlation between diffusion constants of molecular species in aerosols of complex composition, the suppression in the vapour pressure of SVOCs and the reactive uptake coefficient of ozone with the viscosity of the particle phase. These measurements highlight that the Stokes-Einstein equation, relating viscosity with diffusion constants, can be used to provide a good representation of aerosol microphysics under certain conditions but can be many orders of magnitude in error in other instances.

**5AC.2****Evaporation of Alpha-pinene SOA at Atmospherically Relevant Humidity Range.**

TAINA YLI-JUUTI, Aki Pajunoja, Angela Buchholz, Olli-Pekka Tikkanen, Celia Faiola, Olli Väisänen, Hao Liqing, Eetu Kari, Otso Peräkylä, Olga Garmash, Manabu Shiraiwa, Mikael Ehn, Kari Lehtinen, Annele Virtanen, *University of Eastern Finland*

Climate effects of secondary organic aerosols (SOA) are affected by the dynamic processes that SOA goes through in the atmosphere. Here, we investigate the factors that affect the evaporation of alpha-pinene SOA particles. SOA was generated by alpha-pinene ozonolysis in a flow tube. A size selected particle population was conditioned with a desired RH (dry, RH 40 % or RH 80 %) and sampled either through varying length of tubing or led to a 100 L stainless steel residence time chamber before the sampling. This allowed for monitoring the particles' size evolution over a time line from few seconds to few hours. The evaporation rates were analyzed using a liquid-like particle evaporation model and a multi-layer particle evaporation model which includes particle phase diffusion. Both models presented the organic compounds with a volatility basis set (VBS). The evaporation was slower under dry conditions than under humid conditions, and in all cases slower than predicted based on a previously determined VBS without any particle phase diffusion limitations. We determined the initial particle volatility distribution by fitting the liquid-like particle model to the experimental data at RH 80 % using the genetic algorithm. A large mass fraction in the low-volatile VBS bins was needed to capture the evaporation. Using this initial volatility distribution we investigated the effect of particle phase diffusion limitations on the evaporation rate at RH 40 % and dry conditions. We found that particle viscosities consistent with previous studies could explain the slower evaporation at dry conditions compared to RH 80 %. However, a strong composition dependence in viscosity was required. The particle evaporation rates were similar at RH 40 % and RH 80 %. This suggests that the particle phase diffusion limitations had less effect at RH 40 % compared to the dry conditions.

**5AC.3**

**Surface Activity in Secondary Organic Aerosol Liquid Samples.** ANDREW METCALF, Cari Dutcher, *University of Minnesota, Twin Cities*

Recent experimental evidence suggests that ambient aerosol particles, particularly aged secondary organic aerosol (SOA), can be phase-separated into multiple liquid phases. One potential particle configuration is a core-shell morphology, where the presence of an organic surface film may inhibit species uptake and evaporation by providing a mass transfer barrier (kinetic effect) or by mixing with components in the aerosol, reducing the overall particle hygroscopicity (chemical effect). Organic films acting as surfactants affect particles' ability to act as cloud condensation nuclei (CCN) and can, therefore, introduce large variability in cloud droplet number resulting from these CCN. However, we currently lack the ability to accurately predict the formation of these films under most natural conditions. Thus, it is necessary to assess the presence of these organic films in ambient aerosol.

In this talk, our microfluidic platform will be used to measure the presence of surface-active species in aerosol liquid samples. The presence of surface-active constituents will change (usually reduce) the surface (liquid-vapor) and interfacial (liquid-liquid) tension relative to a reference state, resulting in a change in the mixing state of ambient particles and their tendency for growth and activation. We derive aerosol liquid samples from a variety of sources, including laboratory-generated SOA and SOA intermediates. The intermediates are isoprene-SOA intermediates synthesized in the laboratory. SOA liquid is extracted from filters collected during flow-tube or environmental chamber experiments. Sources of SOA liquid examined in this study include photooxidation of naphthalene and both photooxidation and ozonolysis of caryophyllene.

**5AC.4**

**Glass Forming Properties of Secondary Organic Aerosol and Surrogates Examined by Thin Film Dielectric Relaxation Spectroscopy.** YUE ZHANG, Andrew Lambe, Timothy Onasch, Wen Xu, Lindsay Renbaum-Wolff, William Brooks, Wade Robinson, Manjula Canagaratna, Paul Keabian, Andrew Freedman, Shachi Katira, David Chandler, Paul Davidovits, John Jayne, Douglas Worsnop, Charles Kolb, *Boston College; Aerodyne Research, Inc.*

Glass transitions from a liquid to semi-solid and solid phase state have important implications for the reactivity, growth, and cloud forming (cloud condensation nuclei and ice nucleation) capabilities of secondary organic aerosols (SOAs). The small size of SOA makes it challenging to measure glass transitions using conventional methods. This study examined the glass forming properties of various SOA surrogates and their tracers by measuring the dielectric behavior of their thin films on interdigitated electrodes (IDEs). Organic aerosol particles were deposited onto the IDE substrates using electrostatic precipitation and were observed to form uniform thin films. The thin films were then analyzed by dielectric spectroscopy, which provides dipole relaxation about the organic material, such as the motion of the molecules, as a function of temperature. This information was used to calculate the glass transition temperature of single compound surrogates for SOA, simple mixtures, and complex SOA generated in an oxidation flow reactor. Dielectric spectra were obtained as a function of various operating conditions, and the correlations between SOA chemical composition and glass forming properties were examined.

**5AC.5**

**Interfacial Chemistry and Cloud Activation in Organic Aerosol.** JAMES F. DAVIES, Chris Ruehl, Kevin Wilson, *Lawrence Berkeley National Laboratory*

The molecular composition at the surface of airborne particles plays an important role in regulating the chemical and physical dynamics of aerosol. In viscous particles, where molecular transport is limited by slow diffusion, chemistry occurring at the surface can lead to steep interfacial gradients (1). In mixed component particles, phase separation and surface partitioning can influence the cloud activation mechanism, with surface tension playing an important role in regulating the size of droplets approaching the point of activation (2).

In this work, we detail a selection of our laboratory-based studies exploring molecular transport dynamics and chemical kinetics, demonstrating the complex physical chemistry associated with the dynamics of atmospheric aerosol. In particular, we focus on the role of organic species in aerosol, which perturb both viscosity and surface tension. Using a combination of flow-tube methods and single-particle traps, we explore how these properties influence chemical processing, molecular diffusion and cloud activation.

(1) Davies, J. F.; Wilson, K. R. Nanoscale Interfacial Gradients Formed by the Reactive Uptake of OH Radicals onto Viscous Aerosol Surfaces. *Chem. Sci.* 2015, 6, 7020–7027.

(2) Ruehl, C. R.; Davies, J. F.; Wilson, K. R. An interfacial mechanism for cloud droplet formation on organic aerosols. *Science*. 2016, 351, 1447-1450.

**5AC.6**

**Effect of Heterogeneous Uptake of Ammonia on the Properties of Secondary Organic Aerosols Particles.** DAVID BELL, Alla Zelenyuk, Dan Imre, Scot Martin, *Pacific Northwest National Laboratory*

Particle phase and morphology can greatly impact the properties and transformations of secondary organic aerosol (SOA). For example, the rates of heterogeneous reactions strongly depend on particle phase and on whether the condensed-phase reacting substances are on the particle surface or inside the particle. In complex cases, a protective hardened surface layer could be present limiting contact with the gas phase.

We will present the results of a recent study, in which we characterized changes in the properties of  $\alpha$ -pinene SOA particles as a result of exposure to ammonia at different relative humidity (RH).

We show that at low RH (<5% RH) the uptake of ammonia by  $\alpha$ -pinene SOA particles is consistent with surface adsorption by highly viscous semi-solids, in agreement with previous studies. This surface limited process produces particles with size-dependent composition and density, with smaller particles, having larger fraction of reactive products.

We find that after ~4 hours of exposure to 10 ppm of ammonia, SOA particles developed a solid “crust”, which imposes diffusion limitations on gas-particle mass transfer as apparent from changes in SOA evaporation rates. In addition, we measured the coalescence rates of reacted and un-reacted SOA particles as function of particle size and exposure to ammonia. We find that the formation of this thin surface layer slows particle coalescence rates by a few orders of magnitude. As an aside, we note that the presence of this layer needs to be considered when using coalescence time to determine particle viscosity.

At high RH (>95%RH) all characterized particles are spherical, have orders of magnitude lower viscosity, and contain significantly higher fraction of reactive products.

**5AC.7**

**Anthropogenic Influence on Particle Rebound and Phase State in Amazonia.** Adam Bateman, Zhaoheng Gong, Antonio O. Manzi, Paulo Artaxo, Rodrigo A. F. Souza, SCOT MARTIN, *Harvard University*

Particulate matter (PM) in the Earth's atmosphere occurs as liquids, semisolids, and solids. The physical state of organic PM can constrain the available mechanisms of growth and reactivity, ultimately affecting the number, size, and composition of the particle population, especially over Earth's forested regions. Non-liquid PM was recently reported over a boreal forest of Northern Europe. Herein, the physical state, including the response to relative humidity (RH), was investigated for PM ( $< 1 \mu\text{m}$ ) over the tropical rain forest of central Amazonia during the GoAmazon 2014/5 campaign.

Under background conditions in the absence of urban pollution, liquid particles dominated for the range of ambient RH. Under polluted conditions, the rebound response curves shifted toward those of non-liquid particles. The shift was significant enough to indicate the occurrence at ambient RH of at least some non-liquid particles in the atmospheric particle population. The concentrations of biomass burning compounds, aromatic species, and less-oxidized organic species correlated positively with the shifts in the response curves to higher RH, suggesting a causative relation between shifts in particle composition and shifts in non-liquid and liquid states. In turn, the mentioned species have sources related to human activities, including biomass burning, regional industrial activities, and urban pollution.

**5AC.8**

**Surface Tension Modeling of Multicomponent Atmospheric Aqueous Aerosols Using Competitive and Assisted Adsorption.** HALLIE BOYER, Cari Dutcher, *University of Minnesota*

Surface properties of aqueous solutions are necessary for determining atmospheric aerosol particle interactions with the ambient, such as uptake of water vapor and radical species, as well as effects on their optical properties and morphology. In previous work (Boyer et al. *JPC Lett.*, 2015; Wexler and Dutcher, *JPC Lett.*, 2013), we used statistical mechanics to derive analytic expressions for surface tension of binary aqueous solutions, and reduced the number of free parameters down to zero to enable estimation of surface tension for systems where there are little or no data available. Here, the model approach is extended to multi-component aqueous solutions by identifying surface partition functions for solutes of varied molecular sizes. If solutes exhibit similar surface propensities, competitive adsorption between solute species is expected at the surface. Conversely, for solutes with opposite tendencies towards surface adsorption, we foresee assisted adsorption. We apply the model in ternary form to organic acids by considering their partial dissociation and to solute mixtures of organics (glycerol and ethanol) and electrolytes (NaCl and  $\text{NH}_4\text{NO}_3$ ). Using binary model parameter values that were found to correlate strongly with solute physico-chemical properties, parameter free predictions for surface tension of aqueous systems of multiple solutes are presented. Excellent agreement has been found between the model predictions and experimental data obtained both from literature.

**5CO.1**

**Thermophoresis and Differential Mobility Analysis of Soot Nuclei Sampled from a Premixed Flame.** FRANCESCO CARBONE, Alessandro Gomez, *Yale University*

Nascent soot particles were sampled from an ethylene/air premixed flame to measure their Size Distribution Functions (SDFs). Two techniques were used to check for selfconsistency and highlight possible sampling artifacts. Particles were thermophoretically collected on fine SiC wires to retain spatial resolution and minimize flame perturbations. Scanning Electron Microscopy (SEM) and Helium Ion Microscopy (HIM) of the samples showed independence of the measured SDFs for sampling times shorter than 100ms and confirmed the avoidance of collection artifacts with wires sufficiently thick (140  $\mu\text{m}$  in diameter) to prevent overheating and surface reaction. SEM and HIM were quantitative only to measure particles larger than approximately 5nm, with Transmission Electron Microscopy (TEM) revealing the presence of even smaller liquid-like nuclei. An intrusive rapid-dilution probe was used to sample particles directly in the aerosol phase for subsequent High-Resolution Differential Mobility Analysis (HR-DMA). Extremely high dilutions and short residence time in the sampling and neutralizing system are necessary to minimize the post-sampling evolution of the nascent aerosol, with particles neutralized in a controlled way for quantitative measurements of the SDFs. Good agreement between thermophoretic sampling measurements and DMA measurements was found for particles sizes larger than 7nm. Results for smaller particles are only semi-quantitative. Contrary to the conclusions of previous studies, even at dilution levels much higher than those used in past, aerosol coagulation in the probe was not completely quenched, which could be revealed only by using a HR-DMA instrument.

**5CO.2**

**Variation of Mass Absorption Coefficient and Internal Structure of Laboratory Generated Soot Particles with Mass.** RAMIN DASTANPOUR, Steven Rogak, Ali Momenimovahed, Kevin Thomson, Jason S. Olfert, *University of British Columbia*

Light absorption and scattering properties of combustion generated soot particles are important for accurate estimation of emission rates and are used as the inputs for climate models. For decades, mass absorption coefficient (MAC) of soot particles has been assumed to be independent of particle size and mass. MAC numbers approximately in the range of 6 to 8 ( $\text{m}^2\text{g}^{-1}$  at a wavelength of 660 nm) have been reported in literature. Here we consider the possibility that particles produced by a single source can have varying optical properties.

Soot particles were produced by combustion of  $\text{CH}_4$  and  $\text{CH}_4+\text{N}_2$  in air, within a laminar inverted diffusion flame. Particles were diluted and passed through a catalytic stripper, charged by a unipolar diffusion charger, and mass-classified by a centrifugal particle mass analyser (CPMA). Extinction and scattering cross sections were measured by Cavity Attenuated Phase Shift Spectrometer (CAPS-PMssa). Mobility size distributions of mass classified particles were used in combination with effective density measurements for the calculation of arithmetic mean mass for each mass to charge ratio. Primary particle sizing and morphology characterisation were performed by transmission electron microscopy (TEM). Variations of the internal structures of size classified particles were also investigated by a combination of high resolution TEM (HRTEM), and Raman spectroscopy.

Here, for the first time we have shown that MAC changes with the particle mass. Ensemble average MAC numbers of 6.2 and 7.5 ( $\text{m}^2\text{g}^{-1}$  at 660 nm) were calculated for the two operating conditions (methane with and without  $\text{N}_2$  dilution, respectively), but MAC varies with size for both sources, and the size-resolved MAC values lie on the same curve for both sources. MAC number increases from 4.5 to 8.5 ( $\text{m}^2\text{g}^{-1}$ ) with the particle mass increasing from 0.05 to 8 (fg) (roughly an order of magnitude increase in mobility diameter).

**5CO.3**

**Comparison of the Mass-Specific Absorption Spectra of Graphenes to Soots.** JAMES RADNEY, Christopher Zangmeister, Rian You, Courtney Grimes, Jessica Young, Michael Zachariah, Russell Dickerson, *National Institute of Standards and Technology*

Many measurements and studies treat black carbon aerosol as having a very narrow range of spectral properties; i.e. mass specific absorption cross section at  $\lambda = 550$  nm ( $MAC_{550}$ ) of  $7.5 \pm 1.2$  m<sup>2</sup> g<sup>-1</sup> and an assumed power-law wavelength dependence (i.e. Absorption Angstrom Exponent, AAE) of 1. We will compare the MAC spectra of graphene and graphene oxide reduced (rGO) at 320 °C in N<sub>2</sub> and soot aerosols across  $\lambda = 500$  nm to 840 nm; soot aerosols were generated from ethylene, kerosene and diesel diffusion flames and spark discharge (i.e. fullerene soot). Measurements were made in situ by step scanning a photoacoustic spectrometer utilizing a supercontinuum laser with a tunable wavelength and bandwidth filter. While all of these samples have absorption spectra that would label them as spectrally black (AAE  $\leq 1$ ) the magnitude of the MAC values varied wildly. The graphene and rGO had  $MAC_{550}$   $7.2 \pm 0.4$  m<sup>2</sup> g<sup>-1</sup> and  $7.7 \pm 0.3$  m<sup>2</sup> g<sup>-1</sup> while ethylene, fullerene, diesel and kerosene soot had  $MAC_{550}$  of  $3.7 \pm 0.2$  m<sup>2</sup> g<sup>-1</sup>,  $6.1 \pm 0.2$  m<sup>2</sup> g<sup>-1</sup>,  $12.1 \pm 0.1$  m<sup>2</sup> g<sup>-1</sup> and  $13.0 \pm 0.1$  m<sup>2</sup> g<sup>-1</sup>, respectively. Interestingly, only the graphenic samples would be considered black carbon under the accepted definition. Further, if we consider the radiative impact of these other “black carbon” materials, significant errors can arise from incorrectly parameterizing the absorption strengths. This would be especially true in areas where kerosene and diesel represent a large fraction of the particulate emissions since they are commonly used as fuels for heating and lighting.

**5CO.4**

**Speciated Aerosol Emission Factors and AMS Mass-Spectral Profiles of South Asian Combustion Sources.** J. DOUG GOETZ, Michael Giordano, Chelsea Stockwell, Ted Christian, Rashmi Maharjan, Sagar Adhikari, Prakash Bhawe, P.S. Praveen, Arnico Panday, Thilina Jayarathne, Elizabeth Stone, Robert J. Yokelson, Peter DeCarlo, *Drexel University*

Characterization of aerosol emissions from prevalent but under sampled combustion sources in South Asia was performed as part of the Nepal Ambient Monitoring and Source Testing Experiment (NAMaSTE) in April 2015. NAMaSTE source sampling took place in and around the Kathmandu Valley and in the Indo-Gangetic plains of southern Nepal. Targeted emission sources included cooking stoves with a variety of solid fuels, brick kilns, garbage burning, crop-residue burning, diesel irrigation pumps, and motorcycles. Real-time measurements of submicron non-refractory aerosol mass concentration and composition were obtained using an Aerodyne mini Aerosol Mass Spectrometer (mAMS). Black carbon and brown carbon contributions were measured using a 6-channel dual spot aethalometer (Magee Scientific AE-33) and a 2 wavelength PAX System (Droplet Measurement Technology). Emission factors (PM<sub>1.0</sub> per mass of fuel burned) were calculated for all aerosol species and for each source type based on simultaneous CO<sub>2</sub> measurements made using a Picarro cavity ring-down spectrometer (CRDS G2401). Time-integrated unit mass resolution (UMR) mass spectral profiles were retrieved for individual emission sources and burn-phase-specific mass spectra were retrieved for several sources. The mass spectral data were used to make comparisons between the various sample source types and fuels. Additionally, analysis of organic UMR ions to total organic (f<sub>44</sub>, f<sub>43</sub>, f<sub>60</sub>, etc.) are examined as primary emissions in f<sub>44</sub> vs f<sub>43</sub> and f<sub>44</sub> vs f<sub>60</sub> space. Characterizing the mass spectral signatures and aerosol emission factors of the tested emission sources is key to understanding the contribution of these sources to ambient air pollution burdens in rural and urban areas in South Asia and is important for air quality management in the region.

**5CO.5**

**Integrating Laboratory and Field Measurements to Reduce Uncertainties in Cookstove Emissions Estimates.** KELSEY BILSBACK, Rose Eilenberg, Kristen Fedak, Michael Johnson, Jack Kodros, Eric Lipsky, Christian L'Orange, Jennifer Peel, Jeffrey R. Pierce, Allen Robinson, R. Subramanian, John Volckens, *Colorado State University*

Solid fuel cooking technologies are widely used in developing countries. Most of these rudimentary cookstoves operate with inefficient combustion, which produces high levels of air pollution. Development of accurate inventories that account for cookstove emissions has been limited given the diversity of stoves, fuels, and cooking practices used throughout the world and the complexity of combustion chemistry. Additionally, inventories often rely on emissions measurements from laboratory tests because logistics and cost restraints limit testing cookstoves in the developing world. However, many studies have demonstrated that laboratory conditions do not reproduce realistic cookstove performance. A novel testing approach entitled the Firepower Sweep was designed to address some of these gaps. The protocol has shown a 35% improvement in predicting field emissions over laboratory data in the literature. After designing the protocol, we conducted laboratory tests, using the Firepower Sweep, and uncontrolled field tests in China, Honduras, Uganda, and India. Data from these studies are being used to develop predictive models between stove performance parameters and emissions factors. Emissions of C1-C12 organics are highest for traditional wood stoves and lowest for charcoal stoves. Multivariate regression models indicate that firepower explains a larger percent of the variance in particulate matter emissions ( $R^2 = 0.53-0.93$ ) than combustion efficiency ( $R^2 = 0.01-0.03$ ). Furthermore, high particulate matter emissions occur during high firepower and transient firepower events (e.g., refueling). These events are also associated with black carbon emissions, while lower firepower events are associated with more organics. Preliminary results indicate that parameterizations developed using the Firepower Sweep hold under field conditions, although, field conditions tend to produce more low-power smoldering events. This work will help inform global emissions inventories for cookstoves, which will allow for the development of more representative models to predict both climate impacts and the global burden of disease from solid fuel combustion.

**5CO.6**

**Burning Organic Aerosol Composition: Influence of Residential Woodstoves Technology.** AMELIE BERTRAND, Giulia Stefanelli, Emily Bruns, Coty Jen, Simone Pieber, Brice Temime-Roussel, Jay Slowik, Andre Prévôt, Allen H. Goldstein, Imad El Haddad, Henri Wortham, Nicolas Marchand, *Aix-Marseille Université, CNRS, LCE FRE 3416*

In the context of climate change, it is in France a will of its Environmental Agency (ADEME) to strongly push for biomass burning as an alternative source of energy to heat residential homes. In order to limit the consequences in terms of air quality, ADEME offers financial incentives for home owner to install new and cleaner wood stoves. However biomass burning is known to be a dominant source of particulate matter (PM). In addition the emissions from biomass burning like any combustion processes can contain a significant amount of light absorbing carbonaceous aerosol and carcinogenic compounds such as Polycyclic Aromatic Hydrocarbons (PAHs). To better understand the impact on our health and the potential effect these emissions may have on climate, it is important we quantify and characterize them at best. Here were characterized and compared the primary emissions factors of different residential woodstoves technologies (two traditional logwood stoves and one pellet stove) using a variety of tree species including beech, ash, maple and spruce. Biomass burning emissions were analyzed by TAG (Thermal Desorption Aerosol Gas Chromatograph) coupled with a HR-ToF-AMS (High Resolution – Time of Flight – Aerosol Mass Spectrometer), an Aethalometer AE33 for the refractory fraction of the particulate phase and a PTR-ToF-MS (Proton Transfer Reaction – Time of Flight – Mass Spectrometry) for the gaseous phase. Molecular identification was further investigated through GCxGC EI-HF ToF MS analysis performed on quartz filter samples. A hundred of fine particle organic compounds were detected and quantified. Implications in terms of air quality improvement and source apportionment is also discussed.

**5CO.7**

**Characterizing a Two-Angle Light Scattering Instrument for Concentration and Size Measurement of Diesel Particulates with Intra-Cycle Time Resolution.** POOYAN KHEIRKHAH, Jeff Farnese, Patrick Kirchen, Steven Rogak, *University of British Columbia*

To measure the concentration and size of the carbonaceous particulate emissions from a direct-injection engine, a new instrument that measures the light scattering in two angles is used. The Fast Exhaust Nephelometer (FEN) has a short sampling tube to minimize the transfer time from the engine exhaust pipe to the FEN chamber. It samples close to the engine exhaust valve; therefore, its measurement time resolution is close to 1 milliseconds, much shorter than an engine cycle. This is the first instrument of this type with the ability to measure the intra-cycle particulate matter from successive engine cycles. By using the ratio of the scattered light power in two angles, the mass concentration and the median diameter of the particulates are calculated based on the Rayleigh-Debye-Gans (RDG) theory.

The mass concentration measurements from the FEN correlated well with the diluted exhaust measurements sampled by the Dusttrak-DRX. The particle size of the diluted samples measured with the FEN were very similar to the previously reported data from the same engine. However, the median gyration diameter of the undiluted exhaust, taken near the exhaust valve, were 40-70 nm smaller compared to the diluted particles based on the RDG model. Calculations based on estimated particle number concentration and exhaust flow residence time in this engine suggests that the particle coagulation inside the pipes and the exhaust surge tank probably causes this size growth. To confirm the validity of the RDG model and the accuracy of the FEN, the instrument is used to measure the concentration and size of laboratory-generated aerosols. In particular, analysis of the NaCl aerosols with a Scanning Mobility Particle Spectrometer (SMPS) and the FEN were compared against each other.

**5CO.8**

**On the Limits of Current Predictive Tools for an Efficient Control of Emissions from Agricultural Waste Combustion.** Imara Ibarra, Gaizka Aragon, Enrique Rojas, David Sanz, Igor Gomez, Jesus Rodriguez-Maroto, CRISTINA GUTIERREZ-CANAS, *University of the Basque Country, SPAIN*

Mediterranean countries produce 95% of the total world olive oil with important environmental, social and economical implications. Decentralized MCP (medium scale of combustion boilers >1MWth) are of interest for logistic reasons and for its ability to fulfil the requirements of a number of applications, among them, electricity generation, domestic/residential heating and cooling, or heat/steam for industrial processes. Until now, there was a lack of emission limit values for operations with a rated thermal input less than 50 MW. However, the MCP Directive, establishing limit values for both existing and new installations will have to be transposed by Member States by 19 December 2017.

In addition to the characteristic seasonality in supply, which leads to a traditional practice of blending with other fuels, there is a growing interest on “fuel engineering” to minimize corrosion and fouling, and to prevent atmospheric emissions.

However, this kind of practice can enhance the formation of submicronic aerosol (Joeller M. et al., 2007) concentrating a substantial amount of trace heavy metals. A user-friendly and cost-effective approach for these MCP could be based on predictive tools, such as chemical equilibrium modeling. These can also provide systematic information on the behavior of different fuels and could be further utilized to reduce or prevent ash-related issues. Therefore, this work focuses on the assessment of the ability of these tools to provide guidelines for minimizing operation problems, blending rules and estimating emission limits.

Aragon, G. et al (2015) *Energy & Fuels* 29, 2358-2371.  
EU directive 2015/2193 On the limitation of emissions of certain pollutants into the air from medium combustion plants  
Joeller M., et al (2007) *Fuel Proc. Technol.* 88, 1136-1147.

**5IA.1**

**Mixing and Sink Effects of Air Purifiers on Indoor PM<sub>2.5</sub> Concentrations: A Pilot Study of 8 Residential Homes in Fresno, California.** KAI-CHUNG CHENG, Hye-Kyung Park, Afua O. Tetteh, Yan Zheng, Nicholas T. Ouellette, Kari C. Nadeau, Lynn M. Hildemann, *Stanford University*

We measured real-time and integrated PM<sub>2.5</sub> inside 8 occupied single-family homes in Fresno, California to evaluate how turbulent air mixing and pollutant removal caused by a filter-based air purifier influences the levels of fine particles in everyday indoor environments. In each home, we used a real-time monitor to log PM<sub>2.5</sub> levels every 5 min over 12 weeks during which air purifiers were operating, except for a designed 3-day shutdown period for baseline measurements. We assessed how the operation of air purifiers changed the patterns of the frequency distributions for short-term (5-min) concentrations, which included spikes produced by sporadic indoor activities/emissions. This allowed us to examine the reduction effectiveness of air purifiers for different aged aerosols indoors. We observed a systematic change in the 5-min PM<sub>2.5</sub> distributions in different homes – while air purifiers reduced 96% of the 5-min concentrations, they increased the magnitudes of the top 4%, representing transient concentration peaks. This phenomenon is consistent with what would be theoretically expected based on passive scalar turbulence in fluid physics. We also collected gravimetric filter samples, finding significant differences in the long-term (2-5 day) concentrations of indoor PM<sub>2.5</sub> and endotoxin between the air purifier shutdown and before/after periods. A less significant difference was seen for Pb (Lead).

**5IA.2**

**An Integrative, Non-Invasive and Cost-Effective Study of Residents' Health, Indoor Air Quality and Infrastructure Defects.** NIRMALA THOMAS, Leonardo Calderón, Mengyang Guo, MaryAnn Sorensen-Allacci, Deborah Plotnik, Jennifer Senick, Jie Gong, Clinton J. Andrews, Gediminas Mainelis, *Rutgers, The State University of New Jersey*

A multidisciplinary field study was conducted in two multi-apartment residential buildings. Residents' health was correlated with indoor air quality parameters, building construction elements along with energy performance, and structure hazard in a cost-effective way.

Health data related to respiratory illness, building conditions, and maintenance records were compiled via interviews. Building leaks, missing wall insulation, air infiltration, and thermal bridges were inspected using infrared thermography and laser scanning, a time conserving and non-invasive extraction of building hazard related attributes. Key indoor air quality components implicated in sick building syndrome, such as biological and non-biological aerosol concentrations, allergens, volatile organics and indoor gases, were recorded.

Residents who had asthma, including those with ER visits, were positively correlated ( $p < 0.05$ ) with the PM<sub>2.5</sub> mass concentration and its outdoor indoor ratio, orientation and floor level of the apartment, prevalence of building cracks, frequency of pest observations and airborne mold concentrations. High concentrations of indoor bioaerosols were positively correlated ( $p < 0.01$ ) to the prevalence of indoor pets. Allergens had no correlation with the thermal bridge factor and the wall air leak factor. This suggests indoor sources of allergens. The indoor air perceived to be drafty by interviewees had negative associations with endotoxin concentration and prevalence of asthma, while being positively correlated with top floor apartments, missing insulation, cracks noticed in the apartment and apartment facing an inner garden. Moisture sensed by the residents accounting for plumbing leaks and improper building maintenance was positively correlated with the measured indoor relative humidity.

This study suggests that using multiple data streams provides a cost-effective and robust method to evaluate indoor air quality, building defects and their effects in residents' health.

**5IA.3****Effect of Ventilation Type and Air Change Rate on Particle Transport in Breathing Zone between Office Occupants.**FIROZA OMAR, Shamia Hoque, *Univ. of South Carolina*

Two-dimensional and three dimensional computational simulations are performed to investigate the velocity profile, trajectory and behavior of aerosol particles released in an office space from an occupant. An Eulerian – Lagrangian framework is applied for the simulations. The particle movement pattern and the fraction of stagnant air locations are analyzed for mixing and displacement ventilation with varying air change per hour (ACH) in multiple work space designs. The effect of the presence of furniture in a space is also been investigated. The study results show that for mixing and displacement ventilation both ACH and furniture presence has significant effect on the number of particles staying in the breathing zone thus influencing infection rates of office occupants. The influence of temperature difference between inlet air and room air and the impact of the evaporation of droplets released due to sneezing are currently being investigated. The study results illustrate that only focusing on ACH will not ensure the well-being of the occupants regarding exposure to aerosols released in the room. The interior design i.e. furniture orientation, the air inlet and outlet locations and safe space distribution between the working zones can have an equal or even more significant role in determining the most effective, energy efficient and healthy indoor layout.

**5IA.4****Determinants of Particle Concentration in Social Housing in Toronto.**JEFFREY SIEGEL, Alireza Mahdavi, *University of Toronto*

The indoor environmental quality (IEQ) in social housing is often poor and the exposed population vulnerable to the health effects of indoor contaminants. We are conducting an investigation of IEQ in 75 social housing apartments in Toronto with the goal of informing building retrofits and are measuring a variety of building and environmental factors and surveying the occupants in these homes. Concentrations of particles  $>0.5$  and  $>2.5 \mu\text{m}$  were highly variable within and between the units, but were generally higher but comparable to measurements of particles in other urban homes in Canada. The single biggest determinant of elevated particulate matter concentration was the presence of at least one smoker in the apartment. However, even when the impact of smoking was removed, there were no other significant associations with other measured factors including relevant survey questions, building factors (e.g., height of unit within a building), outdoor air quality (e.g., proximity to a major roadway), per person ventilation rate ( $\text{CO}_2$  concentration relative to outdoors), and the concentration of other indoor contaminants (e.g., formaldehyde). This lack of associations suggests the importance of indoor sources, and further the challenges in reducing particle exposure among social housing inhabitants. The purpose of this project is to inform building retrofit measures with the goal of simultaneously improving thermal comfort, reducing energy use, and diminishing exposure to indoor contaminants. These results suggest the challenge of both addressing energy use and IEQ in retrofits like these.

**5IA.5**

**Measuring Penetration Factors of Fine and Ultrafine Particles in Single Family Homes before and after Weatherization Retrofits.** HAORAN ZHAO, Brent Stephens, *Illinois Institute of Technology*

Human exposure to particles of outdoor origin is highly dependent on their infiltration into buildings, which also depends on the nature of leakage pathways in the building envelope. Weatherization retrofits, which typically include efforts to air-seal and insulate building envelopes, are increasingly being applied in homes to improve energy efficiency. Because these retrofits will affect the nature of air infiltration pathways, they may also impact the ability of outdoor particles to penetrate indoors. Here we report preliminary results of the application of a recently developed test method to measure envelope penetration factors for ultrafine particles (UFPs) and fine particles (PM<sub>2.5</sub>) in seven single family houses in and around Chicago before and after their weatherization retrofits were applied. The test procedure involves the following steps to yield estimates of both penetration factors (P) and deposition loss rate coefficients (k) from the same short-term test: (1) introduce outdoor particles through temporary increases in natural ventilation to elevate indoor particle concentrations, (2) measure the subsequent decay of indoor particles during a ~1 hour indoor-only measurement period, and (3) alternately measure indoor and outdoor particle concentrations during normal infiltration conditions over a period of ~3-4 hours. An automatic switching system was used with a TSI NanoScan SMPS and Optical Particle Sizer in all homes. The data were aggregated to provide estimates of P and k for integral measures of UFPs and PM<sub>2.5</sub> mass (assuming spherical shape and unit density). Preliminary results demonstrate that mean(±S.D.) estimates of P for UFPs and PM<sub>2.5</sub> across 14 tests from 7 houses were 0.70±0.16 and 0.78±0.22, respectively, ranging from 0.46 to 0.88 and 0.64 to 0.94. Results from blower door tests show the weatherization retrofits improved the air tightness of these houses by as little as ~0% to as much as ~46%, and the changes in particle penetration factors ranged from a decrease of ~17% to an increase of ~32%. No obvious correlations were found between the retrofits and the changes in envelope penetration factors. Data continue to be collected, with the goal of measuring in a total of 30 homes.

**5IA.6**

**Real-Time Measurements of Fluorescent Biological Aerosol Particles in the Infant Near-Floor Microenvironment in a Child Development Laboratory School.** TIANREN WU, Brandon E. Boor, *Purdue University*

Infants and young children spend a considerable amount of their time (~8 hours/day) in childcare facilities. Crawling, playing, walking, movements in a crib, and other activities can induce resuspension of settled dust, a process that can contribute to early-life inhalation exposures to bacteria, fungi, pollen, and allergens. Infants can be exposed to bioaerosols they themselves resuspend, as well as particles resuspended by other infants and adults, the shedding of skin, and the transport of outdoor bioaerosols indoors via ventilation and infiltration. The objective of this study is to characterize the size distribution and concentration of fluorescent biological aerosol particles (FBAPs) in the infant near-floor microenvironment in field conditions.

Measurements were conducted in the Purple Room at the Ben and Maxine Miller Child Development Laboratory School at Purdue University. Infants in the Purple Room are 6 weeks to 2 years in age (enrollment=8) and are supervised by two teachers and a child care aid. The room is mechanically ventilated and flooring materials consist of carpet and hard tile, which are cleaned daily. A laser-induced fluorescence-based instrument, the Wideband Integrated Bioaerosol Sensor (WIBS-NEO, Droplet Measurement Technology), sampled at infant breathing zone height (50 cm) with copper tubing in an air-cooled, foam-lined plastic box designed to muffle the noise of the pump and maintain security of the infants. Total particle and FBAP size distributions (0.5 to 30 μm) were monitored continuously during occupied (7:30-17:30, M-F) and unoccupied periods for several weeks. We will present preliminary results categorizing the mean number concentration of FBAPs per event, such as free play, group time, lunch, clean-up, and quiet/nap time, to better understand the dynamic nature of infant bioaerosol exposures in childcare facilities. The transient behavior of FBAPs in the infant breathing zone will be related to the spatial proximity of infants and teachers to the WIBS, as monitored via an observation room.

**5IA.7**

**Update on Aerosol Sampling Experiment on the International Space Station.** MARIT MEYER, Gary Casuccio, *NASA Glenn Research Center*

The International Space Station (ISS) is a unique indoor environment which serves as both home and workplace to an astronaut crew, typically six people. The ISS has some aerosol sources in common with buildings on earth, but can be considered an isolated volume of air with only internally generated aerosols from occupants, their activities and ISS infrastructure. An experiment to collect particles in the ISS living spaces has been in work for over a year. The hardware was launched to the ISS in July 2016, and now two types of aerosol samplers are stowed and ready for use. The Active Aerosol Sampler (AAS) is a battery operated thermophoretic sampler with an internal pump which draws in air at a rate of 0.5 mL/min and collects particles on a transmission electron microscope grid. This is a commercial-off-the-shelf device that was modified for operation in low gravity. The Passive Aerosol Sampler (PAS) has five sampling surfaces which will be exposed to air for different durations in an effort to collect an optimal quantity of particles for microscopy analysis. These samples will be returned to Earth in February 2017.

The AAS sample analysis will be primarily focused on ultrafine particles whereas the PAS sample analysis will be used to characterize the larger size fractions. Analysis techniques will include: light microscopy; manual scanning electron microscopy (MSEM) analysis (secondary and backscattered imaging with energy dispersive X-ray spectroscopy (EDS) analysis; computer controlled scanning electron microscopy (CCSEM); and Raman spectroscopy. A key component of the analytical methodology is the ability to relocate particles in different instruments (e.g., light microscope → Raman → SEM → CCSEM).

Information on the flight hardware and planned experiments, astronaut training details, and a status update on the launch and sampling activities to date will be presented.

**5IA.8**

**Spatial Mapping of Indoor Particulate Matter Concentrations Using Wireless Network of Low-Cost Dust Sensors.** SAMEER PATEL, Jiayu Li, Apoorva Pandey, Rajan Chakrabarty, Pratim Biswas, *Washington University in St Louis*

Residential solid fuel combustion results in poor indoor air quality, and subsequent health burden. The majority of indoor air quality studies focus on gravimetric  $PM_{2.5}$  measurements inside the kitchen, mostly as an indicator of personal exposure of the person cooking. But depending on the layout and ventilation characteristics of the household, cookstove emissions can spread to other parts of the household also putting other members at risk. For a better understanding of household air pollution, monitoring the spatial particulate matter (PM) concentration profiles throughout the household is vital. This requires cost-effective instrumentation and low cost PM sensors [1] have good potential to map the spatial variability.

A wireless PM sensor (Sharp GP2Y1010AU0F) network, developed in the laboratory, was deployed in field for performance evaluation. Two households in Raipur, India using solid fuel cookstoves were selected for the study. Multiple sensors, sending real-time data wirelessly to a data-acquisition system, were installed at different locations in the kitchen and adjoining parts of the household. A TSI SidePak was also collocated with one of the sensors for performance comparison.

Data from both the sensor and SidePak demonstrated similar trends. Low spatial variability was observed within the kitchen due to its small size, poor ventilation and high smoke-release rate from the cookstove. Sensors installed in the adjoining rooms demonstrated high PM concentrations throughout the house, exposing other household members to PM levels comparable to the kitchen area. Natural ventilation sources such as open windows and doors provided insufficient air circulation. The same household demonstrated significantly different PM concentration decay rate on different days owing to varying natural air circulation conditions. Further design improvements to the sensors are also recommended to improve their performance in the field.

1. Yang, et al., *Aerosol Science and Technology* 49.11 (2015): 1063-1077.

**SIM.1**

**Mobility Spectrometer Inverted Drift Tube Design for Classification of Submicrometric Sized Particles at Atmospheric Pressures.** MD MINAL NAHIN, Carlos Larriba-Andaluz, *IUPUI*

In the Aerosol field, the Differential Mobility Analyzer (DMA) has been used almost exclusively for the classification of submicrometric sized particles. While the DMA has its strengths, its resolving power cannot compete with some of the newer Ion Mobility Spectrometers such as Drift Tubes (DTIMS) that are ubiquitously used in Analytical Chemistry. In this work, we propose a novel design of an Ion Mobility Spectrometer that couples the Drift Tube design with the flow field characteristics of the DMA: The Inverted Drift Tube (IDTIMS). In short, we propose the use of a small (9cmx5cm) tube where a linearly increasing electric field is used to oppose the migration of ions that are carried by a sheathed flow of inlet velocity  $V_{gas}$ . The ions are released at the entrance of the drift tube and will be fully stopped where there is an equilibrium between the flow velocity and drift velocity;  $V_{gas} = V_{drift} = ZE$ . In order to push the ions into an electrometer or a Condensation Particle Counter, two methods have been devised: 1) Intermittent Push Flow where the field strength is subsequently reduced in “pushes” as the ions travel through the chamber and 2) Stopping Potential Separation where a fixed field is used to stop only one ion Mobility for as long as possible in order to achieve the maximum possible resolution.

Collision Statistical Models (SDS) have been used for the simulation of an IDTIMS using SIMION. Spherical Ions are allowed to migrate through the tube using a CFD generated flow field while 2D axisymmetric calculated electrical fields hinder their progress. Particles are allowed to diffuse and therefore a numerically predicted resolution can be achieved. In particular, spherical particles of up to 120nm in diameters can easily be resolved and the IDTIMS can differentiate two particles of 50nm and 49.5nm in diameter (Width at Half Maximum less than 1%).

**SIM.2**

**Rapid Measurement of Particle Hygroscopicity.** TAMARA PINTERICH, Steven Spielman, Susanne Hering, Jian Wang, *Brookhaven National Laboratory*

We present a Humidity-controlled water-based Fast Imaging Mobility Spectrometer (H-FIMS) capable of rapid measurement of particle hygroscopic growth.

A basic water-based FIMS combines the Fast Imaging Mobility Spectrometer (Kulkarni and Wang, 2006a, b) with laminar flow water condensation methodologies (Hering et al., 2005). The water-based FIMS separates, enlarges and images individual particles to provide complete mobility size distribution measurements over a wide size range with 1-second time resolution.

In the H-FIMS, monodispersed dry particles are first selected by a Differential Mobility Analyzer (DMA). The size-selected particles are humidified, and the resulting size distribution is quickly captured by a water-based FIMS to measure the growth factor and hygroscopicity distributions. By coupling a DMA and a water-based FIMS in series, the H-FIMS system replaces the second DMA of a traditional hygroscopicity tandem DMA (H-TDMA) system with a mobility sizing system that simultaneously measures the sizes of all the humidified particles, greatly increasing the measurement speed.

The performance of H-FIMS was evaluated through laboratory experiments with hygroscopic salts of known behavior, and further through measurements of ambient aerosols. Results show that H-FIMS is able to reproduce, within a few percent, the literature values for the deliquescence and hygroscopic growth of sodium chloride and ammonium sulfate. Ambient data indicate that H-FIMS can measure the hygroscopic growth of six standard dry particle sizes ranging from 35 to 265nm within two minutes, which is an order of magnitude faster than traditional H-TDMA systems.

**SIM.3**

**A New Laminar-Flow, Water-Based Condensation Particle Counter with near 1-nm Detection.** SUSANNE HERING, Gregory Lewis, Steven Spielman, Arantzazu Eiguren Fernandez, Nathan Kreisberg, Chongai Kuang, Michel Attoui, *Aerosol Dynamics Inc*

A new, water-based, condensation particle counter has been developed that provides particle detection near 1 nm at an aerosol flow of 0.3 L/min, without use of a sheath. This “nano-WCPC” employs a three-stage, laminar-flow growth tube that moderates the temperature and water content of the output flow without reducing the peak supersaturation, and makes feasible operation at the large temperature differences necessary for high supersaturations. The sample flow passes through a wet-walled growth tube, the first portion of which is cooled to 1°-10°C. The second portion is heated to 90-95°C, and the third is cooled to ~22°C. The optics are held at 40°C. The warmed section, referred to as the “initiator”, is 20% of the overall length, and the temperature difference between the initiator and the first “conditioner” stage creates the super-saturation for particle activation. The final “moderator” section reduces both water vapor content and temperature, while maintaining the supersaturation. The system is implemented using the optics and motherboard from a TSI model 3783.

The nano-WCPC was calibrated using a “half Mini”-type high resolution differential mobility analyzer, with confirmation of sizing using tetraheptyl ammonium bromide mobility standards. When operated at an 88°C temperature differential between the conditioner and initiator, the nano-WCPC detects metal oxide particles generated from a hot nichrome wire with a 50% cut-point at 1.5 nm mobility diameter. However under these conditions the nano-WCPC also detects 10%-20% of the ions generated from either a Po-210 or soft X-ray bipolar ion source. Operation at a smaller temperature differential of 80°C mostly eliminates this detection of charger ions, but increases the 50% cut-point for the metal oxide particles to 1.8 nm mobility diameter. Pulse heights are observed to be very uniform, even though there is no sheath flow, likely due to Stefan flow driving particles towards the centerline.

**SIM.4**

**Characterization of a Diethylene Glycol Condensation Particle Counter to Rapidly Measure Sub 3 Nanometer Atmospheric Clusters through Pulse Height Analysis.** CHONGAI KUANG, *Brookhaven National Laboratory*

Atmospheric particle nucleation is an important environmental nano-scale process, with field measurements and modeling studies indicating that freshly nucleated particles can contribute significantly to the global population of aerosol and cloud condensation nuclei. Our understanding of atmospheric nucleation and its influence on climate, however, is limited, as few ambient measurements have been made of either the nucleation rate or the chemical composition of the freshly formed clusters, both of which are necessary to gain process-level understanding. Recent advances in the development of condensation particle counters (CPCs) have enabled the detection of gas-phase single molecules and molecular clusters down to 1 nanometer diameter and below through the use of new working fluids and/or varying operating conditions. This new capability has enabled the direct measurement of aerosol nucleation from trace-gas precursors in both laboratory experiments and the ambient environment, providing information necessary to understand and constrain the nucleation mechanism.

While there have been an increasing number of atmospheric cluster measurements from surface-based platforms, there have been very few measurements of the vertically-resolved ambient cluster size distribution from aerial platforms, which are needed to connect atmospheric nucleation with large-scale boundary layer transport processes. To address this measurement need, a UF (universal fluid) CPC has been adapted to rapidly measure (~ 1 Hz sampling time resolution) the cluster size distribution through pulse height analysis using diethylene glycol as the working fluid. Characterizations of the UF CPC size-dependent counting efficiency and analysis of the resulting droplet size spectra to recover the sampled aerosol size distribution will be presented using electrical mobility classified ammonium sulfate aerosol and ambient aerosol.

**SIM.5**

**SEMS Transfer Function Calculation for Fast Up- and Down-scan Operation.** MARK KANAPARTHI, Suresh Dhaniyala, *Clarkson University*

The Scanning Electrical Mobility Spectrometer (SEMS) is a popular instrument for sub-500nm aerosol size distributions measurements. The SEMS is operated with an exponentially increasing voltage step (up-scan) followed by an exponentially decreasing voltage step (down-scan). The classification characteristics of an SEMS instrument under an up-scan operation can be computed via a semi-theoretical approach. The approach involves calculating the arrival-time transfer function (ATF) of particles of one mobility and then transforming the time-based ATF to a mobility-based DMA transfer function. In our current work, we extend the original ATF approach to calculate the DMA mobility transfer function under down-scan operation. We will present the dependence of down-scan transfer function characteristics on DMA operating conditions. As the ATF-based calculation approach is only valid for particles that are injected after the commencement of the scan and that arrive before the scan ends, this approach cannot entirely describe the DMA transfer function characteristics under fast-scan operation. Here, using a combination of the ATF approach and a series representation of the up and down voltage step, we demonstrate the possibility of obtaining SEMS classification characteristics for the entire duration of the up- and down-scan operation for all SEMS operating conditions. We demonstrate that this approach helps establish a relationship between SEMS operating conditions and effective time periods at which invertible data can be obtained.

**SIM.6**

**Scanning DMA Data Inversion.** HUAJUN MAI, Rebecca Schwantes, Kelvin Bates, Weimeng Kong, John Seinfeld, Richard Flagan, *California Institute of Technology*

By scanning the voltage applied to a differential mobility analyzer (DMA) through an exponential ramp, the scanning differential mobility particle sizer (SMPS) enables rapid size distribution measurements. The inversion of SMPS data is more complex than for stepping-mode operation of the DMA (DMPS) due to the finite time response of the condensation particle counter (CPC) or aerosol electrometer (AE) that is used as a detector. Moreover, the transfer function that is most commonly used in data inversion was derived for operation of the DMA at constant voltage. While each of these factors that complicate SMPS data inversion relative to stepping-mode DMA measurements, most SMPS data inversion employs instrument static transfer and response functions for these dynamic measurements. Here we report on full characterization of a scanning DMA/laminar flow CPC measurement system, specifically an SMPS system comprised of a TSI long column DMA and a TSI model 3010 CPC.

Several studies have reported on the scanning DMA transfer function using idealized, coaxial models of the classification channel. We have determined the full scanning DMA transfer function by combining COMSOL Multiphysics™ finite element modeling of the flow and electric fields within the instrument with Monte Carlo simulations of particle transport and classification within the DMA. Mixing within the CPC introduces a residence time distribution that distributes particles that enter it over several seconds. That residence time distribution has been measured experimentally using an aerosol pulse at the instrument entrance. The data produced by the combined SMPS system has been inverted by combining deconvolution to correct the CPC data smearing effects and nonlinear least squares inversion of the scanning DMA response function. Experimental and simulation-based validation of the instrument model and data analysis procedures will be presented. Differences between the detailed analysis and either data analysis using static models or prior, simplified models of the scanning DMA will be discussed.

**SIM.7**

**Transfer Function of a New DMA and Its Use with a DEG-CPC for SMPS Measurements Starting at 1nm.** JACOB SCHECKMAN, Mark R. Stolzenburg, Michel Attoui, Hee-Siew Han, Juergen Spielvogel, *TSI Incorporated*

SMPS systems employing a DMA for sizing and a CPC for counting are widely used for measurement of aerosol particle size distributions. Measurements of particles as small as 1nm in diameter are needed in many applications. Diethylene glycol (DEG) has been used as a working fluid to grow sub-2.5nm particles to a size detectable with a butanol-based CPC (Iida et al, 2009), enabling SMPS size distributions in this size range (Jiang et al, 2011). Recently, TSI introduced the Model 3086 1nm-DMA and the Model 3777 Nano Enhancer which, when combined with a CPC (Model 3772), and suitable neutralizer, form a 1nm-SMPS system capable of size distribution measurements from 1-50nm. Here we characterized the components of this system and combined them for SMPS measurements down to 1nm.

The transfer function and penetration of the TSI Model 3086 1nm-DMA was characterized using monomobile molecular ion standards. Particles were generated by electrospray, and classified with a high-resolution DMA before being introduced into the Model 3086 DMA under test. The concentration upstream and downstream of the test DMA was measured in order to report the DMA penetration efficiencies. The data were inverted using a routine employing the diffusive transfer function introduced by Stolzenburg in order to obtain the true transfer function for the DMA under test.

The response of the TSI 3777 Nano Enhancer+3772 CPC-combination to mobility-classified NaCl was compared to a TSI Model 3068B Aerosol Electrometer and gave a CPC lower detection limit ( $d_{50}$ ) of 1.4nm, consistent with data from the literature for similar designs. The concentration linearity, response time and CPC false count rate of the combination were also characterized.

Iida, K., Stolzenburg, M. R., and McMurry, P. H. (2009). *AS&T*, 43(1), 81–96.

Jiang, J., Chen, M., Kuang, C., Attoui, M., and McMurry, P. H. (2011). *AS&T*, 45(4), 510–521.

**SIM.8**

**Testing Performance of a Scanning Mobility Particle Sizer System using Mobility Classified Challenge Aerosols.** MARK R. STOLZENBURG, Peter H. McMurry, *University of Minnesota*

Scanning Mobility Particle Sizers (SMPS) are widely used to measure aerosol size distributions with respect to mobility equivalent diameter. This paper describes a technique for assessing the performance of the SMPS hardware and software. The technique involves sampling mobility classified particles in parallel with the SMPS system and a second CPC. The SMPS charger is replaced with a "dummy" neutralizer, and the SMPS software must be set for no neutralizer or to use charge fractions equal to 1. This separates particle losses from considerations of charge fractions. (This approach does not allow testing the performance of the charger or assumptions made about charged fractions, though methods described by Wiedensohler et al. (2012) allow for the latter.) Our approach tests the effects of particle losses and SMPS CPC detection efficiencies on the accuracy of concentrations measured with the SMPS. It also provides information on the accuracy of particle size and size resolution measured with the SMPS DMA. The method can be readily implemented in the field using equipment and software that is available in many aerosol laboratories.

The standard SMPS data analysis assumes that the size distribution being measured is broad with respect to the width of the SMPS DMA transfer function. The proposed mobility classified challenge aerosol violates this assumption. It is shown that the resulting fractional errors in the recovered total concentration and mean size are of the order of the square of the dimensionless width, as relative standard deviation  $S$  (Stolzenburg and McMurry, 2008), of the SMPS DMA transfer function. For typical SMPS operation, these errors can be limited to  $S^2 < 0.7\%$ .

Stolzenburg, M.R. and McMurry, P.H. (2008). *Aerosol Sci. Technol.*, 42, 421-432.

Wiedensohler, A. et al. (2012). *Atmos. Meas. Tech.* 5: 657-685.

**5SA.1****AuRo-SoFi: The Gold Standard for Organic Aerosol Source Apportionment Using ACSM Data.**

ANDRE PRÉVÔT, Francesco Canonaco, Yuliya Sosedova, Kaspar Rudolf Daellenbach, Imad El Haddad, Carlo Bozzetti, Athanasia Vlachou, Jay Slowik, Urs Baltensperger, *Paul Scherrer Institute*

Long-term online monitoring with the aerosol chemical speciation monitor (ACSM, Aerodyne Research, Inc.) and subsequent source apportionment analysis reveals major organic aerosol sources. During the past decade the positive matrix factorization algorithm that creates linear combinations of static factor profiles (source profiles) and corresponding contributions (source contributions) has been extensively used for the source apportionment study of organic aerosol particles usually for short campaigns or seasonally divided. One way to overcome static factor profiles and assess in an improved way the uncertainties is the so-called Automated Rolling (AuRo) technique implemented in the Source Finder (SoFi) software developed at PSI. We have implemented the possibility to run thousands of constrained runs and assess the solution space a posteriori in a new way. Thereby we run constrained PMF analyses for windows of 1-2 months and move this window throughout the year leaving us with various solutions for the same day. Various criteria for the choice of "good solutions" are tested and will be presented. As mentioned, a big advantage of such exercises will be that the robustness of the chosen solutions or in other words the uncertainty of the solution can be assessed to some degree in such an approach. We will show results of some European datasets that were obtained within the European ACTRIS program, discussing the uncertainties of the source apportionment and the variability of the secondary organic aerosol factor spectra throughout the year.

**5SA.2****Quantitative Analysis of Long-term Source Contributions to the Organic Aerosol in Switzerland.**

KASPAR RUDOLF DAELLENBACH, Giulia Stefanelli, Imad El Haddad, Carlo Bozzetti, Athanasia Vlachou, Paula Fermo, Raquel Gonzalez, Andrea Piazzalunga, Christina Colombi, Francesco Canonaco, Jay Slowik, Urs Baltensperger, Andre Prévôt, *Paul Scherrer Institute*

Field deployments of the aerosol mass spectrometer have advanced the measurement of organic aerosol. Subsequent application of positive matrix factorization quantifies the contribution of primary emissions sources as biomass burning (BBOA), traffic, cooking and oxygenated OA, qualified as secondary OA (SOA). However, investigation of regional and seasonal differences by systematic long-term deployment of the AMS on a dense measurement network is impractical because of instrument cost and maintenance requirements. To overcome these limitations and to access also coarse particulate matter (PM), we have developed a method of using the AMS for the analysis of conventional aerosol filters collected worldwide. The analysis consists of water extraction of PM and subsequent atomization of the resulting solutions into the AMS. The recovery of bulk organics is approximately 70% and the retrieved mass spectra are comparable to the corresponding online measurements.

We present offline PM10 AMS measurements at 9 stations in Switzerland with different exposure characteristics for the entire year of 2013 (819 samples). Source contributions are combined with back-trajectory analysis for the determination of source regions. We demonstrate that the dominant factors governing air quality can be region-specific, e.g. BBOA is strongly enhanced in alpine valleys relative to urban centers. We observe the production of SOA in summer, following the increase in biogenic emissions with temperature. Also a highly aged SOA, prominent in winter, could be extracted. This factor correlates with anthropogenic secondary inorganic species and is most notably perceived when the site is affected by air masses from continental Europe; it could therefore be related to long-range transport. These results are also compared to laser-desorption/ionization mass spectrometry analyses for further insights in the chemical nature of the aerosol. We will present this thorough assessment of the local and regional sources affecting the air quality during winter and summer at the different sites.

**5SA.3****Source Apportionment of Organic Aerosols in Paris (France) Using Offline-AMS Analysis and Validation of Factors through the Use of External Markers.**

DEEPCHANDRA SRIVASTAVA, Olivier Favez, Nicolas Bonnaire, Kaspar Rudolf Daellenbach, Benjamin Guy Jacques Chazeau, Andre Prévôt, Imad El Haddad, Emilie Perraudin, Valérie Gros, Eric Villenave, Alexandre Albinet, *INERIS/EPOC, Université Bordeaux, France*

A detailed knowledge of the sources, transformation, and fate of organic aerosols (OA) in the atmosphere has become essential because of their major impacts on climate change and air quality. A complete understanding is still hindered by the immense chemical complexity of the organic fraction emitted from both anthropogenic and biogenic sources (primary organic aerosols, POA) or formed into the atmosphere via the photochemical oxidation of (semi-) volatile organic compounds (secondary organic aerosols, SOA). The chemical speciation of OA and the identification of their major sources are then necessary. So far, detailed information on the chemical components is generally only available for 10–30% of OA. In the present study, the source apportionment of OA is presented based on the characterization of the water-soluble organic fraction of ambient air particles, collected onto conventional filters using offline-AMS analysis. An intensive campaign was performed at SIRTA-LSCE, which illustrates the suburban background conditions of Paris (France). Every 4 hour filter measurements were conducted over a period from 6 to 24, March 2015, concomitantly with online measurements, carried out using ACSM, Aethalometer, TEOM-FDMS, NO<sub>x</sub> and O<sub>3</sub> analyzers. Source apportionment was performed on offline-AMS data by multi-linear engine (ME-2), using the newly developed Source Finder (SoFi) package. External markers (i.e. organic species like MSA, levoglucosan, oxalate and SOA molecular compounds) are used to substantiate the presence of primary and secondary factors. SoFi outputs indicate that some factors highlight different contribution over the first and second half of the sampling campaign, advocating the role of different chemical processes during these periods. Data analysis also provides more information about the different factors, their contribution to OA and existing major OA sources in Paris. Finally, results clearly illustrate the benefit of combining different measurements and the use of external markers, in aerosol source apportionment studies.

**5SA.4****Source Apportionment of Time and Size Resolved Ambient Particulate Matter Measured with a Drum Impactor at a European Air Pollution Hot Spot.** Petra Pokorná, Jan Hovorka, Yongjing Zhao, Steven Cliff, Pentti Paatero, PHILIP K. HOPKE, *Clarkson University*

For a long time, the Moravian-Silesian Region has had some of the worst air quality not only in the Czech Republic but in Europe. The objective of present study was to identify sources of five PM size fractions in a residential district in proximity to a large metallurgy complex. Measurements were conducted during two intensive winter sampling campaigns from 26 Jan to 19 Feb 2012 and 7 Feb to 3 Mar 2014 in Ostrava, the regional city of the Moravian-Silesian Region. Eight size fractions were sampled with a Davis Rotating-drum Uniform-size-cut Monitor (8 DRUM) and analyzed for 24 elements by Synchrotron-XRF with 2-h time resolution. Also 2-h mass concentrations were calculated from 5-minute number size distributions recorded with an APS and SMPS. Hourly OC/EC in PM<sub>1</sub> values were also determined. Complete meteorology including wind speed (WS), wind direction (WD), temperature (T), relative humidity and precipitation were also recorded. Databases of 2-h elemental and mass concentrations of five fractions were analyzed using a 3-way factor analysis model. The campaigns' meteorological conditions and PM differed significantly from each other. Campaign in 2012 was characterized by low T (median = -13.8°C), low WS (median = 0.8 ms<sup>-1</sup>), WD prevailing from NE and high PM<sub>1</sub> (median = 78.6 micro-g<sup>-3</sup>). Campaign in 2014 was characterized by mild winter T (median = 5.2°C), low WS (median = 1.2 ms<sup>-1</sup>), WD prevailing from SW and NE and PM<sub>1</sub> (median = 29.8 micro-g<sup>-3</sup>). A prior source apportionment study based on the elemental composition of the fine and coarse fraction sampled during winter 2012 identified coal combustion, sinter and raw iron production, and traffic. Using this more robust database and the advanced receptor model to data with multiple fraction bases, we expect precise source identification to be obtained.

**5SA.5**

**Using the Association with Nitrogen Dioxide to Apportion the Primary and Secondary Sources of Airborne Nitrated Polycyclic Aromatic Hydrocarbons (NPAHs).** YAN LIN, Xinghua Qiu, Yifang Zhu, *University of California Los Angeles*

Nitrated polycyclic aromatic hydrocarbons (NPAHs) are strong environmental mutagens and carcinogens originating from both primary emissions and secondary reactions in the atmosphere. The sources and the toxicity of different NPAH species could vary greatly; therefore a specie-specific source apportionment is essential to evaluate their health risks and to formulate controlling regulations. However, few studies have reported source apportionment of NPAHs species to date. In this study, we developed an easy-to-perform method for the apportionment of primary versus secondary sources of airborne NPAHs based on the relationship between NPAHs and NO<sub>2</sub>. After log-transformation of both NPAHs and NO<sub>2</sub> concentrations, a slope of beta between these two variables was obtained by the linear regression. When beta is significantly smaller than 1, it indicates primary emissions while beta significantly greater than 1 suggests secondary formation. We have validated this method with data previously collected in Beijing. A good correlation, with R value of 0.57, was observed between results produced by this new method and by Positive Matrix Factorization (PMF). The correlation could be further improved (R=0.71) if the gas/particle partition of NPAHs is taken into consideration. This developed method enables the source apportionment for individual NPAHs species and could be used to validate the results of other receptor models.

**5SA.6**

**A Quantitative Assessment of Source Contributions to Fine Particulate Matter (PM<sub>2.5</sub>)-bound Polycyclic Aromatic Hydrocarbons (PAHs) and Their Nitrated and Hydroxylated Derivatives in Hong Kong.** YIQIU MA, Yubo Cheng, Xinghua Qiu, Yan Lin, Jing Cao, Di Hu, *Hong Kong Baptist University*

Atmospheric polycyclic aromatic hydrocarbons (PAHs) and their derivatives are of great concern due to their adverse health effects. However, source identification and apportionment of these compounds, particularly their nitrated and hydroxylated derivatives (i.e., NPAHs and OHPAHs), in fine particulate matter (PM<sub>2.5</sub>) in Hong Kong are still lacking. In this study, we conducted a 1-year observation at an urban site in Hong Kong. PM<sub>2.5</sub>-bound PAHs and their derivatives were measured, with median concentrations of 4.59 nanogram, 44.4 picogram and 31.6 picogram per cubic meter for total 21 PAHs, total 17 NPAHs, and total 12 OHPAHs, respectively. Higher levels were observed on regional pollution days than on long regional transport (LRT) or local emission days. Based on positive matrix factorization analysis, four sources were determined: marine vessels, vehicle emissions, biomass burning, and a mixed source of coal combustion and NPAHs secondary formation. Coal combustion and biomass burning were the major sources of PAHs, contributing over 85% of PAHs on regional and LRT days. Biomass burning was the predominant source of OHPAHs throughout the year, while NPAHs mainly originated from secondary formation and fuel combustion. For benzo[a]pyrene (BaP)-based PM<sub>2.5</sub> toxicity, the mixed source of coal combustion and NPAHs secondary formation was the major contributor, followed by biomass burning and vehicle emissions.

**5SA.7**

**Source Apportionment of Ambient Particle Number Concentrations in Central Los Angeles Using Positive Matrix Factorization (PMF).** MOHAMMAD SOWLAT, Sina Hasheminassab, Constantinos Sioutas, *University of Southern California*

In this study, the Positive Matrix Factorization (PMF) receptor model (version 5.0) was used to identify and quantify major sources contributing to particulate matter (PM) number concentrations, using PM number size distributions in the range of 13 nm to 10  $\mu\text{m}$  combined with several auxiliary variables, including black carbon (BC), elemental and organic carbon (EC/OC), PM mass concentrations, gaseous pollutants, meteorological, and traffic counts data, collected for about 9 months between August 2014 and 2015 in central Los Angeles, CA. A six-factor solution was identified as the optimum: nucleation, traffic 1, traffic 2 (having a larger mode diameter), urban background aerosol, secondary aerosol, and soil/road dust. Traffic sources were the major contributor to PM number concentrations, collectively making up to above 60% (60.8-68.4%) of the total number concentrations. Their contribution was also significantly higher in the cold phase compared to the warm phase. Nucleation was another major factor significantly contributing to the total number concentrations (an overall contribution of 17%, ranging from 11.7% to 24%), having a larger contribution during the warm phase than in the cold phase. The other identified factors were urban background aerosol, secondary aerosol, and soil/road dust, with relative contributions of approximately 12% (7.4-17.1), 2.1% (1.5-2.5%), and 1.1% (0.2-6.3%), respectively, overall accounting for about 15% (15.2-19.8%) of PM number concentrations. As expected, PM number concentrations were dominated by factors with smaller mode diameters, such as traffic and nucleation. On the other hand, PM volume and mass concentrations in the study area were mostly affected by sources having larger mode diameters, including secondary aerosols and soil/road dust. Results from the present study can be used as input parameters in future epidemiological studies to link PM sources to adverse health effects as well as by policy makers to set targeted and more protective emission standards for PM.

**5SA.8**

**Organic Aerosol Sources Determined by Molecular Markers Observed during the St. Louis Air Quality Regional Study.** MICHAEL WALKER, Yaping Zhang, Xiaochen Zuo, Raul Martinez, Dhruv Mitroo, Munkhbayar Baasandorj, Lu Hu, Dylan Millet, Jay Turner, Brent Williams, *Washington University in St. Louis*

Organic aerosol (OA), which is known to influence global climate and adversely affect human health, can be enhanced through mixing of anthropogenic and biogenic emissions. The St. Louis Air Quality Regional Study (SLAQRS) was conducted in East St. Louis, Illinois between August and October of 2013, with a focus on the chemical properties of OA as urban pollution from the St. Louis metropolitan area was periodically impacted by isoprene-dominated biogenic emissions from the Ozarks to the southwest. The specific molecular composition of OA was measured with a Thermal Desorption Aerosol Gas Chromatograph (TAG), with supporting measurements of both gaseous and particulate organics with a Proton Transfer Reaction – Mass Spectrometer (PTR-MS) and High-Resolution Time-of-Flight Aerosol Mass Spectrometer (HR-ToF-AMS), respectively. Over 150 individual organic compounds have been quantified with hourly time resolution for a three week focus period that included several high isoprene events. Positive matrix factorization (PMF) analysis of these molecular markers was used to provide insight into the various OA sources. These analyses are compared with those from a recently developed chromatogram binning method, which allows for rapid PMF analysis of mass spectral datasets with chromatographic separation. This comparison highlights the advantages of each source apportionment method, with a particular focus on the isoprene-related OA.

**5UA.1**

**In-use Heavy-duty Diesel Vehicle Emission Measurements Used to Investigate the Durability of Diesel Particulate Filters.** MOLLY HAUGEN, Gary Bishop, Donald Stedman, *University of Denver*

Heavy-duty diesel trucks are important sources of oxides of nitrogen and particulate emissions. The recent introduction of selective catalytic reduction systems (SCR) and diesel particulate filters (DPF) can dramatically lower the levels of both of these when properly maintained. The Ports of Los Angeles and Long Beach instituted a forced retirement program requiring all trucks operating to have 2007 U.S. compliant engines (requiring a DPF) by January 1, 2012. This fleet comprises one of the largest concentrations of DPF equipped heavy-duty diesel trucks making it an ideal fleet for studying particulate emission deterioration. The University of Denver has collected in-use fuel specific emission measurements from heavy-duty trucks since 2008 at the Port of Los Angeles using optical remote sensing equipment. Beginning in 2013 we began using a new emission collection method that allowed for enhanced information of particle emissions at our Port of Los Angeles location and a new site on I-5 near Cottonwood, CA in Northern California.

The On-road Heavy-duty Vehicle Emission Monitoring System (OHMS) employs a 15.25m long tent and a perforated pipe to capture the integrated exhaust emissions of a heavy-duty truck as it drives through. Gaseous emissions collected include carbon monoxide, carbon dioxide, hydrocarbons, nitric oxide and total oxides of nitrogen. Particle mass and number concentration are measured with a Dekati Digital Mass Monitor while black carbon is quantified using a Droplet Measurement Technologies Photoacoustic Soot Meter. In two field campaigns in 2013 and 2015 we have collected more than 5000 fuel-specific emission measurements from the two sites. These data allow us for the first time to the investigation of the performance and durability of diesel engine emission controls. DPF's initially produced large reductions in particle mass and number emissions, however, the 2015 data shows increases in both raising concerns as to their durability.

**5UA.2**

**Effects of Particle Filters and Selective Catalytic Reduction on In-Use Heavy-Duty Diesel Truck Emissions.** CHELSEA V. PREBLE, Troy Cados, Robert Harley, Thomas Kirchstetter, *University of California, Berkeley*

Heavy-duty diesel trucks (HDDT) are a major source of nitrogen oxides (NO<sub>x</sub>) and black carbon (BC) in urban environments, contributing to persistent ozone and particulate matter air quality problems. Diesel particle filters (DPFs) and selective catalytic reduction (SCR) systems that target PM and NO<sub>x</sub> emissions, respectively, have recently become standard equipment on new HDDT. DPFs can also be installed on older engines as a retrofit device.

Previous work has shown that DPF and SCR systems can reduce NO<sub>x</sub> and BC emissions by up to ~70% and ~90%, respectively, compared to modern trucks without these after-treatment controls (Preble et al., ES&T 2015). DPFs can have the undesirable side-effect of increasing ultrafine particle (UFP) and nitrogen dioxide (NO<sub>2</sub>) emissions. While SCR systems can partially mitigate DPF-related NO<sub>2</sub> increases, these systems can emit nitrous oxide (N<sub>2</sub>O), a potent greenhouse gas.

We report new results from a study of HDDT emissions conducted in fall 2015 at the Port of Oakland and Caldecott Tunnel in California's San Francisco Bay Area. We report pollutant emission factors (g kg<sup>-1</sup>) for emitted NO<sub>x</sub>, NO<sub>2</sub>, BC, PM<sub>2.5</sub>, UFP, and N<sub>2</sub>O on a truck-by-truck basis. Using a roadside license plate recognition system, we categorize each truck by its engine model year and installed after-treatment controls. From this, we develop emissions profiles for trucks with and without DPF and SCR. We evaluate the effectiveness of these devices as a function of their age to determine whether degradation is an issue. We also compare the emission profiles of trucks traveling at low speeds along a level, arterial road en route to the port and at high speeds up a 4% grade highway approaching the tunnel. Given the climate impacts of BC and N<sub>2</sub>O, we also examine the global warming potential of emissions from trucks with and without DPF and SCR.

**5UA.3**

**Exposure to Outdoor Ultrafine Particles: Role of Traffic and Atmospheric New Particle Formation.** SHAHZAD GANI, Kyle Messier, Joshua Apte, *University of Texas at Austin*

Ultrafine particles (UFP) ( $d_p < 0.1$  micrometer) may pose important health risks. However, routine monitoring of UFP is still uncommon in most urban areas. We exploit time-resolved particle number concentration (PN) data from an extensive monitoring network in the San Francisco Bay Area to investigate the contributions of primary emissions, meteorology and new particle formation to space-time patterns of urban UFP. Our analysis incorporates ~4 years of hourly data from a network of 6 condensation particle counters (CPCs) operated by the Bay Area Air Quality Management District. Overall annual-average PN span a range of  $\sim 3 \times 10^3 \text{ cm}^{-3}$  at a semi-rural site to  $\sim 30 \times 10^3 \text{ cm}^{-3}$  at a near-road site near a major freeway with heavy truck traffic.

We observe a strong influence of traffic on PN levels: near-freeway sites show consistently higher PN than more distant sites. By separating weekdays and weekends, we observe impacts of primary sources such as traffic. For near-freeway sites, we employ traffic data to investigate the contribution of vehicles to elevated PN concentrations. Seasonal variations in ventilation modulate the effect of primary emissions. Stagnant conditions lead to elevated levels of PN and other gaseous combustion tracers (CO, NO) on winter nights relative to winter days. In contrast, strong midday peaks in PN lasting 5-7 h occur on most days in summer months, reaching concentrations similar in magnitude to those on winter nights. Because these mid-day peaks are evident at all PN monitoring sites, yet absent in the time series of any other measured pollutant, we hypothesize that they are the result of atmospheric new particle formation.

Our preliminary findings suggest that new particle formation and primary emissions may each contribute in similar magnitude to urban background PN levels during summer days in the San Francisco Bay Area.

**5UA.4**

**Understanding Ultrafine Particulate Emissions & Dispersion from Wastewater Treatment Processes in an Urban Environment.** PEDRO PIQUERAS, Robiul Md Islam, Fengying Li, Jill Luo, Mark Matsumoto, Elizabeth Stone, Akua Asa-Awuku, *University of California, Riverside*

The construction and use of wastewater treatment plants is increasing significantly as water resources become scarce and population grows. Wastewater treatment plants (WWTP) are common in urban environments and their aerosol emissions have been associated with local and regional health burden.

In this study, we present particle concentration and size distribution measurements from Orange County Sanitation District aeration basins and we relate them to filter samples collected from ambient air. In addition, we have used EPA's model AMS/EPA Regulatory Model (AERMOD) to establish a relationship between basin coverage, source emission and dispersion. Three different scenarios were modeled with annual, monthly and daily meteorological data. The scenarios that were taken into consideration were complete open basins, partially covered basins and mainly covered basins.

Results show that aerobic processes from WWTP generate particles through bubble bursting mainly in the ultrafine size range. Model outcomes suggest that the particles are transported to residential neighborhoods and public spaces such as school and parks within 1000 meters from the plant. Chemical characterization of filter samples further prove that these particles originated in the WWTP due to the incidence of fecal sterols in the collected particles.

From the model it is determined that although OCS D's aeration basins are partially covered, coverage of the basins does not substantially reduce the particle concentration emitted; therefore a different mitigation design and full coverage of the basins is advised. The relationship presented in this study can also be used in the future to determine the emission rates from other wastewater treatment facilities if area and airflow injected in the aeration basins are known.

**5UA.5**

**Role of Automobile Exhaust on the Photoreductive Solubilization of Atmospheric Iron.** JOHN HAYNES, Eva Cutler, Brian Majestic, *University of Denver*

Atmospheric iron (Fe) plays an essential role in the carbon cycle, affecting the Earth's energy balance and human health. Fe catalyzes oxidations of organic carbon species and serves as a limiting nutrient for phytoplankton in about half of the world's oceans. Wind-blown dust is the major source of atmospheric insoluble Fe while urban areas are correlated with relatively high percentages of soluble Fe. The occurrence of elevated levels of soluble Fe near urban and industrial regions suggests a correlation between Fe solubilization and organic combustion products, including polycyclic aromatic hydrocarbons (PAH). Fossil fuel consumption for internal combustion engines produce atmospheric PAH as a major component of automobile exhaust. Under light, PAH transform into oxidized components such as ketones and carboxylic acids. For example, phthalic acid (formed from naphthalene) inhibits Fe oxidation reactions and therefore may contribute to Fe reduction and increased solubility. The wind-blown dust and PAH-containing combustion products undergo long-range atmospheric transport leading to mixing and metal-organic interactions. The current study focuses on how a saturated PAH suspension affects the production of soluble Fe. Reactions of soil-based Fe and saturated solutions of PAH are performed under controlled conditions simulating natural sunlight. Samples are analyzed by ICPMS for soluble Fe before and after solar exposure reactions; soluble Fe is separated from total Fe by filtration and total Fe by acid-assisted microwave digestion. Data indicate an increase in Fe solubility (1.2% to 4.2%) in the presence of PAH, as compared to soil in water alone, and an even greater increase in Fe solubility (4.2% to 8.4%) when exposed to solar radiation. Research is ongoing to determine the dependence of oxidized PAH on kinetic and overall Fe solubility.

**5UA.6**

**Deposition and Washoff of Atmospheric Trace Metals and Anions from Two Large Building Roofs.** ALEXANDER JOHNSON, Cliff Davidson, *Syracuse University*

Building roofs are receptors of dry deposited aerosols. During a rainstorm, these aerosols may be washed off and contaminate stormwater runoff. Wet deposition can also contribute contaminants. However, there is limited understanding of the contributions of dry and wet deposition in contamination of runoff from building roofs. In addition, the potential for green roofs to act as sinks for dry and wet deposited contaminants is not well understood. Here we report the results of studies on two adjacent roofs in downtown Syracuse, New York: a 1.5 acre green roof on the Onondaga County Convention Center and a 1.3 acre asphalt roof on the War Memorial Sports Arena.

Fluxes of manganese, copper, lead, sulfate, and nitrate were measured using symmetric airfoils during dry weather periods of at least three days on the Syracuse University campus near downtown. Airborne concentrations were simultaneously measured. The dry deposition velocity for each contaminant was calculated by dividing the flux by the airborne concentration. Preliminary deposition velocities for manganese were determined to be 2.04, 1.43, and 0.733 cm/s for July 22-25 2015, November 15-18 2015, and January 21-24 2016, respectively. For the same sampling events, preliminary deposition velocities for copper were calculated as 1.34, 0.57, and 0.34 cm/s while those for lead were computed as 0.65, 0.40, and 0.26 cm/s. During rainstorms following dry periods of at least three days, fresh precipitation was collected and analyzed for the same contaminants to estimate wet deposition. In addition, stormwater runoff was collected from the roofs on the Convention Center and Sports Arena. These data are being used to compute a mass balance for each contaminant to estimate the amount washed off the asphalt roof as well as the potential leaching from the green roof.

## 5UA.7

**Uncovering an Unexpected Source of Atmospheric Lead Particle Hotspots in Delhi India.** ANDREW AULT, Hongru Shen, Thomas Peters, Gary Casuccio, Traci Lersch, Roger R. West, Amit Kumar, Naresh Kumar, *University of Michigan*

High mass concentrations of lead in particulate matter are frequently observed in the Delhi, India metropolitan area, although the sources of the lead in particles are poorly understood. In this study, particles sampled across Delhi (August – December 2008) were analyzed by computer-controlled scanning electron microscopy with energy dispersive x-ray spectroscopy (CCSEM-EDX) to improve our understanding of the spatial and physicochemical variability of lead-rich particles (> 90% lead). Levels exceeding 1.5 microgram/m<sup>3</sup> of a pure lead particle type were observed in 16% of samples, while the average across the remaining 84% was 0.7 microgram/m<sup>3</sup>. Based on individual particle composition, size, and morphology our analysis indicates that informal recycling of lead-acid batteries is the likely source of the lead. This source is not included in emission inventories, and the observed hotspots could lead to dramatically different lead exposure on a neighborhood-scale in densely populated Delhi.

## 5UA.8

**Municipal Solid Waste Burning: Discoloring the Taj Mahal and Human Health Impacts in Agra.** RAJ LAL, Ajay Nagpure, Lina Luo, Sachchida Tripathi, Anu Ramaswami, Michael Bergin, Armistead G. Russell, *Georgia Institute of Technology*

The Taj Mahal – an iconic World Heritage monument built of white marble – has become discolored with time, due, in part, to high levels of particulate matter (PM) soiling its surface. Such discoloration has required extensive and costly treatment and despite previous interventions to reduce pollution in its vicinity, the haze and darkening persists. PM responsible for the soiling has been attributed to a variety of sources including industrial emissions, vehicular exhaust and biomass burning, but the contribution of the emissions from the burning of open municipal solid waste (MSW) may also play an important role. A recent source apportionment study at the Taj Mahal showed biomass burning emissions, which would include MSW emissions, accounted for nearly 40% of organic matter (OM) – a component of PM – deposition to its surface; dung cake burning, used extensively for cooking in the region, was the suggested culprit and banned within the city limits, although the burning of MSW, a ubiquitous practice in the area, may play a more important role in local air quality. Using spatially detailed emission estimates and air quality modeling (AERMOD), we find that open MSW burning leads to about 150 (+- 130) mg m<sup>-2</sup> yr<sup>-1</sup> of PM being deposited to the surface of the Taj Mahal compared to about 12 (+- 3) mg m<sup>-2</sup> yr<sup>-1</sup> from dung cake burning. Those two sources, combined, also lead to an estimated 710 (380-1050) premature mortalities in Agra each year, dominated by waste burning in socioeconomically lower status neighborhoods. An effective waste management strategy would reduce soiling of the Taj Mahal, improve human health, and have additional aesthetic benefits.

**6AC.1****Volatility and Particle-phase Hydrolysis of Alkyl Nitrates from Anthropogenic Alkanes and Alkenes.** DONGYU

WANG, Alexander Bui, Sahil Bhandari, Jeffrey Bean, Surya Dhulipala, Henry Wallace, Robert Griffin, Lea Hildebrandt Ruiz, *University of Texas at Austin*

Alkyl nitrates (AN) are formed in the presence of nitrogen oxides (NO<sub>x</sub>) during atmospheric oxidation chemistry. Gas-particle partitioning of AN has been suggested as a mechanism for NO<sub>x</sub> cycling and transport, contributing to the regional nature of pollution events. Recent field and laboratory studies point towards hydrolysis of particulate alkyl nitrates (pAN) as a potential NO<sub>y</sub> removal pathway. The gas-particle partitioning of AN and the pAN hydrolysis rate remain largely unknown.

We carried out environmental chamber experiments to generate AN and secondary organic aerosol (SOA) from reactions of OH + NO<sub>x</sub> or nitrate radical with anthropogenic volatile organic compounds (VOCs), including four C<sub>10</sub> alkanes and alkenes (1-decene, n-decane, butylcyclohexane, and 2-methyl-1-nonene). A High Resolution Time-of-Flight Aerosol Mass Spectrometer (AMS) and a thermodenuder (TD) were deployed to determine the SOA concentration, composition, and volatility. A High Resolution Time-of-Flight Chemical Ionization Mass Spectrometer coupled to a Filter Inlet for Gases and AEROSOLS (FIGAERO) was used for molecular identification of alkyl nitrates in the gas and particle phases.

Significant SOA formation was observed, with NO<sub>3</sub>-initiated oxidation producing higher pAN mass fractions than oxidation initiated by OH + NO<sub>x</sub>. The hydrolysis rate is determined based on the pAN decay rate under low and high relative humidity conditions. An aerosol evaporation kinetics model is used to estimate SOA and pAN volatility distributions based on TD-AMS data obtained at different desorption temperatures. The pAN volatility distribution and hydrolysis rates from this work can be used in air-quality models to more accurately represent NO<sub>x</sub> cycling and the formation of SOA and ozone.

**6AC.2****Evaluation of Anthropogenic Secondary Organic Aerosol Tracers.** IBRAHIM AL-NAIEMA, Elizabeth Stone, *University of Iowa*

Secondary organic aerosols (SOA) represent an important, but undefined fraction of atmospheric fine particulate matter (PM<sub>2.5</sub>). An organic tracer-based approach has been useful in the source apportionment of PM<sub>2.5</sub> to primary and secondary biogenic sources; however, this approach has lagged behind for anthropogenic SOA. The aim of this study is to evaluate the efficacy of several classes of organic species that were previously identified in smog chamber studies of benzene, toluene, ethylbenzene, and xylenes (BTEX) in their ability to serve as tracers of anthropogenic SOA. Specifically, nitromonoaromatics, furandiones, aromatic dicarboxylic acid isomers, and 2,3-dihydroxy-4-oxopentanoic acid (a unique tracer from toluene photooxidation) were assessed in terms of their source specificity, ambient concentration, and gas-particle partitioning. First, an integrated solvent extraction and GCMS method to accurately quantify the target compounds in particle and gas phases. Second, ambient concentrations and gas-particle distributions of these species were quantified for samples were collected daily in Iowa City, IA in the fall of 2015. Third, correlations of target species with established tracers for biomass burning, vehicular emissions, and SOA were evaluated. 2,3-Dihydroxy-4-oxopentanoic acid was the most specific to toluene SOA and was only detected in the particle phase, while at low, but measureable ambient concentrations ( $0.3 \pm 0.1 \text{ ng m}^{-3}$ ). Aromatic dicarboxylic acids were detected at higher concentrations (e.g.  $13.0 \pm 4.3 \text{ ng m}^{-3}$  for phthalic acid), although some isomers showed appreciable partitioning to the gas phase and associations with primary sources. Nitromonoaromatics were dominated by particle-phase nitrocatechols that were associated with biomass burning. Meanwhile, other nitromonoaromatics were detected in lower concentrations and are possibly specific to anthropogenic SOA. The outcome of this study is that 2,3-dihydroxy-4-oxopentanoic acid and select isomers of aromatic dicarboxylic acids, nitromonoaromatics, and furandiones are good candidates for tracing anthropogenic SOA.

**6AC.3**

**Unified Method for Predicting Aerosol Formation and Composition from Aromatic Hydrocarbon under NO<sub>x</sub> Conditions in Urban Atmosphere.** LIJIE LI, Ping Tang, David R. Cocker III, Kelley Barsanti, *University of California, Riverside*

A simplified algorithm, derived from generalized reaction mechanisms, is required to enhance the efficiency of SOA predictive models. Current SOA models include increasing amount of constraints and parameters to bridge the gap between field observation and model prediction. Aromatic hydrocarbons, a class of major anthropogenic SOA precursors, are usually photooxidized in the presence of NO<sub>x</sub> in urban areas. Understanding the determinant structure in aromatic hydrocarbons to SOA formation under NO<sub>x</sub> conditions in urban region is important to SOA model prediction. This work evaluates the leading role of the aromatic ring in SOA formation from aromatic hydrocarbons under NO<sub>x</sub> conditions comparable to urban atmosphere by investigating SOA yield and elemental ratio from aromatic precursors with differing the number of alkyl substitutes, alkyl substitute length and branch ratio. Unified methods for predicting aerosol composition and formation is developed on an aromatic ring basis as both "Ring normalized SOA yield (yield<sub>r</sub>)" and "Ring based elemental ratio (O/R and H/R)". It is demonstrated that four oxygens are obtained per aromatic ring during the oxidation of aromatic hydrocarbons regardless of the alkyl substitutes attached to the ring. Ring normalized SOA yield among all aromatic hydrocarbons show similar trend to mass based SOA yield of benzene. Further, the sensitivity of current SOA model to the new batch of SOA yield parameters under low NO<sub>x</sub> conditions is presented. The SOA model predictions based on single ring normalized yield curve and multiple mass based yield curves are compared and evaluated.

**6AC.4**

**Measurement of Semivolatile and Intermediate-Volatility Organic Compounds (S/IVOC) with a Novel Thermal Desorption Electron Impact Mass Spectrometer.**

JONATHAN FRANKLIN, Gabriel Isaacman-VanWertz, Jesse Kroll, *MIT*

Intermediate-volatility and semivolatile organic compounds (S/IVOCs) are believed to be key intermediates in the oxidation of large hydrocarbons and efficient precursors to secondary organic aerosol (SOA). However, a detailed understanding of the concentrations and chemical properties of these compounds in the atmosphere has been limited by a lack of fast and reliable measurements. S/IVOCs have traditionally been difficult to measure due to their low volatilities leading to losses to sampling surfaces as well as very low concentrations of individual compounds. Presented here are data collected by the Thermal Desorption- Electron Impact- Mass Spectrometer (TD-EIMS), a novel technique for the quantification and characterization of such compounds. The system cryogenically preconcentrates sample before thermally desorbing it into a high-resolution time-of-flight mass spectrometer, yielding ensemble measurements of the concentration, volatility, and chemical composition (e.g., elemental ratios) of S/IVOCs, with fast time resolution (4-6 measurements per hour). We examine an increase in oxygen content in S/IVOCs with increasing time during oxidation experiments of typical SOA precursors in the environmental chamber at MIT.

**6AC.5****On-line and Batch Lab Measurements of Primary and Photochemically Aged Biomass Cook-stove Emissions.**

STEPHEN REECE, Aditya Sinha, Roshan Wathore, Andrew Grieshop, *North Carolina State University*

Combustion in rudimentary and improved cook-stoves used by billions in developing countries emits black carbon (BC), primary organic aerosols (POA) and precursors for secondary organic aerosol (SOA). Recent studies suggest that SOA formed during photo-oxidation of primary emissions from biomass burning may make important contribution to its atmospheric impacts. However, the extent to which stove type and operating conditions affect the amount, compositions and characteristics of SOA formed from the aging of cookstoves emissions is still largely undetermined. Here we present results from experiments with a field portable oxidation flow reactor (F-OFR) designed to assess aging of cook-stove emissions in both laboratory and field settings. Lab testing will compare the quantity and properties of fresh and aged emissions from an open fire and alternative stove designs operated on the standard water boiling test (WBT) and alternate protocols.

Diluted cook-stove emissions were exposed to a range of OH and O<sub>3</sub> concentrations in the OFR. Primary emissions were aged both on-line, to study the influence of combustion variability, and sampled from a fixed emission population in a smog chamber to examine different aging conditions. Data from real-time particle- and gas-phase instruments and integrated filter samples were collected up and down stream of the OFR. Preliminary experiments aging diluted biomass emissions from distinct phases of stove operation (smoldering and flaming) showed peak enhancement for both phases occurring between 3 and 6 equivalent days of aging with slightly greater enhancement during the flaming phase. OA emission factors, determined using the carbon balance, were also distinct to burn conditions for fresh and aged emissions. OA/BC ratios were orders of magnitude greater during smoldering than the flaming phase and both phases increased with aging. These results highlight importance of stoves operating conditions and aging on composition and characteristics of SOA with important climate forcing implications.

**6AC.6****Known and Newly Identified Semi-Volatile Organic Compounds from Biomass Burning in Amazonia:**

**Variability and Sources.** REBECCA WERNIS, Lindsay Yee, Gabriel Isaacman-VanWertz, Nathan Kreisberg, Suzane de Sá, Yingjun Liu, Scot Martin, Lizabeth Alexander, Brett Palm, Weiwei Hu, Pedro Campuzano-Jost, Douglas Day, Jose-Luis Jimenez, Paulo Artaxo, Juarez Viegas, Antonio O. Manzi, Rodrigo A. F. Souza, Susanne Hering, Allen H. Goldstein, *University of California, Berkeley*

Aerosols are a source of great uncertainty in radiative forcing predictions and have poorly understood impacts on human health. In many environments, biomass burning contributes a significant source of primary aerosol as well as reactive gas-phase precursors that can form secondary organic aerosol (SOA). One class of these precursors, semi-volatile organic compounds (SVOCs), has been shown to have a large contribution to the amount of SOA formed from fire emissions. At present, SVOC emissions from biomass burning are poorly constrained and understanding their contributions to SOA formation is an important research challenge.

In the Amazonian dry season, biomass burning is a major source of gases and aerosols reducing regional air quality. As part of the GoAmazon 2014/5 field campaign, we deployed the Semi-Volatile Thermal desorption Aerosol Gas Chromatograph (SV-TAG) instrument at the rural T3 site, 60 km to the west of Manaus, Brazil to measure hourly concentrations of SVOCs in the gas and particle phases. This comprehensive technique detects thousands of compounds, enabling the discovery of previously unidentified compounds. In this work we explore compounds for which a correlation with well-known biomass burning tracers is observed to discover the identities of new markers. We discuss contributions to the total organic aerosol from well-known, rarely reported and newly-identified biomass burning markers. We present source apportionment analysis of the identified compounds to reveal chemically specific source factors. Additionally, we report gas-particle partitioning of all identified compounds with comparison to theoretical predictions. We find that the commonly used biomass burning tracer levoglucosan existed entirely in the particle phase and contributed 0.6% and 0.3% of total organic aerosol mass in the dry and wet seasons, respectively.

**6CC.1**

**Brown Carbon Aerosol in Fresh and Aged Biomass Burning Emissions: Contribution of Individual Compounds.** ANDREY KHLYSTOV, Vera Samburova, Jessica Connolly, Chiranjivi Bhattarai, Deep Sengupta, Adam Watts, Hans Moosmuller, *Desert Research Institute*

Brown carbon (BrC) has been shown to be a potentially important contributor to light absorption by atmospheric aerosols. A significant part of atmospheric BrC has been associated with wildfires, such as forest and peat fires. No attempt has been made so far to quantitatively analyze the contribution of individual organic species and different compound classes, including Humic Like Substances (HULIS), polycyclic aromatic hydrocarbons (PAHs), and other water-soluble and non-water-soluble organic species, both primary and secondary, to light absorption by biomass burning aerosols. We will report optical properties and chemical composition of fresh and aged (using the Aerodyne potential aerosol mass reactor) biomass-burning emissions measured during laboratory combustion of fuels from five different locations around the world (boreal forest and peat land, Siberia, Russia; extra tropical forest, Oregon, USA; tropical forest and peat, Brazil; coastal swamp peat, Florida, USA; mixed conifer forest, Sierra Nevada mountains USA), covering the main wildfire-prone areas of the globe. Chemical characterization of particulate and gaseous species collected on filters and XAD cartridges includes gas chromatography mass spectrometry (GC-MS; Varian 4000 Ion Trap and Scion Triple Quad MS/MS), ultrahigh performance liquid chromatography coupled to evaporative light scattering detector (Waters UPLC-ELSD), and Total Organic Carbon analyzer (TOC; Shimadzu TOC-VCSH). In addition to a detailed chemical characterization, we will discuss contribution of individual compounds to light absorption by aerosol material extracted with polar and non-polar solvents. The contribution of an individual compound is calculated using its absorption efficiency, as measured using UV-VIS spectrophotometer, and concentration obtained for each aerosol extract.

**6CC.2**

**Real Time Absorption Spectra of Smoke from Smoldering Combustion.** Rian You, James Radney, Michael Zachariah, CHRISTOPHER ZANGMEISTER, *National Institute of Standards and Technology*

Biomass burning (BB) is a large contributor to carbonaceous aerosols in the terrestrial atmosphere. High in mass concentration, but weakly absorbing across the visible portion of the spectrum, much of the BB is formed from smoldering smokes. In this study absorption spectra of laboratory produced smoldering smokes from six types of wood were investigated. Absorption data were measured in situ between 500 nm and 840 nm using a photoacoustic spectrometer and a step-scanning a supercontinuum laser source coupled to a tunable wavelength and bandwidth filter. Smoldering smoke particles were mobility and mass-selected prior to optical characterization allowing data to be reported as mass-specific absorption cross sections (MAC). The measured MAC at 500 nm was time dependent, ranging from 0.25 m<sup>2</sup>g<sup>-1</sup> and gradually dropped to 0.03 m<sup>2</sup> g<sup>-1</sup> within 12 min of smoldering initiation. All six materials studied had a median MAC ranging between 0.026 m<sup>2</sup> g<sup>-1</sup> to 0.133 m<sup>2</sup> g<sup>-1</sup> at a wavelength of 500 nm and absorption Ångström exponents (AAE) ranged between 3.7 to 5.6. It was shown both experimentally and computationally that weakly absorbing smoldering smoke particles behave as volume absorbers for particles in excess of 750 nm.

**6CC.3****Measurements of Black Carbon and Aerosol Absorption during Global Circumnavigation and Arctic Campaigns.**

GRISA MOCNIK, Luka Drinovec, Primoz Vidmar, Grega Razorsek, Matevz Lenarcic, *Aerosol d.o.o., Slovenia*

During three flight campaigns: around the world (2012, 2016) and over the Arctic (2013) we demonstrated the feasibility of scientific research and aerial measurements of aerosolized black carbon (BC) with ultra-light aircraft. Measurements provided first ever information on BC concentrations and sources over such a large area at altitude. These data and especially the vertical distribution of BC are a crucial requirement for our understanding of the dispersion of pollutant species of anthropogenic origin, and their possible effects on radiative forcing, cloud condensation, and other phenomena which can contribute to adverse outcomes. Light absorbing carbonaceous aerosols and BC in particular are a unique tracer for combustion emissions, and can be detected rapidly and with great sensitivity by filter-based optical methods.

We have demonstrated that an ultra-light aircraft can provide valuable information on BC concentrations, their regional heterogeneity and vertical profiles with a minor payload and for a fraction of the cost associated with large airborne platforms. We have modified the aircraft to include an aerosol inlet and have developed a dedicated filter photometer, the Aethalometer prototype to measure black carbon in this challenging environment. The flights covered all continents and oceans, and operated at altitudes around 3000 m ASL and up to 9000 m ASL.

The results have shown that the BC concentrations are highly variable and reach above 2500 ng/m<sup>3</sup> at 3200 m ASL. Measuring the dependence of the aerosol absorption on the wavelength, we show that aerosols produced during biomass combustion can be transported to high altitude in high concentrations and we estimate the underestimation of the direct forcing by models assuming a simple linear relationship between BC concentration and forcing in comparison to observations.

**6CC.4****Spectral Dependence of Black Carbon Aerosol Optical Properties and Implications for Direct Radiative Forcing.**

RAJAN CHAKRABARTY, Yu Yang, Ian Arnold, Apoorva Pandey, William Heinson, *Washington University in St Louis*

The radiative properties of black carbon (BC) aerosols have been implicated in rapid global warming, accelerated melting of glaciers, changing monsoon patterns, and degradation of human health and the environment. Their poor parameterization in climate models and satellite retrieval algorithms have contributed to large uncertainties in current estimates of climate forcing. To address this issue, researchers have made thorough efforts in recent years to characterize the wavelength-dependent absorption and scattering properties of BC emitted from both small-scale, controlled combustion systems (e.g. prescribed/slash burns and cook stoves) and large-scale wildfires as a function of various process parameters such as fuel type, fire phase, environmental conditions driving the combustion process, and interrelationships of these parameters. In this talk, I will present our recent experimental and theoretical findings on the wavelength dependence of mass absorption and scattering cross-sections, single scattering albedo, and upscatter fraction of BC aerosols in the UV-Vis-IR solar spectra. Angstrom exponent analyses of these optical parameters will be presented, which provide a way for ground-based instruments and satellites to distinguish between BC emissions from a small-scale versus large-scale combustion source. I will end my talk with a discussion on the implications of our findings on the direct radiative forcing by BC.

**6CC.5****Fractal Morphology of Black Carbon Aerosol Enhances Absorption in the Thermal Infrared Wavelengths.**

WILLIAM HEINSON, Rajan Chakrabarty, *Washington University in St. Louis*

Black carbon (BC) aerosols have been identified as major contributors to global warming and climate change. Due to their formation via Brownian diffusion in high-temperature combustion systems, these particles are emitted in the form of fractal-like aggregates of carbon spherules or monomers. The light absorbing properties of BC aggregates in the visible wavelengths are now fairly well understood and quantified. On the contrary, their absorption properties in the thermal infrared (TIR) wavelengths have been an understudied area of research. Owing to their small size parameters in the TIR wavelengths, BC aggregates are simplistically parameterized in climate models and remote sensing algorithms using the Lorenz–Mie theory for spheres. This could lead to substantial errors in atmospheric correction of remotely sensed data and estimation of absorption by greenhouse gases. We numerically calculate the mass absorption cross sections (MACs) of BC fractal aggregates in the (TIR) wavelengths. Compared to equivalent-size spheres, the MAC values of BCs show a percent enhancement of  $\approx 150$  and 400 at small and large length scales, respectively. The absorption properties of aggregates with size parameters  $>1$  surprisingly continued to remain in the Rayleigh optics regime. We explain this phenomenon using the Maxwell–Garnett effective medium theory and the concept of phase shift parameter

**6CC.6****Two Wrongs Do Make a Right: The Interplay Between Assumed Morphology and the Direct Radiative Effect of Light-absorbing Organic Aerosol.**

RAWAD SALEH, Allen Robinson, Neil Donahue, Peter Adams, *Carnegie Mellon University*

Mie theory is widely employed in aerosol direct radiative effect (DRE) calculations and to retrieve the absorptivity (imaginary part of the refractive index) of light-absorbing organic aerosol (OA) from measurements. However, OA is often internally mixed with black carbon and may exhibit complex morphologies whose optical behavior cannot be predicted using Mie theory, introducing errors in the retrieved absorptivities. In this study, we performed numerical experiments and global radiative transfer modeling (RTM) to investigate the propagation of these errors to the calculated global DRE of light-absorbing OA emitted by biomass-burning. The numerical experiments involved retrieving OA absorptivities from pseudo measurements that simulated common light-absorption measurements performed in the laboratory and the field. We performed the retrievals using either the true complex morphology or simplified spherical core-shell morphology, where Mie theory could be applied. We then used the resulting absorptivities as inputs to an RTM to calculate the global DRE of biomass-burning carbonaceous aerosols.

We show that using the true OA absorptivity, retrieved with the true complex morphology, can lead to significant errors in DRE when the RTM employs Mie theory. On the other hand, when Mie theory is consistently applied in both OA absorptivity retrieval and the RTM, the errors cancel out, yielding accurate DRE. RTMs employing Mie theory should thus use parametrizations of light-absorbing OA derived from retrievals based on Mie theory.

**6IA.1**

**Characterization of Emissions from the Combustion of Solid Fuels Used for Heating in the Navajo Nation.** WYATT CHAMPION, Lea Connors, Lupita Montoya, *University of Colorado Boulder*

Over 60 percent of homes in the Navajo Nation use a wood stove for heating. Many of the stoves are old, damaged, or improperly used for coal. Previous studies in Navajo homes found elevated indoor concentrations of fine particulate matter (PM<sub>2.5</sub>) and increased risk of respiratory tract infection linked to the use of a solid fuel stove for heating. The present study characterizes gas-phase and particle emissions from two coal types (Black Mesa and Fruitland) and four wood types (Pine, Juniper, Cedar, and Oak) commonly used by the Navajo. Fuels were tested following standard protocols and using a standard cookstove, and actual Navajo woodstove, respectively. Fine particulate matter (PM<sub>2.5</sub>) was collected onto quartz and Teflon filters, while carbon monoxide (CO) and carbon dioxide (CO<sub>2</sub>) were also monitored. Particle analyses included mass, elemental and organic carbon, select polycyclic aromatic hydrocarbons (PAHs), metals, and inflammatory response to filter extracts. Preliminary results found 430 percent higher fine emissions and 53 percent more CO emissions from coal use compared to wood. Coal emitted 33 percent more CO, and nearly all PM<sub>2.5</sub>, during the ignition and cold-start phase compared to steady combustion (simmer). Wood emitted slightly more CO, but much less PM<sub>2.5</sub>, during the ignition and cold-start phase compared to steady combustion. Refined emission factors and an estimation of cellular oxidative response from exposure to these relevant solid fuels may help inform decision making in this community.

**6IA.2**

**Impact of Environmental Tobacco Smoke on Membrane-Based Energy Recovery Ventilators.** ALEXANDER SYLVESTER, Amin Engarnevis, Ryan Huizing, Steven Rogak, Sheldon Green, *University of British Columbia*

Environmental Tobacco Smoke (ETS) is a mixture of aerosols and chemical compounds known to cause health risks, respiratory irritation, and odor discomfort. ETS is the product of 'Main-Stream' smoke, exhaled by the smoker, and 'Side-Stream' smoke, released from the tip of the lit cigarette. While the relative quantity of these components varies, the Side-stream component is always dominant. In order to meet building code requirements, HVAC systems in ETS environments must supply a significant amount of outdoor air to dilute the ETS, making them extremely demanding of energy. The use of an Energy Recovery Ventilator (ERV) has the potential to substantially reduce this energy cost by transferring moisture and heat between exhaust and intake air streams.

This work investigates the influence of ETS on the performance of paper- and polymer-based materials used in ERVs via accelerated ETS exposure tests using an analogue of Side-Stream ETS, generated by drawing air through a lit cigarette and diluting the resultant smoke with fresh air.

We find that, as a result of ETS loadings equivalent to about two years of operation in a typical casino in North America, the water vapor flux through polymer- and paper-based membrane samples is reduced to 70%-34% of the initial value. In general, polymer-based membranes have much greater initial water vapor fluxes making them more desirable candidates for in-field longevity. Results from pressurized air leakage and crossover tests indicate that paper-based membranes are significantly more permeable to gases, odors, and other unwanted contaminants.

While we have found that an upstream filter has no significant effect on VOC levels, others have shown that a filter can significantly reduce ETS PM levels. Because the PM component is likely the cause of degradation, an upstream filter could be an effective method of extending ERV life in smoking environments.

**6IA.3**

**PM<sub>2.5</sub> Concentration inside Smoking and Non-smoking Hospitality Venues: Results from a Study Examining 20 Matched Pairs in Atlanta, Georgia.** ROBY GREENWALD, Amanda Renée Gailey, Rodney Lyn, *Georgia State University*

As part of the Fulton County (Georgia) Partnership to Improve Community Health project, we conducted PM<sub>2.5</sub> sampling at smoking and non-smoking hospitality venues in the Atlanta region. We compiled a list of all venues licensed to sell alcohol in Atlanta, Alpharetta, Sandy Springs, Roswell, and Union City as well as unincorporated portions of Fulton County. Study staff identified 105 bars or restaurants that allow smoking in an indoor area. We selected 20 venues at random from this list and matched them with 20 venues that prohibit smoking on the entire premises. This matching was performed in terms of venue type, size, geographic location, and targeted demographic (if any). We conducted all sampling during a 2-week period in February 2016 and visited each location during their peak occupancy hours. Matched pairs were visited consecutively on the same day or night. The sampling teams visited all venues as normal customers and unobtrusively carried monitoring equipment on their persons. We used TSI SidePak Personal Aerosol Monitors (model AM510) to measure PM<sub>2.5</sub> concentration. These monitors were calibrated against co-located filter samples obtained in a subset of smoking venues. The sampling protocol called for 15 minutes of outdoor sampling followed by at least 30 minutes inside. The number of smoking and non-smoking patrons was recorded every 5 minutes. The PM<sub>2.5</sub> concentration was 151±178 microgram/m<sup>3</sup> inside of smoking venues and 14±17 microgram/m<sup>3</sup> inside of non-smoking venues. The mean difference between matched pairs was 113±103 microgram/m<sup>3</sup> for indoor concentration and 0.19±5.6 microgram/m<sup>3</sup> for outdoor concentration. The difference between indoor and outdoor PM<sub>2.5</sub> at non-smoking venues was 5.9 microgram/m<sup>3</sup>, likely as a result of cooking activities, whereas at smoking venues, it was 144 microgram/m<sup>3</sup>. These results will be used by county health officials as part of a campaign to encourage voluntary compliance with an initiative for smoke-free public spaces.

**6IA.4**

**Indoor Indirect Emissions from Smoking in a Summertime Classroom.** ANITA AVERY, Michael Waring, Peter DeCarlo, *Drexel University*

The chemistry of the indoor environment is influenced by a combination of outdoor aerosols and indoor emissions. To analyze the impact of varying pollutant sources, measurements were made simultaneously outdoors and in a classroom at Drexel University in Philadelphia in two seasons: August 2014 and February 2016. A high-resolution time-of-flight aerosol mass spectrometer (HR-ToF-AMS) measured size-resolved non-refractory chemical components while black carbon and size distribution were measured using an aethalometer and scanning electrical mobility system (SEMS). For AMS measured sulfate, nitrate, and organic material, measured median indoor to outdoor concentration ratios were 0.37, 0.55, and 0.39, respectively. The organic aerosol (OA) measured with the AMS was further analyzed with positive matrix factorization (PMF). PMF results revealed some factors previously identified outdoors, including oxygenated OA (OOA), hydrocarbon-like OA (HOA), as well as a new factor, an indoor-originated OA (IOOA) factor. In both environments, the HOA factor followed daytime traffic patterns from nearby highway sources, COA followed patterns of lunchtime and evening outdoor cooking, and OOA peaked in the evening consistent with photochemical aging. The IOOA contained high nitrogen content and is consistent with “third-hand” cigarette emissions. This factor was not seen in the outdoor aerosol dataset and contributed 29% of the total submicron aerosol loading indoors. The classroom was located close to an outdoor balcony frequently used for illicit smoking, but changes in IOOA concentrations were variable over hours, indicating that it is emitted over time after deposition indoors. Impacts of occupancy on submicron aerosol composition is also investigated with increasing CO<sub>2</sub> levels used as a proxy for occupancy. Aerosol composition and ozone levels pre, during, and post occupancy will also be discussed.

**6IA.5**

**Buildup Rate of Organic Film on Household Surfaces Estimated from Particle Production from the Heated Surfaces.** LANCE WALLACE, Wayne Ott, Charles Weschler, Alvin Lai, *EPA - retired*

Ultrafine particles are produced in very large quantities by heating electric stovetops and cooking pans. These particles may be ultimately due to an organic film (possibly SVOCs) coating the heated surfaces. When heated, molecules escape from the surface, but as they enter cooler air, supersaturation and condensation occur and particles are created. As time goes on, a surface that has been heated, losing its surface film, will build up a new film after it cools. Assuming a relatively unchanging indoor environment, the buildup would be expected to approach an equilibrium thickness. The time to equilibrium has been estimated by several investigators, varying from a few months to a few years. We report on initial results from an extended experiment to measure whether indeed an equilibrium can be reached in an inhabited house, and if so what the time to equilibrium might be. We also consider the relation between particle production and surface temperature. The approach is to heat surfaces (e.g. borosilicate glass Petri dishes) until no particles are created and then to reheat them after known intervals during which they are exposed to indoor air in an inhabited home. Size-resolved particles in the range of 3-160 nm are counted. Presently 70 experiments have been carried out over exposure periods from 3 to 98 days. Initial indications are that the characteristic time tau may be on the order of 120 days. Observed production rates range from about 10 billion to 1 trillion particles per square cm, with an associated mass of about 0.03 to 3 micrograms per square cm. Few particles are produced below temperatures of 200 degrees C, or above temperatures of 350 degrees C. These values may change as further experiments accumulate (to more than 200 days) over the period between now and the AAAR conference.

**6IA.6**

**Evaluation of the Emissions Performance of Natural and Forced Draft Cookstoves in Rural Malawi (Field) and Laboratory Settings.** Roshan Wathore, Kevin Mortimer, ANDREW GRIESHOP, *North Carolina State University*

Biomass burning cookstoves used by over 3 billion people accounts for 25% of global black carbon (BC) emissions and a huge burden on human health and the environment. A recent proposal to issue credits certifying BC mitigation efforts, such as replacing traditional cookstoves with improved models, depends on having knowledge of achievable BC reductions. To contribute in this initiative, an emission measurement campaign was undertaken in 2 districts of Malawi (Chikhwawa and Balaka) where over 90% of the population is dependent on wood fuel for household energy. Traditional and cleaner burning cookstoves were tested during routine cooking activities in rural households. Improved stoves included 2 forced draft gasifier stoves - Philips HD4012 and ACE-1, and a locally manufactured natural draft clay stove - Chitetezo Mbaula. CO<sub>2</sub>, CO, particle light scattering (for PM<sub>2.5</sub>) and absorption (from BC) were measured in real-time along with integrated filter samples for PM<sub>2.5</sub> and Organic/Elemental Carbon (OC/EC) analyses.

Fuel based emission factors (EF; g pollutant per kg fuel), were estimated using the carbon balance approach. PM<sub>2.5</sub> EFs for traditional cookstoves averaged  $7.8 \pm 2.9$  g/kg, with the Philips showing roughly 50% reduction ( $4.1 \pm 0.6$  g/kg), although far lower EFs (0.8 g/kg) have been observed in US-EPA laboratory tests using the standard water boiling test (WBT) protocol. In the field, gasifiers indicated highest EC (akin to BC) to total carbon (TC = OC + EC) ratios and lowest single scattering albedos, indicating greater specific climate warming. When accounting for cooking time and wood consumed, gasifiers showed the lowest global warming potential. Frequency distributions of real-time particle properties for gasifier stoves show that few events such as startup and wood addition dominate particle scattering and absorption respectively. The discrepancy between laboratory and field performance will be investigated for the aforementioned cookstoves from standard WBTs and newly developed laboratory protocols.

**6IM.1**

**An On-line Monitor of the Oxidative Capacity of Airborne Particulate Matter (o-MOCA).** ARANTZAZU EIGUREN FERNANDEZ, Nathan Kreisberg, Susanne Hering, *Aerosol Dynamics Inc*

We have developed a laboratory prototype of an on-line, field-deployable instrument for the time-resolved quantification of the capacity of airborne particles to generate reactive oxygen species (ROS). Our approach adapts the widely accepted dithioerythritol (DTT) redox assay to on-line analysis of concentrated samples of airborne particles collected directly into sub-milliliter volumes of liquid using our firm's condensationally-enhanced particle collection technology. The on-line Monitor of the Oxidative Capacity of Airborne Particulate Matter (o-MOCA) consists of a liquid collector coupled to a chemical module where the DTT analysis is conducted in-situ. The liquid collector is uniquely capable of collecting both soluble and insoluble constituents of airborne particles, and employs moderate temperatures to achieve particle growth, so that the sample is never subjected to temperatures above approximately 35 °C. The standard DTT assay has been modified for fast (30 min) analysis and coupled to the liquid collector for programmed sample transfer. The concentrated nature of the suspension allows measuring the oxidative potential of particulate matter with time resolution of a few hours.

The system was optimized and tested using 9,10-Phenanthroquinone (PQ). A linear response in DTT consumption rate ( $\mu\text{M}/\text{min}$ ) with PQ concentration was obtained. The o-MOCA chemical module was validated using a diesel exhaust particle (DEP) extract, which has been well characterized over the years and used for the development and validation of the standard DTT analysis (provided courtesy of Dr. Arthur Cho; University of California at Los Angeles). This extract has been used. The DTT consumption rates ( $\text{nmol}/\text{min}$ ) obtained with the o-MOCA were within experimental uncertainties of those reported by the UCLA group over a range of DEP concentrations. Our fully automated o-MOCA prototype was operated unattended for 3 days, collecting and analyzing 3-hr ambient particulate matter samples.

**6IM.2**

**Comparison of Aerosolization Devices for Colloidal Particles.** SIQIN HE, Derek Oberreit, *Kanomax FMT, Inc.*

The properties of aerosol particles generated by nebulization-evaporation of a liquid sample are affected by the size distribution of the dispersed droplets as well as the concentrations of dissolved and discrete non-volatile residue. In this work, we measure and compare the droplet size distributions of four commercially available nebulizers. Additionally, we measure and compare the aerosol particle size distributions of colloidal samples aerosolized with these devices. We vary both the concentration of dissolved non-volatile residue within the sample as well as the number concentration of colloidal particles to explore the practical limits for each of the devices.

We also compare the aforementioned measurements to PSD measurements of electrospray generated aerosols. Electrospray aerosolization is the de-facto standard for generating gas phase nano-particles from liquid samples; however, electrospray aerosolization has several limitations with respect to sample properties as well as stability and ease of use. We show that pneumatic type nebulization devices are able to achieve similar results compared to electrospray without the associated limitations.

**6IM.3**

**Aerosol Concentration Calibration and Controlled Delivery for 1 to 8 Micron.** VASANTHI SIVAPRAKASAM, Jay D. Eversole, David Silcott, Miles Owen, John E. Tucker, Jesse Linnell, Frank MacDonald, Anthony Woods, *Naval Research Laboratory*

We describe a calibration method for aerosol instruments that determine particle concentration, such as optical particle counters. Ideally, aerosol samples of a known, fixed concentration would be used to calibrate an instrument that measures concentration. However, until now, traceable aerosol concentration standards, and controlled aerosol generation have not been available.

We have developed and demonstrated a simple device referred to as a constant concentration aerosol generator (CCAG) based on a Collison nebulizer with feedback control from a custom OPC that monitors the total output particle count rate, to adjust the pressure in the nebulizer to achieve homeostasis. Output aerosol concentrations are controlled to a level where the temporal variation in the particle counts is dominated by Poisson statistics. The dynamic output concentration can be controlled over a range of at least a factor of four using this method, while the nominal value can be selected over a wide range based on the polymer bead liquid suspension concentration used. Total flow is controlled, and can be selected over a range from 20 to 60 lpm.

To reference the CCAG output, a pathway for a traceable count concentration standard has also been developed. Essentially monodisperse aerosols of polymer spheres can be generated at a stationary rate and provided simultaneously to an OPC and a reference settling chamber. We will discuss use of a commercially available Wafer Surface Scanner (WSS) to provide a total particle count from the settling chamber, which can be subsequently verified by direct microscopy. Comparison of the total counts on the wafer to the OPC total counts permits a determination of OPC efficiency. Using this method to determine OPC concentration measurement efficiency for particle sizes in the micron range, it is possible to provide a standardized aerosol generator of known, fixed particle concentrations.

**6IM.4**

**Experimental Evaluation of Mass Measurement Accuracy of Two Commercial Aerosol Particle Mass Analyzers in Sub-100 nm Range.** HIROMU SAKURAI, Yoshiko Murashima, *AIST*

Two commercial aerosol particle mass analyzers, namely Kanomax APM 3601 and Cambustion CPMA, were experimentally compared on the mass measurement accuracy in the size range between 12 nm and 200 nm. Laboratory-generated monodispersed aerosol particles that were size classified by a differential electrical mobility classifier (DEMC) were fed simultaneously into the two instruments that measured the number-weighted mass distribution of the fed aerosol. For each size, the mode masses determined by the two instruments were compared to the mass calculated from the particle size set on the DEMC and the material density assuming that the particles were spherical. At 100 nm and 200 nm, the measured and calculated masses agreed with each other for both instruments within 5 %. At 20 nm and 30 nm, the measured masses by the two instruments agreed with each other within 5 %, but underestimated the calculated mass by about 10 %. At 12 nm and 15 nm, the two instruments gave very different masses. On one hand, the masses by the APM underestimated the calculated mass by about 30 %. On the other hand, the mass by the CPMA overestimated the calculated mass by about 20 % and 90 % at 15 nm and 12 nm, respectively. The reason for the difference in the mass measurement performance between the two instrument at 12 nm and 15 nm was not identified.

**6IM.5**

**Development of a Universal Aerosol Conditioning Device for Particle Measurement.** Kerry Chen, Charles Robert Koch, JASON S. OLFERT, *University of Alberta*

Aerosol measurement typically requires some form of conditioning before measurements can be conducted. Typical aerosol conditioning processes include dilution, denuding, and humidification. These processes normally require separate devices; however, a newly developed device, the Universal Aerosol Conditioner (UAC) is able accomplish all of these tasks in one device with an additional application of being able to dilute the gas-phase of the aerosol without diluting the concentration of the particle-phase. This property is useful for applications where a low concentration of particles is present yet gas-phase dilution is required to prevent condensation of condensable material. For example, when measuring particulate from a DPF equipped diesel vehicle it is beneficial to reduce the concentration of the gas-phase to avoid water condensation while maintaining the initial concentration of the particles. The UAC is able to achieve this by exploiting the differences in diffusivity between the particle and gas-phases of the aerosol.

A convective-diffusion equation is used for a physics-based model of the UAC. The theoretical model was validated experimentally by running the UAC in a condition that dilutes the aerosol gas-phase but maintains the particle concentration. Particle penetration and gas-phase dilution performance of the UAC was evaluated using humid ambient particulate as the aerosol and dry air as the dilution gas. Dilution gas to aerosol flow was kept at a ratio of 10:1. At a low aerosol flow rate (0.2 LPM), the particle penetration efficiency was found to be 85% while the penetration efficiency at high flow (1.4 LPM) was 90% which agreed well with theory. Water vapour concentration was measured at the inlet and outlet of the UAC. The dilution factor was found to be ~9 which also agreed well with theory.

**6IM.6**

**Application of Centrifugal Filter to Measurement of Aerosol Particle Size Distribution.** YUTAKA TANAKA, Kosuke Shimazu, Hyun-Jin Choi, Mikio Kumita, Takafumi Seto, Yoshio Otani, *Kanazawa University*

The authors have proposed the centrifugal filter which has a tunable collection efficiency by changing the rotation speed of the filter without increasing the pressure drop. In the present work, the centrifugal filter was applied to classify aerosol particles followed by the detection of total mass or number concentrations so that we can continuously measure the size distribution of aerosol particles. The structure and operating condition of centrifugal filter were optimized in order to attain sharp separation curves with various cut-off sizes between 0.3 and 5 micro-meters. The aerosol penetrating the centrifugal filter at various rotation speeds was measured with a photometer to determine the total mass concentration (it is also possible to use a condensation particle counter when the centrifugal filter is applied to nanoparticles). The virtue of this system is such that the cut-off size is varied just by scanning the rotation speed of filter and that it can be applied to the measurement of high concentration aerosols without dilution by choosing an appropriate filter medium. We found that the centrifugal filter can achieve sharp separation curves which are comparable to a cascade impactor and it can continuously measure the change in size distribution of high concentration aerosols.

**6SA.1**

**The Relative Importance of Tailpipe and Non-tailpipe Emissions on the Oxidative Potential of Ambient Particles in Los Angeles, CA.** FARIMAH SHIRMOHAMMADI, Sina Hasheminassab, Dongbin Wang, James Schauer, Martin Shafer, Ralph J. Delfino, Constantinos Sioutas, *University of Southern California*

This study examines the associations between the oxidative potential of ambient  $PM_{2.5}$  and  $PM_{0.18}$ , measured by means of the dithiothreitol (DTT) assay, and their chemical constituents and modeled sources. Particulate matter (PM) samples were collected during 2012-2013 in Central Los Angeles (LA) and 2013-2014 in Anaheim, California, USA. Detailed chemical analyses of the PM samples, including carbonaceous species, inorganic elements and water-soluble ions were conducted. Univariate analysis indicated high correlation ( $R > 0.60$ ) between the DTT activity and the concentrations of carbonaceous species at both sites. The strongest correlations were observed between DTT and organic tracers of primary vehicle tailpipe emissions including polycyclic aromatic hydrocarbons (PAHs) and hopanes as well as EC, with higher correlations for  $PM_{0.18}$  versus  $PM_{2.5}$  components. Moreover, metals and trace elements (e.g., Ba, Cu, Fe, Mn, Pb and Sb) in both size ranges were also associated with DTT activity. Multiple linear regression (MLR) analysis was performed on DTT activity and PM sources identified by a Molecular Marker-Chemical Mass Balance (MM-CMB) model (i.e. major carbonaceous sources: vehicle tailpipe emissions, wood smoke, primary biogenic, secondary organic carbon) together with other typical sources of ambient PM (i.e. crustal material, vehicular abrasion, secondary ions and sea salt). Overall, our findings illustrate the relative importance of different traffic sources on the oxidative potential of ambient PM. Despite major reductions of tailpipe emissions, the lack of similar reductions (and possibly an increase) in non-tailpipe emissions makes them an important source of traffic-related PM in Los Angeles and their increasing role in the overall PM toxicity raises concerns for public health. This was also reflected in DTT activity levels' comparison with previous studies conducted in Central LA for  $PM_{2.5}$  and  $PM_{0.18}$  in the past decade. The trends revealed a reduction in  $PM_{0.18}$  DTT activity, while a slight increase was observed for  $PM_{2.5}$  size range.

**6SA.2**

**Source Apportionment Algorithm for an Urban Micro-environment Based on Sub-micrometer Particle Number Concentration, Equivalent Black Carbon and  $PM_{2.5}$  Mass Concentration Measurements.** RICARDO MORALES BETANCOURT, Boris Galvis, Sivaraman Balachandran, Julian David Gomez Tibaquira, *Universidad de los Andes*

A source apportionment method for fine aerosol particles at traffic impacted urban micro-environments is presented in this work. The proposed source apportionment algorithm is based on the assumption (from reported literature values) of the aerosol particle size distribution and elemental carbon content for the most prevalent sources in the micro-environments considered in the study. The contributing sources considered in this work include freshly emitted diesel exhaust particles, light duty gasoline vehicle exhaust emissions, and the contribution from urban background aerosol particles. The proposed method was applied to data collected during a 12-day measurement campaign performed in the city of Bogota during late July and early August of 2015. The exposure concentration to particulate matter to which commuters in different modes of transport (pedestrians, bicycle users, private vehicles, and several public transport alternatives) was measured. The measurements were performed with portable Diffusion Size Classifiers (DiSCmini) for sub-micrometer particle number concentration ( $N_p$ ), hand held Aethalometers (AethLabs, AE51) for mass concentration of equivalent black carbon (eBC), and laser scattering monitors for  $PM_{2.5}$  mass concentration (TSI DustTrack 8520). The mass concentration of equivalent black carbon reported by the AE51 monitors was used in combination with detailed Mie-Scattering calculations to quantify the impact of light-absorbing material on the laser scattering intensity and therefore, on the DustTrack instrument response. Additionally, a model of the DiSCmini instrument was developed to further constrain the size distribution of particles that would reproduce the reported signals by the DiSCmini instrument. The method presented here allowed us to use the limited information available from these portable instruments in the determination of the source contribution to the particle exposure of commuters in different transport micro-environments investigated.

**6SA.3**

**Seasonal Source Apportionment of Primary and Secondary Fine Particulate Matter in China Using a Source-oriented Air Quality Model.** JIANLIN HU, Qi Ying, Hongliang Zhang, *Nanjing University of Information Science & Technology*

China have been facing extreme particulate matter (PM) pollution problems due to the combination of fast increase of population, industrialization, urbanization and associated energy consumption and lagging of sufficient emission control. Studies have identified that the major components of fine PM (PM<sub>2.5</sub>) include primary species, sulfate and nitrate, and organic aerosols (OA). However, contributions of different sources to different PM components are not clear due to differences in emission, transformation and deposition processes, which are critical information needed by policy makers to design effective emission control strategies.

In this study, a source-oriented version of the Community Multiscale Air Quality (CMAQ) model that directly tracks the contributions from multiple emission sources to PM<sub>2.5</sub> components is developed, and applied to determine the regional contributions of power, industry, transportation and residential sectors to primary PM, nitrate and sulfate concentrations in China. Four months in 2012-2013 are simulated and model predictions are evaluated with ambient measured concentrations. The source-oriented CMAQ model is capable of reproducing most of the available total PM<sub>10</sub> and PM<sub>2.5</sub>, and PM<sub>2.5</sub> EC, POC, nitrate and sulfate observations. Predicted source contributions for EC also generally agree with the source contributions estimated by receptor models in literature. Model predictions suggest residential is a major contributor to primary PM (30-70%) in the spring and winter, and industrial contributes 40-60% of primary PM in the summer and fall. Transportation is an important source for EC (20-30%); Power sector is the dominating source of nitrate and sulfate in both winter and summer, transportation sector is an important source of nitrate (20-30%), and industry sector contributes 20-30% to nitrate and sulfate.

**6SA.4**

**Background PM<sub>2.5</sub> Source Apportionment at Cheeka Peak Atmospheric Observatory in the Olympic Mountain Range.** ODELLE HADLEY, *Olympic Region Clean Air Agency*

This study used the Environmental Protection Agency's positive matrix factorization model (EPA PMF5.0) to identify five primary source factors comprising the ambient PM<sub>2.5</sub> concentrations at Cheeka Peak Atmospheric Observatory (CPO), Neah Bay WA in 2011, 2012, and 2013. Cheeka Peak is home to both an IMPROVE (Interagency Monitoring for Protected Visual Environments) and an Ncore trace gas monitoring site. The first factor, identified as marine traffic residual fuel oil (RFO), was the highest contributor to PM<sub>2.5</sub> in late summer months. Over the 3-year analysis, the RFO total concentration and percent contribution to PM<sub>2.5</sub> steadily declined. This may be attributed to regulations restricting the sulfur content of ship fuel implemented in June 2012. In winter, biomass combustion (BMC) and sea salt were the highest contributors to PM<sub>2.5</sub> observed at CPO. BMC accounts for a large percent of the particulate pollution when winds are easterly. Sea salt is the dominant winter factor when winds blow from the west. Trace carbon monoxide (CO) and reactive nitrogen species (NO<sub>y</sub>) are most strongly correlated with the BMC factor. While CO is a major pollutant emitted during biomass combustion, the correlation with NO<sub>y</sub> is likely due to a shared source region, i.e. urban and suburban centers. The fourth factor was identified as aged crustal material, or dust, and was the least significant. In all three years, dust peaked in the spring and was associated exclusively with north-easterly winds. The last factor was identified as aged sea salt mixed with nitrate and sulfate. It did not exhibit a strong seasonal cycle and was not specifically associated with a particular wind direction.

**6SA.5**

**Spatial Variability of Traffic-related PM<sub>2.5</sub> Chemical Species and Sources: Comparison between Near-road and Background Environments in Metropolitan Toronto, Canada.** CHEOL-HEON JEONG, Jon M. Wang, Nathan Hiker, Jerzy Debosz, Uwayemi Sofowote, Tony Munoz, Dennis Herod, Ewa Dabek-Zlotorzynska, Greg J. Evans, *SOCAAR, University of Toronto*

Particulate matter (PM) originates from different emission sources and its toxicity can be determined based on chemical composition and sources. Much of PM<sub>2.5</sub> mass in urban areas is often associated with regional secondary aerosols resulting in relatively homogeneous contributions across cities. By contrast, metal-rich PM<sub>2.5</sub> sources (e.g. urban road dust) are often minor contributors to total PM<sub>2.5</sub> mass but their contributions can be spatially inhomogeneous. Furthermore, these metal rich sources may disproportionately contribute to PM<sub>2.5</sub> toxicity due to the high oxidative potential of some transition metals. Thus the spatial variability of traffic-related metals are of great interest as these may disproportionately mediate health outcomes arising from PM<sub>2.5</sub> exposures across metropolitan areas.

Recently, two near-road (within 20 m of major roadways) and two urban background monitoring stations were established across Toronto, Canada as part of a near roadway monitoring study. Hourly trace metal concentrations in PM<sub>2.5</sub> were measured using continuous metals monitors (Xact 625, Copper Environ) at the near-road and urban background sites. In addition to the high time resolution speciation data, 24-hr integrated PM<sub>2.5</sub> speciation measurements were conducted every 3 days using filter-based samplers at the multiple sites. The variations of PM<sub>2.5</sub> chemical speciation data were examined to identify local pollutants with more spatial variability. The hourly continuous chemical speciation data and the 24-hr integrated PM<sub>2.5</sub> speciation data at these sites were analyzed using positive matrix factorization (PMF). Local (e.g. traffic-related metal sources) and regional scale PM<sub>2.5</sub> sources were characterized at the multiple sites. The spatial and temporal variations of local traffic-related metal sources at near-road and urban background sites will be discussed.

**6SA.6**

**A Hybrid Source-receptor Modeling Approach for Estimating Source Contributions to Trace Metals in Airborne Particulate Matter.** QI YING, Jianlin Hu, Hongliang Zhang, *Texas A&M University*

Estimating of regional concentrations of trace metals using a chemical transport model (CTM) is challenging in that speciation profiles needed to estimate their emissions are often unavailable or have significant uncertainties due to very limited source testing data. A hybrid source-receptor modeling approach is developed to calculate regional distribution of trace metals utilizing predicted regional source contributions to primary PM (PPM) mass concentrations from a source-oriented CTM and the nominal emission factors of the trace metals (g/g of PPM emitted) derived from a multilinear regression analysis. For a trace metal species with measured concentrations on multiple days, the multilinear regression analysis uses predicted source contributions to PPM to estimate the optimal emission factors of the trace metal for each source so that root mean square of the difference between the predicted and observed trace metal concentrations were minimized.

In this study, regional distributions of 13 trace metals (Al, As, Ba, Ca, Cr, Cu, K, Mn, Na, Pb, Si, Ti, Zn) as well as elemental carbon (EC) concentrations in airborne particulate matter (PM) in China and the contributions of six major sources (windblown dust, residential sources, transportation, power generation, industries and open burning) to these elements were estimated using the hybrid approach. Observed concentrations of trace metals on campus of the Beihang University, which is located at an urban location in Beijing, along with the predicted PPM concentrations at that location were used to derive the emission factors. The ability of the hybrid method in predicting trace metal concentrations was evaluated by comparing the predicted and observed concentrations of trace metals in Nanjing, a major city in the Yangtze River Delta that is about 1000 km south of Beijing, and in Chengdu, a major city in Western China.

**6UA.1**

**Mapping Urban Air Quality in Oakland, CA with Google Street View Vehicles.** JOSHUA APTE, Kyle Messier, Shahzad Gani, Melissa M. Lunden, Roel Vermeulen, Christopher Portier, Steven Hamburg, *University of Texas at Austin*

Urban concentrations of traffic air pollutants vary sharply over fine spatial scales. However, spatial variation in population exposure to these pollutants is not usually well represented by routine fixed-site observations. Data from mobile air quality monitoring platforms can contribute to a richer understanding of intraurban variation in air pollution.

This study analyzes a dataset of routine mobile air quality measurements in Oakland, CA collected by a fleet of Google Street View cars equipped with fast-response (1 Hz) particle and gas instrumentation. These vehicles collect 40-60 h per week of on-road daytime air quality measurements, including black carbon (BC), size-resolved particulate matter (PM), ultrafine particles (UFP) and nitrogen oxides (NO and NO<sub>2</sub>). The dataset presented here incorporates >1200 h and >30,000 km of on-road data collected from May 2015 – April 2016. Within our core sampling region, we made ≥ 20-40 sampling trips along every public street, yielding ~20,000 repeatedly sampled 30 m road segments. We employ a suite of data reduction routines to yield stable estimates of time-averaged spatial patterns in daytime air quality.

The high-resolution maps that emerge from our data reduction exhibit consistent spatial patterns. For pollutants with a strong primary source (BC, NO, UFP), concentrations on highways are approximately twice as high on highways as on arterial streets, which in turn have levels approximately twice as high as residential streets. Pollutant concentrations decay away from freeways in a manner that can be well represented by a simple two-component exponential model. The degree of decay away from highways varies by pollutant, and is least sharp for pollutants for which a major secondary contribution, such as NO<sub>2</sub>. Consistent concentration hotspots are notable for the primary pollutants at major intersections, on roads with heavy-duty diesel traffic, and on stretches of highway prone to traffic congestion.

**6UA.2**

**Application of Google Street View Cars for Air Pollution Measurements at Community, Urban, and Regional Scales: Denver CO.** PAUL A. SOLOMON, Surender Kaushik, Andrew Whitehill, Ashok K. Singh, Melissa M. Lunden, Nick Staubach, Alexandra Teste, Davida Herzl, *U.S. EPA, Office of Research and Development, Las Vegas, NV*

Stationary National Ambient Air Quality Standards (NAAQS) require measurement of key pollutants on a community scale, but measurement sites are sparsely located in urban areas where pollutants can vary greatly on small spatial scales. Understanding variability of pollutants on small spatial scales is important for exposure assessment, air quality model evaluation, and empowering individuals to reduce health risks from air pollution. Deployment of air pollution monitors on mobile platforms greatly improves air quality information on the spatial resolution of air pollutants compared with resolution provided by routine, stationary air monitoring sites. In the current study, three Google Street View cars were instrumented with a suite of high-quality reference-grade equipment to measure pollutants of interest, such as O<sub>3</sub>, NO, NO<sub>2</sub>, CO<sub>2</sub>, black carbon, and particulate matter. Supplemental measurements that included temperature (T), relative humidity (RH), wind speed (WS), and wind direction (WD) were also included. These three instrumented automobiles were driven concurrently in a variety of spatiotemporal patterns in Denver, Colorado over 22 days from mid-July to mid-August 2014, including dense driving around stationary air monitoring and the Denver near-roadway sites as well as regionally. Routes were designed to make use of simultaneous sampling from three mobile platforms, including interconnected and overlapping patterns. This presentation will describe (1) performance characteristics of the air pollution monitors as employed in three mobile platforms relative to each car and to the NAAQS stationary sites and (2) spatial representativeness of central sites and variation of pollutants across a range of spatial scales and temporal dimensions.

**6UA.3**

**Three Dimensional Air Sampling in TAMUMAP: A Campus Collaborative for Urban Health.** SAMUEL BECK, Xingmao Ma, Juan Pedro Maestre, Yassin Hassan, Kerry Kinney, Maria D. King, *Texas A&M University*

A healthy environment is central to a healthy life. Globally, nearly 25 percent of all deaths and the total disease burden can be attributed to environmental factors according to the World Health Organization (WHO).

Engaging the population in sustainable urbanization is a powerful approach which could transform the environmental management of urban ecosystems. Indeed, a growing number of individuals and communities are participating in the collection of environmental data using low cost monitoring devices or cell-phone based sensors. However, despite the increasing public awareness and participation, a comprehensive surveillance network has yet to be developed. A unique feature of the urban environment is the potential exposure of urban population to the air hundreds of feet above the ground. The monitoring of air quality at different altitude therefore, has to be a critical component of the urban environmental management. Recently, we joined a UT Austin initiative to engage university communities in the collection and analysis of environmental samples worldwide and develop an interactive mapping platform for the public to access environmental data. We employed the wetted wall cyclone bio - nanoaerosol collector and a novel air sampler, the Unmanned Aerial System (UAS Hexacopter), for high volume aerosol sampling and detection. In addition, we have further developed the UAS Hexacopter to sample air at high elevations (e.g. 300 ft) for 3-dimensional stratified aerosol mapping. Aerosol collection has been conducted at different locations around the TAMU campus, including the cooling tower, wastewater treatment facility, veterinary hospital pond and the campus golf course creek. Concomitantly, water, soil and plant samples were collected at each location. The samples are analyzed for representative biological and chemical pollutants. The collected microbiomes are delineated by Illumina sequencing to identify existing and emerging pathogens including the bacteria *Legionella* and *Mycobacteria* and track antimicrobial resistance.

**6UA.4**

**Air Quality Impacts of Widespread Adoption of Cool Roofing Technology in the South Coast Air Basin: Ozone and PM<sub>2.5</sub>.** SCOTT A. EPSTEIN, Sang-Mi Lee, Aaron Katzenstein, Salvatore Farina, Pouya Vahmani, George Ban-Weiss, Philip Fine, *South Coast Air Quality Management District*

Cool roofs are designed to reflect a larger fraction of incident sunlight than traditional roofs, reducing the urban heat island effect and leading to a reduction in emissions from decreased air conditioning use. Lower daytime ambient temperatures and reduced NO<sub>x</sub> emissions from energy production should slow the formation of ozone and PM<sub>2.5</sub>. However, widespread adoption of cool roofs in a large urban area like the South Coast Air Basin of California may change important meteorological parameters that govern pollutant concentrations such as the planetary boundary layer height and the ventilation rate. In addition, several cool roofing materials reflect UV radiation more effectively than traditional roofing materials, increasing the path length for ozone formation, potentially leading to an increase in ozone concentrations.

We developed a comprehensive database of rooftop area apportioned by sector to project changes in albedo in response to potential air pollution control strategies within the South Coast Air Basin, a region encompassing the greater Los Angeles area with 17 million residents and significant air pollution problems. MODIS-derived high-resolution albedo measurements under a current and a future policy scenario were used along with the Weather Research and Forecasting (WRF) model to simulate Southern California meteorological fields for each day of 2012 under each scenario. The Community Multi-scale Air Quality Management System (CMAQ) was then employed to forecast changes in ozone and PM<sub>2.5</sub> concentrations under future emissions scenarios and meteorology. The multi-wavelength albedo parametrization used to calculate photochemical rate constants within CMAQ was modified to capture the effects of increased UV reflection from widespread cool roof implementation. Results of these simulations can help guide existing cool roof policies at the state and national level. Findings will inform the development of an Ozone and PM<sub>2.5</sub> control measure focused on the strategic implementation of cool roof technologies and improvement of existing local cool roof ordinances in the South Coast Air Basin.

**6UA.5**

**Influence of Future Low Carbon Energy Scenarios on California Air Pollution and Health.** Christina Zapata, Christopher Yang, Sonia Yeh, MICHAEL KLEEMAN, *University of California Davis*

California's goal to attain unprecedented greenhouse gas (GHG) emission reduction targets as low as 80% below 1990 levels by the year 2050 will require aggressive adoption of lower carbon energy resources system wide. Dramatically reducing fossil fuel combustion to reduce carbon dioxide emissions will also have ramifications for short-lived conventional criteria pollutants that affect public health such as ozone and PM<sub>2.5</sub>. This study aims to understand how air pollution and health will transform under a (i) basecase scenario (BAU) and (ii) low carbon energy scenario (GHGai) for California residents in 2050. The energy-economic optimization model CA-TIMES, was used to produce two economy-wide emission inventories that reflect each scenario's alternative fuels, electric technologies, fuel switching, and energy activity changes. Simulations of future air quality were conducted with the UCD/CIT photochemical airshed model using 2054 Weather Research Forecasting meteorological projections to produce annual PM<sub>2.5</sub> and ozone (O<sub>3</sub>) concentrations for each energy scenario. Mortality, mortality rate, and cost associated with long-term PM<sub>2.5</sub> and O<sub>3</sub> exposure were estimated using annual-average concentration fields and Center for Disease Control mortality data. Results indicate PM<sub>2.5</sub> and O<sub>3</sub> associated deaths would drop by 24-26% to 4,800-7,900 in the 2050 GHGai scenario, saving \$13-24B USD. This equates to a 54-56% PM<sub>2.5</sub> and O<sub>3</sub> mortality rate reduction relative to 2010. Ozone concentrations were predicted to increase slightly in VOC-limited regions (Los Angeles and San Diego) in the GHGai scenario, but overall 8-hour O<sub>3</sub> exceedances are greatly reduced from 2010 to 2050 and the PM<sub>2.5</sub> benefits of the GHGai scenario overwhelmingly exceed the small O<sub>3</sub> penalty.

**6UA.6**

**Clustering of Time-resolved Raman Spectra Measured Using an Aerosol Raman Spectrometer.** DAVID DOUGHTY, Steven Hill, *US Army Research Lab*

We study temporal changes of ambient aerosol measured using an automated aerosol Raman spectrometer (ARS) developed by Battelle (called the REBS). This ARS automatically samples aerosol and measures Raman spectra of individual particles from these particles. We present results from 24 hours of ambient sampling near the Washington, DC area in the United States, analyzing over 10,000 individual spectra. These results are clustered into several categories including inorganics of various types, organics, and soot and humic like substances (HULIS). Time-series of the numbers of spectra which fall into various clusters are shown. Relationships between meteorological variables and the types of Raman spectra are also examined.

**7BA.1**

**Red Tide Bioplume Assessment during BOAS Campaign: Understanding Bioaerosols Abundance and Cloud Lifecycle.** ARNALDO NEGRON-MARTY, Natasha DeLeon-Rodriguez, Natasha Hodas, Matthew Coggon, Kelvin Bates, Samantha M. Waters, Armin Sorooshian, Hafliði Jonsson, John Seinfeld, Richard Flagan, Kostas Konstantinidis, Athanasios Nenes, *Georgia Institute of Technology*

Air-Sea interactions involve the emission of particles by the sea-spray, which can release primary biological atmospheric particles (PBAP) and abiotic particles to the marine boundary layer. During bloom periods (high biological activity events) the organic fraction of the marine aerosol contributes up to 63% to the sub-micron aerosol mass and it could be a substantial marine biota contribution to cloud formation (O'Dowd CD et al., 2004). The PBAP source is highly uncertain, and depends on meteorological (e.g., wind, UV radiation, temperature) and ecosystem parameters. Particularly uncertain is the distribution and type of PBAP emissions from blooms during their growth and dissipation phases (Prather et al., 2013). Also, is unknown on how the life cycle of phytoplankton will affect the group of microorganisms emitted to the boundary layer and its possible effect in cloud formation. In this study a (Wideband Integrated Bioaerosol Sensors) WIBS-4 and SpinCon II, a wetted-wall sampler, were integrated in a Twin-Otter aircraft to collect bioaerosols samples over the marine environment in the California Coast. Additionally, a cloud condensation nuclei counter (CCNc) was onboard of the aircraft to study the CCN activity of atmospheric particles. WIBS-4 data was used to quantify the abundance of fluorescent biological atmospheric particles (FBAP) and SpinCon II samples were post-processed by flow cytometry (FCM) to quantify the total biological atmospheric particles (TBAP). Several flights were performed over the Red Tide bloom under different meteorological conditions and at different altitudes. WIBS-4 results show a day-to-day variability in the FBAP concentration over the Red Tide. Also, it shows higher concentrations of FBAP in the free troposphere than in the marine boundary layer. The data will be compared to CCNc results to understand the possible influence of the Red Tide bloom in the cloud droplet concentrations, given that previous results with bacteria isolates suggest bioaerosols could activate at cloud relevant supersaturations.

**7BA.2**

**Cloud Condensation and Ice Nucleation Phenotypic Analyses of Taxonomically Diverse Bacteria Isolated from Rainwater.** SAMANTHA M. WATERS, Sara Purdue, Smruthi Karthikeyan, James Hite, Kostas Konstantinidis, Athanasios Nenes, *Georgia Institute of Technology*

Bacteria are ubiquitous in the environment, including the atmosphere, and are capable of influencing their surroundings. While it is known that some bacteria are capable of ice formation when studied by immersion freezing (INA), characterization of cloud condensation activity (CCN) of bacteria is sparser. Additionally, most studies on these two phenotypes in bacteria is limited to very select taxonomic lineages. Bacteria are large and theoretically expected to condense water at much lower super-saturation conditions than some other aerosols, irrespective of their exterior chemistries. Therefore, it is important to empirically characterize the CCN activity and subsequent INA of taxonomically diverse bacteria. And, as bacteria vary in size from submicron to super-micron in size, depending on the species, it is of interest to understand underlying, extracellular chemistries when comparing bacteria of similar size. This interdisciplinary study employed a combination of laboratory techniques and environmental sampling to investigate the CCN and IN phenotypes of bacterial isolates collected in urban Atlanta, GA. Briefly, approximately 100 bacterial isolates from rainwater were taxonomically identified based on 16S rRNA sequencing. Interesting and previously uncharacterized bacteria (~25 isolates) were chosen from the isolates collected and phenotypic investigation of CCN and IN activity was performed. CCN experiments were conducted using a DMT Continuous Flow Streamwise Thermal Gradient CCN counter across a range of super-saturation conditions. For INA of the bacterial isolates, a droplet freezing assay (DFA) previously developed in the laboratory was used to measure immersion freezing activity of the isolates. Here we present exhaustively collected, empirical data on the cloud condensation and ice nucleation activity of the bacteria. Our CCN results agree strongly with theory, size is important even in biological surfaces; submicron bacteria, irrespective of chemistry, activate at higher supersaturation conditions than supermicron bacteria.

**7BA.3****Physical Chemistry of Biological Particles in Amazonia.**

SWARUP CHINA, Bingbing Wang, Johannes Weis, Libor Kovarik, Luciana Rizzo, Glauber Cirino, Paulo Artaxo, Mary Gilles, Alexander Laskin, *Pacific Northwest National Laboratory*

The Amazon basin, a biogeochemical reactor also known as “green ocean” due to similarities in particle concentration and cloud condensation nuclei concentration of Amazon area with remote oceanic region. Biological particles, the most abundant in the supermicrometer particles in the Amazonia- influences the cloud dynamics and hydrological cycles of Amazon basin. Physical chemistry of biological particles in the Amazon basin are still poorly understood. Measurements for this study were conducted during wet season of 2015 at the ZF2 Tower, a pristine rainforest site in the central Amazonia. The ZF2 site is located at 80 km North of Manaus. Using an array of micro-spectroscopic techniques, we investigate the chemical composition and hygroscopicity of biological Particles in Amazonia. Furthermore, we find that biological spores can rupture and release loads of fragments under high humid conditions, such as in the Amazon basin. Further investigation reveals that fragments are hygroscopic and can potentially influence cloud properties. Our findings underscore the climatic impacts of biological particles under high humidity.

**7BA.4****Sugar Polyol and Bioaerosol Concentration Variations Influenced by Rainy and Dry Periods in a Semi-Arid Rocky Mountain Pine Forest.**

MARIE GOSSELIN, Chathurika Rathanyake, Ian Crawford, Christopher Pöhlker, Janine Frohlich-Nowoisky, Beatrice Schmer, Guenter Engling, Martin Gallagher, Elizabeth Stone, Ulrich Poeschl, J. Alex Huffman, *University of Denver*

During the summer of 2011, aerosol sampling was conducted as part of the BEACHON-RoMBAS campaign (Bio-hydro-atmosphere interactions of Energy, Aerosols, Carbon, H<sub>2</sub>O, Organics, and Nitrogen – Rocky Mountain Biogenic Aerosol Study) performed at the Manitou Experiment Forest Observatory located northwest of Colorado Springs, CO. Two instruments utilizing ultraviolet laser-induced fluorescence (UV-LIF) for bioaerosol detection were operated simultaneously with many other instruments, including a high volume filter sampler. Filter fractions were analyzed for sugar polyols including arabitol and mannitol, which are chemical tracers of fungal spores. Another fraction of these filters were analyzed for fungal and bacterial DNA. This study provides the first comparison of UV-LIF instrumentation with more established tracer methods.

The ultraviolet aerodynamic particle sizer (UV-APS) and wideband integrated bioaerosol sensor (WIBS) showed trends that were generally consistent with one another. WIBS data previously analyzed by hierarchical clustering (Crawford et al., *Atmos. Meas. Techn.*, 2015) had assigned a subset of particles to a cluster they defined as fungal spores. We compared the concentrations of different categories of fluorescent particles, including the clusters, with the molecular tracer concentrations and also estimated fungal spore number concentrations from the tracer values. The UV-LIF to molecular tracer correlations varied strongly as a function of meteorological conditions. During and after rain periods the estimated concentration of airborne fungal spores was approx.  $3 \times 10^4 \text{ m}^{-3}$  and the concentration of fluorescent particles scaled strongly with both mannitol and arabitol ( $R^2$  up to 0.9). During dry periods, fungal concentrations were much lower (approx.  $1 \times 10^4 \text{ m}^{-3}$ ) and the same types of correlations were generally much poorer. Genomic results further suggest that the fungal communities were very different during rainy and dry periods.

**7BA.5****Outdoor Field Testing of a Passive Bioaerosol Sampler Based on Polarized, Ferroelectric Polymer Films.**

JENNIFER THERKORN, Nirmala Thomas, Jerry Scheinbeim, Gediminas Mainelis, *Rutgers, The State University of New Jersey*

A passive bioaerosol sampler can reduce logistical burdens and costs of active bioaerosol sampling. Here, we report on field testing of a passive bioaerosol sampler developed using parallel layers of a polarized, ferroelectric polymer (polyvinylidene fluoride, PVDF), or Rutgers Electrostatic Passive Sampler (REPS). We have shown that PVDF which has been permanently polarized by application of an external electric field enhances electrostatic capture of microorganism-sized biological particles from 15 nm to 5000 nm. Four 10 day long outdoor field test campaigns were conducted in highly varied conditions (-2 to 33°C, 17 to 98% RH) to compare collection efficiencies of REPS to an active control (Button Aerosol Samplers) and passive controls (PTFE settling filters and agar settling plates). Total bacteria and fungi were counted by Acridine Orange staining/microscopy each day for the Button Samplers and at the end of each field campaign for passive samplers. Culturable bacteria and fungi were determined daily by plating aliquots of extracted Button Sampler filter suspension and via agar settling plates, and at the end of campaigns for passive samplers. Compared to passive PTFE filters, REPS enhanced passive deposition of total microorganisms by 7-fold. REPS also significantly enhanced passive capture of culturable bacteria and fungi by 82% and 77%, respectively, and collected 65% of the culturable bacteria that the active Button Samplers collected. Since the Buttons operated at 4 L/min, REPS had an average equivalent flow rate of 2.6 L/min and 1.2 L/min for culturable bacteria, and total bacteria and fungi, respectively. These results suggest that REPS passively collects microorganisms comparably to an active sampler over long sampling durations, especially for culturable bacteria. This is most likely due to better preservation of culturability in the absence of a desiccating flow rate. Future tests will include indoor testing and development of a personal passive sampler.

**7BA.6****Metagenomic Investigation of African Dust Events in Puerto Rico Across Multiple Years.**

SAMANTHA M. WATERS, Sara Purdue, Natasha DeLeon-Rodriguez, Roy Armstrong, Yasmin Detres, Athanasios Nenes, Kostas Konstantinidis, *Georgia Institute of Technology*

The Sahara generates tons of atmospheric dust that travels intercontinental distances, including to the Caribbean islands. These events not only deposit dust but also microbial organisms; some of these organisms may include causative agents of disease outbreaks in humans, livestock, and agricultural crops. Despite the reports of Saharan dust signals in various regions of the globe, it is unknown how atmospheric transit may influence population changes of microorganisms originating from the Sahara. For the purpose of understanding transformation of microbial signals after atmospheric transport, metagenomes from Saharan Dust events (SDPR), collected in Puerto Rico, were compared to metagenomes from various environments: the Sahara, cold and hot deserts, Atlantic Ocean, tropical forest soil, and urban (Beijing) air. Puerto Rican dust events, originating from African, were confirmed by atmospheric satellite (CALIOP) and Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLOT) Model data. Analyses on extracted small subunit (SSU) rDNA fragments from the metagenomes revealed that on the bacterial level, SDPR samples have more oceanic influences than desert ones, most likely due to emission of surface water droplets containing microorganisms mixing with the air masses from dust events. However, the eukaryotic (e.g. fungal) signals considerably shift the SDPR samples to what is seen in atmospheric bioaerosol samples of the SDPR samples show a dominance of fungi typical of other air samples. SDPR metagenomes were further analyzed for the presence of pathogenic fungal signals. While a major proportion of the pathogenic fungal signals are known to affect plants (including agricultural crops), there were detectable human pathogenic agents, of which, several are known to affect the immunocompromised, such as *Cryptococcus* spp. (>90 percent nucleotide identity), which is considered to be on the rise in terms of lethality in Asian and Africa AIDS populations. Results indicate that despite long-term transit in the atmosphere, dust events from could carry persistent pathogenic signals originating from the source environment with potential of disease outbreaks.

**7BA.7**

**Comparison of Evolving Fluorescence Signatures of Biological Particles Measured with an SPFS, UV APS, and WIBS as a Function of Aging in a Rotating Drum.** SEAN KINAHAN, Yong-Le Pan, Don Collins, Matthew Tezak, Keiko Salazar, Mark Coleman, Andres Sanchez, Joshua Santarpia, *Sandia National Laboratories*

Fluorescence measurement techniques are routinely used for characterizing bioaerosols in the environment and laboratory, both when they are present as isolated populations and as parts of more complex aerosol backgrounds. The light-induced fluorescence (LIF) techniques used here employ 263- or 280-nm light to excite fluorescence from the amino acids tryptophan and tyrosine, and 351-, 355-, or 370-nm light to excite fluorescence from NADH and flavins. As biological aerosols age due to exposure to evolving environmental conditions their fluorescent signatures are altered. We used a Goldberg rotating drum to age biological simulants during a series of experiments designed to assess changes resulting from exposure to varying relative humidity, UV intensity, and concentrations of ozone and other pollutants. Fluorescence signatures were measured using the ARL Single Particle Fluorescence Spectrometer (SPFS), the TSI Inc. Ultraviolet Aerodynamic Particle Sizer, and the DMT Wideband Integrated Bioaerosol Sensor (WIBS-4A). We sought both to study the effects of aging and to compare the response of the three instruments, which employ different LIF excitation sources and sizing mechanisms. The changing strengths and characteristics of the fluorescence signatures of a variety of biological particles, including MS-2 bacteriophage and *Bacillus thuringiensis*, are presented.

**7CA.1**

**Broadband Measurements of the Mass Absorption Coefficient of Soot.** Lindsay Renbaum-Wolff, Al Fischer, Taylor Helgestad, Andrew Lambe, Geoff Smith, Christopher Cappa, Arthur J. Sedlacek, Paul Davidovits, TIMOTHY ONASCH, Andrew Freedman, *Aerodyne Research, Inc.*

Emission of soot by combustion systems comprises the primary source of light absorbing carbon-based aerosols, a species which plays an important role in radiative transfer affecting climate change. We present wavelength dependent measurements of the mass absorption coefficient (MAC) of nascent soot produced by a methane diffusion flame at 10 points over a wide spectral range (300-660 nm) in order to determine the validity of the assumption that the Angstrom Absorption Exponent is 1.0. Polydisperse soot particles were generated by an inverted methane diffusion flame. Relatively uniform single mass samples were generated by using a DMA to produce a monodisperse soot distribution and then using a CPMA to select a specific per particle mass. The average mass of that sample was measured using a second CPMA and then corrected for the presence of doubly charged particles the concentration of which was determined using an SP2. The soot absorption was measured using three separate instruments including laser-based photoacoustic absorption monitors, a CAPS PM<sub>ssa</sub> monitor, and a photoacoustic monitor employing a lamp as a light source. TEM images and the measured mass/mobility diameter relationship indicated that the soot was fractal (dimension=1.8). The absolute MAC values for the soot at several wavelengths was in excellent agreement with previously reported values. The measured AAE was  $1.25 \pm 0.24$  where the 2-sigma error is determined by the precision of the photoacoustic absorption measurements

## 7CA.2

**Effect of Thermal Denuding on Soot Aggregates Structure.**

JANARJAN BHANDARI, Swarup China, Timothy Onasch, Lindsay Renbaum-Wolff, Paul Davidovits, Eben Cross, Adam Ahern, Manvendra Dubey, Claudio Mazzoleni, *Michigan Technological University*

Soot particles are formed during incomplete combustion of carbonaceous materials and are fractal-like aggregates of carbonaceous spherules. After exposure to the atmosphere, these aggregates can undergo structural changes (e.g., coating and compaction), which in turn can affect their optical properties. One of the common approaches used to measure the effect of coating on soot optical properties is to measure absorption and scattering values in ambient air and then measure them again after removing the coating using a thermal denuder. Results of these measurements, using a thermal denuder are interpreted by making two assumptions: 1) all and only the coating material is removed from soot, 2) the pre-existing refractory soot structure is left unaffected.

In this study, we investigated the validity of the second hypothesis by studying the effect of thermal denuding on soot samples that had been generated in controlled conditions with a minimal coating and assessing whether the refractory soot particles were restructured (compacted) or not. We investigated five sets of nascent soot samples before and after thermal denuding. The samples were collected during the Boston College Experiment II and IV. More than 1200 soot particle micrographs from a Scanning Electron Microscope were used to quantify morphological parameters like roundness, convexity and fractal dimension. Our investigation shows only minimal restructure of the fresh soot during the thermodenuding, supporting the validity of the second hypothesis.

## 7CA.3

**Formation of Secondary Organic Coating on BC Particles and Its Impact on Mixing State of Carbonaceous Aerosol in the Urban Atmosphere.**

ALEX K. Y. LEE, Raghu Betha, Chia-Li Chen, Jun Liu, Derek Price, Xiaolu Zhang, Jonathan Abbatt, Christopher Cappa, Lynn Russell, *University of Toronto*

Black carbon (BC) particles emitted from fossil fuel combustion and biomass burning can result in a significant warming effect on climate. Organic coatings can be formed on BC surfaces by condensation of co-emitted primary organic aerosol (POA) material near emission sources and secondary organic aerosol (SOA) during transport, modifying light absorption and cloud condensation nuclei activity of BC. Understanding the mixing state of ambient BC and the characteristics of its associated coatings are therefore particularly important to evaluate the fate and environmental impacts of ambient BC. In this study, we examine the mixing state of BC, POA and SOA in an urban environment (Fontana, California) in summer 2015 using both single particle and ensemble measurements from an Aerodyne Soot-Particle Aerosol Mass Spectrometer (SP-AMS). The SP-AMS was operated in a configuration that can detect BC-containing particles exclusively. Using NO<sub>x</sub>/NO<sub>y</sub> ratio as a proxy for photochemical age of air masses, we observed substantial formation of SOA coatings on BC particles during the daytime. Positive matrix factorization and elemental analysis of ensemble data illustrate that most of the observed SOA coatings are freshly formed (O:C ratios ranged from 0.30 to 0.44), providing an opportunity for investigating SOA coating formation on BC particles near emissions. Preliminary results of cluster analysis of single particle measurements further indicate the presence of various types of POA and SOA coatings on BC particles based on their mass spectral characteristics and size distributions. Our observations can be used for further developing our understanding of BC mixing state and its evolution in the urban atmosphere.

## 7CA.4

**Primary and Secondary Organic Functional Groups in Vehicle Emissions by Mobile Sources Testing.** LYNN RUSSELL, Fabian Hagen, Elizabeth Singh, Jun Liu, Yunliang Zhao, Rawad Saleh, Greg Drozd, Allen H. Goldstein, Allen Robinson, *Scripps Institution of Oceanography*

Fourier Transform Infrared (FTIR) spectroscopy of organic mass collected on Teflon filters sampled from primary and photochemically-aged vehicle emissions was used to characterize the amount and organic functional group (OFG) composition of particle organic mass (OM). The vehicle emission types tested met the following emission standards: Partial Zero Emissions Vehicle (PZEV), Super-Ultra-Low-Emission Vehicle (SULEV), Ultra-Low-Emission Vehicle (ULEV), Pre-Low Emission Vehicles (LEV) (prior to 1994), LEV1 (1994-2003), and LEV2 (2004-2012). Vehicle emission categories showed differences in amount and composition of emissions, with low primary OM concentrations and emission factors characterizing the newer vehicle categories (PZEV, ULEV, SULEV). For all vehicle emission categories, we found the OFG composition was clearly distinguished for primary and secondary samples: primary emissions (sampled directly from a Constant Volume Sampler, CVS) had alkane and amine groups but no oxidized groups; secondary OM was approximately half oxidized groups with one-third alcohol and two-thirds acid groups in the Potential Aerosol Mass (PAM) chamber and more than two-thirds oxidized groups (mostly acid) in the mobile photochemical (SMOG) chamber. Comparing the compositions measured during this vehicle testing with atmospheric measurements reveals that PAM and SMOG chamber samples are very similar to vehicle-related emission factors identified in Bakersfield and elsewhere. The low OM in the CVS samples is consistent with a small primary contribution, and their amine group fraction indicates that vehicle emissions provide primary amine groups in the non-volatile fraction of primary emissions. Comparisons to FTIR OFG composition from laboratory smog experiments with individual hydrocarbon precursors indicate that the PAM and SMOG chamber samples collected here are similar to the secondary OM composition produced by very high oxidant exposures of both aromatic and alkane precursors.

## 7CA.5

**Distinct Seasonal Differences in Secondary Organic Aerosol Formation from In-situ Oxidation of Near-highway Air.** PROVAT SAHA, Stephen Reece, Andrew Grieshop, *North Carolina State University*

Motor vehicles are a major source of primary aerosols and secondary aerosol precursors. However, the extent to which motor vehicles contribute to ambient SOA production remains highly uncertain. Here, we present in-situ measurements of secondary organic aerosol (SOA) formation using an Oxidation Flow Reactor (OFR) from summer and winter field campaigns at a site 10 m from Interstate 40, outside Durham, North Carolina. In July-2015 (summer) and February-2016 (winter), ambient air at this near-highway site was exposed to high oxidant (O<sub>3</sub> and OH; hydroxyl radical) concentrations in an OFR. Submicron aerosol chemical composition, size distributions, and volatility using a thermodenuder were measured alternatively between the OFR-processed and ambient air (bypass). Results from this study show substantial seasonal differences in SOA formation upon OFR-oxidation. While a peak enhancement of OA mass concentration of ~ 3-10 µg m<sup>-3</sup> was observed during summer campaign with 2-5 days of equivalent atmospheric aging, very low enhancement (~0.5 µg m<sup>-3</sup>) was observed during winter. In contrast, measurement at both seasons show nearly consistent changes of O:C and H:C in bulk OA with OH exposures in OFR. Substantial SOA formation during summer-time and very low at winter-time suggest that biogenic emissions, which have a very strong dependence on temperature, make the dominant contribution to observed OFR-SOA production in this near-road site. These results highlight the utility of the OFR for studying the prevalence of SOA precursors in complex real-world settings.

**7CA.6**

**Study of Vehicle-emitted Nonvolatile Particles in a Traffic Tunnel Using a Thermodenuder: Measurements and Modeling.** XIANG LI, Yutong Guo, Timothy Dallmann, Satbir Singh, Albert A. Presto, *Carnegie Mellon University*

Traffic-emitted particulate matter (PM) is an important contributor to the atmospheric PM in the urban environment, which could potentially become cloud condensation nuclei (CCN) and therefore contribute to climate change. Previous work has shown that it is important to reduce the uncertainty in primary emission rates in order to reduce the uncertainty in predictions of CCN concentrations.

In the present work we have studied the size distributions of vehicle-emitted PM in a traffic tunnel in Pittsburgh, PA. PM with sizes of 7 – 500 nm were measured by a pair of scanning mobility particle sizers. A thermodenuder (TD) was held at a high temperature (250 C) and a short residence time (3 seconds) to quantify the size distribution of nonvolatile PM. After evaporating under high temperature, the nonvolatile PM appeared at two modes downstream of the TD – one consisting of EC with a peak at 80-100nm, and another consisting of particles smaller than 10 nm. The chemical composition of the smaller nonvolatile mode is uncertain.

In order to understand the characteristics of the smaller nonvolatile mode, TD experiments are simulated using a Computational Fluid Dynamics (CFD) model and the Two-Moment Aerosol Sectional (TOMAS) microphysics model. First, we simulate the condensation of semivolatile organics onto the EC particles traveling from vehicle tailpipe to the sampling inlet to predict the size-dependent OA-to-EC ratio in the particle phase. Then, we allow the aerosol particles to evaporate inside the TD. Preliminary modeling results suggest that particles with sizes of 20 - 70 nm have very high OA-to-EC ratio ranging from 6 to 30 and that the smaller non-volatile mode could potentially come from the shrinkage of larger particles when exposed to such high temperatures inside the TD.

**7CA.7**

**Climate Impact of Gasoline Direct Injection (GDI) Vehicles.** GEORGES SALIBA, Rawad Saleh, Yunliang Zhao, Albert A. Presto, Andrew Lambe, Bruce Frodin, Satya Sardar, Hector Maldonado, Andrew May, Allen Robinson, *Carnegie Mellon University*

Gasoline direct injection (GDI) vehicles are being increasingly introduced because of their improved efficiency relative to traditional port fuel injection (PFI) vehicles. A concern is that GDI vehicles can have higher EC emissions than PFI vehicles. In this study we investigated the climate implications of switching from PFI to GDI engines using the global warming potential as a metric. Forty chassis dynamometer tests using the cold-start unified cycle were conducted at the California Air Resource Board's Haagen Smit Laboratory. Gas (CO<sub>2</sub>, CO, NO<sub>x</sub>, THC, NMHC, and TOG) and particle phase (EC, OC, and PM) emission factors from 15 GDI vehicles were measured and compared to emissions from 10 PFI vehicles. GDI vehicles had lower CO<sub>2</sub> emission rates (170 g/mi reduction) and higher EC emission rates (3.7 mg/mi increase) compared to PFI vehicles. We estimated that replacing a PFI fleet by a GDI fleet will produce a net global cooling two years after emission, because reduced CO<sub>2</sub> emissions (due to higher efficiency) more than offset the additional warming from increased EC emissions. To further investigate the climate implications of GDI vehicles, we characterized (using two photo-acoustic extinctions) the presence of brown carbon in fresh and photo-chemically aged (inside a potential aerosol mass reactor) tailpipe emissions. Fresh vehicle emissions exhibited an angstrom exponent of 1.40 (with 95% CI of [1.18, 1.62]) potentially suggesting that fresh tailpipe emissions contain brown carbon. Aging tailpipe emissions slightly increased the angstrom exponent from 1.40 to 1.47 (with 95% CI of [1.28, 1.66]) indicating that oxidation of primary vapors emitted during vehicle combustion contribute negligibly to brown carbon formation.

## 7CC.1

**Microphysics of Amazonian Aerosol under Background Conditions.** JIAN WANG, Radek Krejci, Scott Giangrande, Chongai Kuang, Henrique Barbosa, Joel Brito, Samara Carbone, Xuguang Chi, Jennifer Comstock, Florian Ditas, Jost Lavric, Hanna Manninen, Fan Mei, Daniel Moran-Zuloaga, Christopher Pöhlker, Mira Pöhlker, Jorge Saturno, Beat Schmid, Rodrigo A. F. Souza, Stephen Springston, Jason Tomlinson, Tami Toto, David Walter, Daniela Wimmer, et al., *Brookhaven National Laboratory*

Aerosol particles can strongly influence the radiative properties of clouds, and they represent one of the largest uncertainties in computer simulations of climate change. The large uncertainty is in large part due to a poor understanding of processes under natural conditions, which serves as the baseline to measure change against. Understanding the processes under natural conditions is critical for a reliable assessment and quantification of ongoing and future climate change. The Amazon rainforest is one of the few continental regions where aerosol particles and their precursors can be studied under near-natural conditions.

The Observations and Modeling of the Green Ocean Amazon (GoAmazon 2014/5) campaign took place from January 2014 to December 2015 in the vicinity of Manaus, Brazil. One main objective of GoAmazon 2014/5 is to investigate the aerosol lifecycle under background conditions. Here we present the variation of aerosol size distribution observed at the T0a background site (Amazon Tall Tower Observatory, 150 km upwind of Manaus) during the wet season from March 1 to May 31, 2014. Air masses arriving at T0a during the wet season are typically brought by the north-easterly trade winds and travel across at least 1000 km of undeveloped tropical rainforest, therefore are generally clean. Also shown are vertical distributions of aerosol observed onboard the DOE Gulfstream-1 research aircraft. The sources and sinks of the boundary layer aerosol particles under the background conditions, and their impact on CCN budget will be discussed.

## 7CC.2

**Observations of the Marine Boundary Layer in the Remote North Atlantic: The Impact of Limited Nuclei on Cloud Properties.** EWAN CROSBIE, Richard Moore, Luke Ziemba, Gao Chen, Johnathan Hair, Michael Shook, Kenneth Thornhill, Edward Winstead, Armin Wisthaler, Bruce Anderson, *NASA*

Five research flights were conducted over the remote North Atlantic Ocean during the first deployment of the North Atlantic Aerosols and Marine Ecosystems Study (NAAMES) in November 2015. During these flights, near-surface aerosol and trace gas concentrations were very low indicating a scarcity of locally produced or regionally transported particles, which could serve as nuclei in the activation of cloud droplets. As a result, low cloud droplet number concentrations were observed and, during several flights, rapid onset of precipitation was apparent in warm clouds despite modest liquid water content and shallow cloud depths. We present in-situ and remote sensing data from these case flights and examine relationships between microphysics and dynamics to evaluate processes driving cloud variability over the remote oceans.

## 7CC.3

**Seasonal Variation in Remote Marine Aerosol and Cloud Condensation Nuclei Relevant for Cloud Formation.**

RICHARD MOORE, Ewan Crosbie, Luke Ziemba, Timothy A. Berkoff, Gao Chen, Chelsea Corr, Johnathan Hair, Chris Hostetler, Michael Shook, Kenneth Thornhill, Edward Winstead, Bruce Anderson, NAAMES Science Team, *NASA Langley Research Center*

It is well known that increased ocean biological activity translates into increased concentrations of submicron organic aerosol that can be transported over large distances (e.g., O'Dowd et al., *Nature*, 2004); however, the impact of these organic aerosols on CCN and the sensitivity of clouds to these aerosols in the local remote marine atmosphere remain highly uncertain. Model simulations suggest that clouds in these remote oceanic regions are highly CCN-limited as compared to continental clouds that are close to aerosol emissions sources (Moore et al., *Atmos. Chem. Phys.*, 2013). Thus, it might be expected that these clouds would be highly sensitive to presence of these biogenic aerosols.

We present airborne in situ measurements of aerosol and cloud microphysical properties and cloud condensation nuclei (CCN) spectra carried out during November 2015 and May 2016 as part of the North Atlantic Aerosols and Marine Ecosystems Study (NAAMES). These field campaigns target the minimum and maximum of the annual North Atlantic phytoplankton bloom, respectively, and provide an excellent opportunity to examine the influence of biogenic aerosols on CCN and clouds in the absence of anthropogenic pollution. The cloud droplet sensitivity to aerosols in this region will be discussed.

## 7CC.4

**Revising the Hygroscopicity of Inorganic Sea Spray Aerosol.**

PAUL ZIEGER, Olli Väisänen, Joel Corbin, Daniel Partridge, Sandra Bastelberger, Mehrnoush Mousavi-Fard, Caroline Leck, Evelyne Hamacher-Barth, Martin Gysel, Douglas Nilsson, Bernadette Rosati, Annele Virtanen, Ulrich Krieger, Ilona Riipinen, Matthew Salter, *Stockholm University*

Sea spray aerosol (SSA) particles are hygroscopic - they readily exchange moisture with their surroundings, and therefore they change their equilibrium water content and radii under different atmospheric conditions. This influences their role in chemical reactions and the rate at which they uptake gases, as well as their light-scattering properties. To date, the growth of a SSA particle above 70% relative humidity has been considered to be very close to that of NaCl. However, using a laboratory sea spray chamber we have observed that inorganic SSA particles have a significantly lower hygroscopicity than NaCl. We report these measurements alongside simulations using large-scale models designed to test the sensitivity of radiative forcing to the hygroscopicity of SSA. These highlight that the lower hygroscopicity we observe has important implications for calculations of the radiative balance of the Earth given that most models currently use NaCl as a model for inorganic SSA hygroscopicity.

## 7CC.5

**What All Organic Aerosols Serving as Ice Nuclei Have in Common.** SARAH BROOKS, Kristen Collier, *Texas A&M University*

A wide range of organic compounds can act as heterogeneous ice nuclei including polycyclic aromatic compounds, long chain alkenes, alkanes, and even glucose. Mounting experimental evidence suggests that molecular structure has seemingly no impact on the freezing temperatures of these and more work is needed to determine what alternative traits, if any, can be used to predict organic aerosols' ability to act as ice nuclei. In this study, we use an optical ice microscope apparatus equipped with a sealed cooling stage and CCD camera to examine freezing events of droplets in contact with organic ice nucleating particles (INP). Two of the representative compounds studied, squalane and squalene are liquids while the remainder are solids. Samples exposed to ozone to represent atmospheric oxidative aging. Fresh and oxidized samples are characterized using two methods, Fourier Transfer Infrared Spectroscopy with Horizontal Attenuated Total Reflectance (FTIR-HATR) and Raman Microspectroscopy. Two of the representative compounds studied, squalane and squalene are liquids while the remainder are solids. Oxidative aging causes modest improvements in ice nucleation efficiency. Both solids and viscous liquids were observed to nucleate water ice, indicating that not even phase is a strong determinant in determining the ice nucleation ability of SOA type compounds. In the case of viscous liquids, while freezing temperatures are not well correlated with viscosity, it has been shown that increased viscosity is proportional to decreased nucleation rate.

## 7CC.6

**Quantifying the Sources of Atmospheric Ice Nucleating Particles from Prescribed Burns and Wildfires.** GREGORY SCHILL, Ezra Levin, Kaitlyn J. Suski, Paul DeMott, Sonia Kreidenweis, *Colorado State University*

Despite being a basic atmospheric process, our current understanding of ice nucleation in the atmosphere is low. One reason for this low understanding is that ice nucleating particle (INP) concentrations are low (only  $\sim 1$  in  $10^5$  particles in the free troposphere nucleate ice), making it challenging to identify both the composition and sources of ambient INP. Carbonaceous combustion aerosol produced from biomass burning is one potential source of INP, as it can contribute to over one-third of all aerosol in the North American free troposphere. Unfortunately, previous results from both field measurements and laboratory studies are in conflict, with estimates of the impact of carbonaceous combustion aerosol ranging from no impact to rivaling the well-known INP mineral dust. It is, however, becoming clear that the ice nucleation activity of these aerosols depend greatly on both their fuel type and combustion conditions.

Given these dependencies, we propose that sampling from real-world biomass burning sources would provide the most useful new information on the contribution of carbonaceous combustion aerosols to atmospheric INP. In this work, we will present recent results looking at the sources of INP from prescribed burns and wildfires. To determine the specific contribution of refractory black carbon (rBC) to INP concentrations, we have coupled the Single Particle Soot Photometer (SP2) to the Colorado State University Continuous Flow Diffusion Chamber (CFDC). The SP2 utilizes laser-induced incandescence to quantify rBC mass on a particle-by-particle basis; in doing so, it also selectively destroys rBC particles by heating them to their vaporization temperature. Thus, the SP2 can be used as a selective pre-filter for rBC into the CFDC. Furthermore, we have also use a filter-based technique for measuring INP, the Ice Spectrometer, which can use pretreatments such as heating and digestion by  $H_2O_2$  to determine the contribution of biological and organic particles, respectively.

## 7CC.7

**Alteration of the Ice Nucleating Properties of Biological and Biomass Burning Particles.** Michael Polen, Hassan Beydoun, Emily Lawlis, Leif Jahn, Lydia Jahl, RYAN SULLIVAN, *Carnegie Mellon University*

Particles can experience extensive chemical and physical evolution during atmospheric transport, and this can significantly alter the particles' ice nucleation properties. We found that photochemical oxidation in a smog chamber enhanced the ice nucleation ability of authentic biomass burning aerosol. The droplet freezing temperature spectrum was observed to increase by more than 5 C following photochemical aging. We suspect this is caused by the oxidation of soot particle surfaces and have investigated this using online particle mass spectrometry and offline electron and x-ray spectromicroscopy.

We have found the immersion freezing properties of Snomax bacterial particles to be substantially unstable, observing a loss of ice nucleation ability over months of repeated droplet freezing measurements of the same batch of Snomax stored in a freezer. This reflects the fragility of the most ice active large protein aggregates. The easy loss of the most efficient ice nucleating proteins presents issues for the use of Snomax as an INP standard, and has implications for the evolution of ice nucleation properties of biological particles during atmospheric transport. Using an oil-immersion droplet freezing technique, repeated freezes of Snomax droplets resulted in a decrease in ice nucleation ability after successive refreezes. We attribute this to the disruption or displacement of the most ice active protein aggregates that are thought to contain the ice nucleants. Caution therefore is warranted in the use of oil-immersion droplet freezing methods to determine immersion freezing properties of biological or other hydrophobic particle types.

## 7EC.1

**Toxicant Production in the Electronic Cigarette Reaction Vessel.** ROBERT STRONGIN, David Peyton, James F. Pankow, Robert Jensen, Wentai Luo, Jorge Escobedo, Anna Duell, James Salamanca, *Portland State University*

Knowledge of the mechanism of formation, levels and toxicological profiles of the chemical products in the aerosols of e-cigarettes is needed in order to better inform basic research as well as the general public, regulators and industry. To date, studies of e-cigarette emissions have mainly focused on chromatographic techniques for quantifying and comparing the levels of selected e-cigarette aerosol components to those found in traditional cigarettes. E-cigarettes heat and vaporize the solvents propylene glycol (PG) and glycerol (GLY), thereby affording unique product profiles as compared to traditional cigarettes. The chemical literature strongly suggest that there should be more compounds produced by PG and GLY than have been reported in e-cigarette aerosols to date. We previously reported the discovery of hemiacetal products of the reaction of PG/GLY with the formaldehyde that is formed during PG/GLY aerosol generation. Herein, we present a more extensive investigation of the products derived from vaporizing PG and GLY under e-cigarette conditions. In addition to known e-cigarette PG/GLY derived products, many compounds have been identified for the first time under vaping conditions. Their origin and potential toxicological effects will be described.

**7EC.2**

**Partition of Free Base and Protonated Nicotine in Electronic Cigarette Liquids and Aerosols.** Ahmad El Hellani, Rachel El Hage, Rima Baalbaki, Rola Salman, Soha Talih, Alan Shihadeh, NAJAT A. SALIBA, *American University of Beirut*

As with other tobacco aerosols, nicotine delivery from e-cigarettes (ECIG) depends on the total nicotine and its partitioning between free-base (Nic) and protonated (NicH<sup>+</sup>) forms. Previous studies of ECIG nicotine emissions have generally reported “nicotine yield” without attention to whether the methods employed resulted in quantification of the total nicotine or only one of its forms, making reported results difficult to compare across studies, or to evaluate against reported blood exposure. This study reports a convenient method for determining total nicotine and its partitioning in ECIG liquids and aerosols. Apparent pH was found to correlate with nicotine partitioning and can provide a useful indirect measure when chromatography is unavailable. Standard and commercial ECIG liquids and aerosols were analyzed and it was found that aerosols exhibit higher Nic concentration than the parent liquids and that differences in nicotine partitioning across ECIG liquids carry over to the inhaled aerosol, and may influence nicotine delivery. The notion that Nic is the only form that can be volatilized upon heating and that the presence of NicH<sup>+</sup> in the aerosol likely derives from the recombination of Nic with H<sup>+</sup> in the propylene glycol / glycerin (PG/VG) matrix of the aerosol droplets is investigated and discussed.

**7EC.3**

**Lab Studies to Determine Gas-to-Particle Partitioning of Emissions from Electronic Cigarettes.** CLAIRE FORTENBERRY, Brent Williams, Raul Martinez, Walton Sumner, Steven Brody, *Washington University in St Louis*

Electronic cigarettes (e-cigs) have become an increasingly popular alternative to traditional cigarettes, and although recent studies have characterized the composition of e-cig-generated aerosol, the health effects associated with e-cig use remain poorly understood. Nicotyrine, a nicotine oxidation product, inhibits nicotine metabolism in the airways and liver and has been reported as a component of e-cig aerosol and liquid, meriting research on the use of e-cigs as smoking cessation aides. Nicotine and nicotyrine are both semi-volatile and are thus expected to partition between the gas and particle phases when e-cig aerosol is generated, affecting absorption by the body following inhalation (vaping). Further study on the phase partitioning of nicotine and nicotyrine in e-cig-generated aerosol is therefore necessary for fully understanding the health impacts of e-cig use.

The Thermal desorption Aerosol Gas chromatograph (TAG), which achieves in situ ambient collection and molecular level speciation with hourly time resolution, has recently been modified to collect semi-volatile and intermediately volatile organic compounds (SVOCs and IVOCs, respectively) in parallel with low volatility particulate material. In this study, the partitioning of nicotine, nicotyrine, and other SVOCs/IVOCs in e-cig-generated aerosol was characterized using the TAG. The effects of different e-cig liquids and vaping methods on aerosol composition and partitioning will be presented. Finally, the potential health effects and implications for e-cig use as a smoking cessation aide will be discussed.

**7EC.4**

**Analysis of Aerosol Size Distribution Measurement of Electronic Cigarettes Emissions.** VLADIMIR MIKHEEV, Marielle Brinkman, Alexander Ivanov, Sydney Gordon, Pamela I. Clark, *Battelle Public Health Center for Tobacco Research*

Electronic cigarette use is increasing worldwide but our understanding of their health risk relative to combustible tobacco products has not kept pace with this tobacco product's popularity. There is lack of data describing the aerosol size distribution generated by e-cigarettes. This is an important data gap, as aerosol size is a critical parameter that defines the delivery site and deposition efficiency in the human respiratory system, and thus governs the systemic uptake of inhaled compounds. Due to the abundance of relatively volatile compounds (i.e., propylene glycol and water), the e-cigarette aerosol/vapor mixture is a highly dynamic system that, under different conditions, could result in either rapid particle growth or evaporation. For example, at high dilution, e-cigarette aerosol quickly evaporates and the nano-size fraction significantly increases. The chemical content of e-liquid (propylene glycol, glycerol, water, nicotine, and flavorings), heating power, and the puffing flow rate, also have an effect on the particle size distribution.

In order to obtain an undistorted picture of aerosol size distribution, minimal sample dilution is required, along with quick delivery and real-time measurements that cover wide range of particle size (from nanometers to microns) and high concentration (up to 8-9 orders of magnitude). Analysis of the available techniques shows that none of the single aerosol measurement instruments could satisfy all these requirements. Combination of differential mobility with optical scattering or/and impactor techniques seems to be most applicable to measure e-cigarette aerosol.

Our differential mobility measurements taken at low sample dilution typically show a bi-modal particle size distribution which includes high concentration of nanoparticles. This size distribution is different from that reported for combustible tobacco smoke. Nanoparticles that are more active biologically and therefore could possess higher health risk requires investigation of their chemical content. Size-segregated chemical analyses of e-cigarette aerosol emissions will be discussed.

**7EC.5**

**Thermodynamics and Transport Phenomena Governing Electronic Cigarette Aerosol Emissions.** Soha Talih, Zainab Balhas, Rola Salman, Rachel El Hage, Nareg Karaoghlanian, Ahmad El Hellani, Mohamad Baassiri, Ezzat Jaroudi, Thomas Eissenberg, Najat A. Saliba, ALAN SHIHADDEH, *American University of Beirut*

Electronic cigarettes (ECIGs) electrically heat and aerosolize a liquid containing propylene glycol (PG), vegetable glycerin (VG), flavorants, water, and nicotine. Depending on such variables as electrical power, liquid composition, and puff behavior, ECIG users can extract in a few puffs far more or far less nicotine than from a conventional combustible cigarette; in fact, ECIGs probably provide users with a degree of influence over nicotine emissions that is unprecedented for a tobacco product. Because nicotine is an addictive drug, understanding ECIG nicotine emissions is a key regulatory issue. In this study we sought to map the relationships between nicotine emissions and ECIG design features, liquid composition, and operating conditions. To do so, we developed and empirically verified a mathematical model of the unsteady heat and mass transfer phenomena that underlie ECIG operation under a wide range of conditions, and used it to explore the principal processes that govern nicotine and aerosol emission rates (mg/sec). We present data showing that mean nicotine emission rates can range four orders of magnitude for a single device, from 0.1 to 100 ug/s, over a range of realistic use conditions. We also present data and model simulations demonstrating that for a given ECIG device, nicotine emission rates depend on electrical power, nicotine concentration, PG/VG ratio, and puff duration, and, conversely, that emissions are independent of puff velocity and ECIG liquid water content. Using NaCl as a tracer, we also present evidence indicating that bubble burst phenomena represent a measureable but minor source of aerosol emissions during ECIG operation. Finally, we demonstrate that constraining ECIG nicotine emission rates requires regulations that address multiple factors in combination, rather than one factor at a time.

**7EC.6**

**An Exploration of the Factors Affecting E-Cigarette Particle Size Distributions.** Jordan Berger, Phoebe Belser, Mark Daley, Timothy Raymond, James Baish, DABRINA DUTCHER, *Bucknell University*

Electronic cigarettes are hand-held devices intended to allow users to engage in smoking behaviours while delivering nicotine and other flavored vapors. These are being promoted as a healthier alternative to smoking cigarettes(1). However, the electronic cigarettes devices are evolving quickly, from inexpensive, disposable, single coil cartridge-based devices to rebuildable drip-based atomizers with temperature and voltage controllers costing hundreds of dollars. While e-cigarette hardware choices have been changing rapidly, so too have the e-liquids. Recent trends in e-liquid composition have moved away from propylene glycol and towards higher glycerin contents. This impacts the surface tension and boiling point of the e-liquid. The recent decision to regulate these devices and liquids by the Food and Drug Administration(2) makes it even more essential that their function and impacts are fully understood.

The particle sizes produced by electronic cigarettes determine the most likely region of deposition in the user's respiratory tract. This, in turn, affects the pharmacokinetics of the nicotine or other components of the vapor. In this study, the particle size distributions were determined for a series of different hardware configurations and e-liquid compositions and flavors. The distributions were measured with a Scanning Mobility Particle Sizer (SMPS) and an Optical Particle Counter (OPC). Additionally, the effects of the particle concentrations of the air being drawn through the e-cigarette while it is activated were explored. This allowed the effects of heterogeneous vs homogeneous nucleation on the particle size distribution to be explored.

Among the observations that will be presented are the importance of including the mass of the e-liquid that is splattered during the transport and vaporization process in order to achieve mass balance and the significant effect of the hardware of the particle size distribution.

(1) McNeill A, Brose LS, Calder R, Hitchman SC, Hajek P, McRobbie H, E-cigarettes: an evidence update: A report commissioned by Public Health England, August 2015.

(2)

<http://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ucm499234.htm> accessed 5/6/2016.

**7EC.7**

**Chemical Composition of the Aerosols Emitted from Heated-Tobacco Smoking Devices, Electronic Cigarettes and Regular Cigarettes.** ARIAN SAFFARI, Ario Ruprecht, Cinzia De Marco, Paolo Pozzi, Roberto Boffi, Dane Westerdahl, Sina Hasheminassab, Constantinos Sioutas, *University of Southern California*

Over the last few years, increasing popularity of electronic cigarettes (e-cigarettes) and more recently, the new "heat-not-burn" tobacco products (e.g. IQOS) as alternatives of traditional tobacco cigarettes has necessitated further documentation and research on the composition and potential health risks/benefits of these (largely unregulated) devices. In a recent study, we compared second-hand exposure to particulate metals and organic compounds from e-cigarettes and traditional cigarettes, by conducting continuous and time-integrated measurements in an indoor environment, followed by computing the emission rates using a single-compartment mass balance model. In this study, we have used a similar approach to further expand our previous analyses by characterizing black carbon, metal particles, organic compounds and size-segregated particle mass and number concentrations emitted from these devices in addition to the newly marketed IQOS. Our results indicated a substantial decrease in the emission of black carbon and organic compounds (e.g. aldehydes and PAHs) in e-cigarettes compared to traditional cigarettes. Metal emissions were similarly lower in e-cigarettes, although specific transition metals (e.g. Ni and Cr) were found to have a higher emission rate from e-cigarettes. Further analysis showed that elevated emission of these metals almost exclusively originates from the e-cigarette's cartridge, rather than the e-liquid. Analysis of the same species in the IQOS side-stream smoke, however, indicated that the particulate emission of organic compounds from these devices is significantly dependent on the type of organic groups. While Polycyclic Aromatic Hydrocarbons (PAHs) were mostly non-detected in the IQOS smoke (implying that these carcinogenic compounds are the outcome of the actual "combustion" of tobacco and not the heating), certain n-alkanes, organic acids (such as suberic acid, azelaic acid and n-alkanoic acids with carbon numbers between 10-19) as well as levoglucosan were still emitted in substantial levels from IQOS (up to 2-6 mg/hr during a regular smoking regimen).

**7IM.1**

**Low Frequency Shift Macro-Raman Spectroscopy for Analysis of Non-uniform Multi-component Powders.** Hui Wang, Lisa Williams, Susan Hoe, David Lechuga-Ballesteros, David Barona, REINHARD VEHRING, *University of Alberta*

Pharmaceutical aerosols are frequently generated from powder mixtures that may consist of different chemical components with varying particle size. Macro-Raman spectroscopy is capable of analyzing the composition, and in the low frequency shift version, also the solid phase of individual aerosol particles. This study presents a newly developed macro-Raman spectrometer for quantitative analysis of multi-component, non-uniform bulk powder samples that are impractical to measure with micro-Raman spectroscopy. Pointwise measurement utilizing a 2mm conical cavity sample holder and continuous scanning along a 5mm groove cavity sample holder were used. The effective sampling volume of the macro-Raman system during static pointwise measurement was determined to be about 0.1  $\mu\text{L}$  by comparing the uncertainty of measured powder compositions of two commercial lactose-carrier based dry powder inhalers Flixotide® (250  $\mu\text{g}$  fluticasone / dose) and Seretide® (50  $\mu\text{g}$  salmeterol + 500  $\mu\text{g}$  fluticasone / dose) with Monte-Carlo simulations. Binary mixtures (1:1 by mass) of L-leucine (ACROS) and D-mannitol (Sigma-Aldrich) particles were mixed using a wrist action shaker for 1, 2, 5, and 10 hours and measured using both point-by-point and scanning methods. The spatial uniformity of the powder mixtures was characterized by the standard deviation of pointwise measured compositions. The uniformity decreased with longer mixing time, indicating that this is not an effective method of mixing powders with small particle size. However, both the mean value of 20 pointwise measured compositions and the composition derived from a single scan along the groove sample holder agreed with the nominal composition. Thus, macro-Raman spectroscopy with sample scanning achieves a greatly increased sampling volume and decreases sampling error in non-uniform powder samples. Also, spatial variability in sample compositions can be analyzed to evaluate the level of mixing of multi-component powder samples.

**7IM.2**

**Infrared Elastic Scattering Spectroscopy of Individual Aerosol Particles.** WILLIAM HERZOG, Jonathan Richardson, Brian Saar, David Wolinski, Jason Jong, Jay D. Eversole, *Lincoln Laboratory, Massachusetts Institute of Technology*

We have performed chemical composition classification of individual micron-sized aerosol particles using infrared elastic scattering spectroscopy. We describe electromagnetic scattering calculations and experiments that demonstrate that the absorption features of single aerosol particles may be inferred from the particle's spectrum of elastically scattered infrared light.

An experimental setup was constructed to collect infrared elastic scattering spectra from individual aerosol particles. A Wavelength Beam Combined-Quantum Cascade Laser (WBC-QCL) array was used as the multi-wavelength, long-wave infrared (LWIR) source to illuminate individual aerosol particles entrained in an airflow. Elastically scattered light from each individual aerosol particle was collected onto a single-element HgCdTe detector. A variety of materials, including laboratory particle standards such as polystyrene latex spheres and poly-methyl methacrylate spheres were measured. For a few of the materials, the complex index of refraction versus wavelength was available for use in computational scattering modeling. Mie scattering calculations were performed that show good agreement with experimental results. This work demonstrates that single-aerosol particle infrared elastic scattering spectroscopy can be used as a fingerprint of the vibrational modes of aerosol materials to allow differentiation of aerosol species based upon their chemical structure in real time on a particle-by-particle basis.

**7IM.3**

**Using Aluminum Foil Impaction Substrates for Elemental Analysis of Airborne Particulate Matter Samples.** WEI XUE, Jian Xue, Peter Green, Michael Kleeman, *University of California, Davis*

Aluminum foil substrates and Teflon filters are the two main substrates for airborne particulate matter (PM) collection using Micro-Orifice Uniform Deposition Impactors (MOUDIs). Samples collected on foil substrates are analyzed for carbonaceous compounds while Teflon samples for ions and elements. The Teflon filters typically cost 10 times more than the foil substrates, so a method that could serve both desired chemical analyses from a single MOUDI instead of two would improve our ability to characterize regional trends of PM<sub>0.1</sub> and other size fractions.

In this work we examine the feasibility of performing elemental analysis of PM samples collected foil substrates in MOUDIs. The PM extraction method developed at UC Davis for Teflon filters (sonication in a mixture of 75% acetone and 25% nitric acid followed by nitrogen evaporation of acetone) was modified by sonicating foil samples in pure acetone and then transferring them to a second vial where they are mixed with nitric acid. The original foil substrates are exposed to the acetone / nitric acid mixture for only a brief time to avoid excessive dissolution of the aluminum substrate. Acetone is then evaporated with nitrogen and analysis is conducted with ICPMS.

Two collocated MOUDIs - loaded with Teflon filters and foil substrates, respectively - were used to test the efficiency of the new method. Results showed that Teflon and foil gave similar PM size distributions for elements of interest. The modified method was able to measure 80% of the total mass of all elements of interest, suggesting that an extraction efficiency correction may be needed. The method detection limits of the foil method are similar to the Teflon method for most of the elements of interest, except for vanadium, gallium, thallium and lead. This study suggests feasibility of using a single MOUDI loaded with foil substrates for sampling networks.

**7IM.4**

**Development of a Real-time Aerosol Mass Distribution Instrument.** MODI CHEN, Francisco Romy, Lin Li, Amir Naqwi, Virgil Marple, *MSP Corporation*

A novel instrument has been developed for real-time aerosol mass distribution measurements. The instrument includes two major components: a relative humidity (RH) conditioner and a 6-stage quartz crystal microbalance (QCM) micro-orifice impactor. The RH conditioner ensures that the incoming aerosol is conditioned to the range of 40 % to 65 % RH. The impactor operates at 10 L/min inlet flow rate and measures the mass of the collected particles in six aerodynamic diameter channels covering the range of 45 nm to 2.5  $\mu\text{m}$ . The nozzles of the impactor stages are clustered so that the particles are collected at the center of the QCM, where the mass sensitivity is known from theory. Laboratory tests conducted with monodisperse aerosol particles showed that the RH conditioning ensured excellent agreement between the mass calculated from direct condensation particle counter (CPC) readings and the mass calculated for the QCM using the Sauerbrey equation. Good agreement was found for mass loadings of up to about 130  $\mu\text{g}$  for solid particles and up to about 2  $\mu\text{g}$  for liquid particles. The agreement also indicated that the RH conditioning eliminated solid particle bounce.

The QCM impactor collection efficiency curves were calibrated with monodisperse liquid particles using conventional calibration techniques. The experimental cutpoints were in good agreement with numerical predictions from classical impactor theory.

The QCM cascade impactor was also tested in an outdoor environment. The measured ambient aerosol distribution was compared with an independent co-located measurement carried out by a wide-range particle spectrometer (WPS). The WPS mobility distribution was converted to the mass distribution assuming the particles were spherical and of 1 g/cm<sup>3</sup> density. Good agreement was achieved between the two instruments.

**7IM.5**

**A New Portable Dual Smog Chamber Facility with UV Lights for Field Studies.** CHRISTOS KALTSONOUDIS, Evangelos Louvaris, Epameinondas Tsiligiannis, Evangelia Kostenidou, Spyros Pandis, *University of Patras, Patra, Greece*

Field smog chamber experiments using as a starting point ambient air can improve our understanding of the evolution of atmospheric pollutants at timescales longer than those achieved by traditional laboratory experiments. These types of studies can take place under more realistic environmental conditions. Use of two identical smog chambers, with the first being the baseline chamber and the second the perturbation chamber (e.g. addition or removal of pollutants, addition of oxidants, change in the RH etc.) can assist in the interpretation of the results in such inherently complex chemical systems. The differences of the measurements in the two chambers can be used as the basis for the study of the corresponding chemical or physical processes.

In this work a new dual smog chamber system was developed. A set of two identical smog chambers (1.5 m<sup>3</sup> each) were constructed from Teflon (PTFE) 0.2 micrometer film. The two chambers are pillow-shaped and permanently mounted on metal frames. The relatively small dimensions along with the fixed frames enable the easy and safe transport of the empty chambers without having to disassemble them or remove the sampling ports. The two chambers are surrounded by 60 (36 W each) UV lamps in a hexagonal arrangement (with one side open) yielding a  $J_{\text{NO}_2}$  of 0.1 min<sup>-1</sup>. The lamps are mounted on five metal frames creating five sub-structures that can be easily disassembled and transported. Once assembled the UV light support structure has a footprint of 4.5 m in diameter and a height of 2.5 m which can be fully covered or partially uncovered if natural sunlight is required. The system has been evaluated in a series of experiments testing its levels of contamination, similarity of the behavior of the two chambers, wall losses and perturbation experiments of ambient air showing promising results.

**7IM.6**

**Quantification of Gas-Wall Partitioning in Teflon Environmental Chambers and Its Effects on Gas-Wall Partitioning.** JORDAN KRECHMER, Demetrios Pagonis, Paul Ziemann, Jose-Luis Jimenez, *University of Colorado-Boulder*

Partitioning of gas-phase organic compounds to the walls of Teflon environmental chambers is a recently reported phenomenon that can affect the yields of reaction products and secondary organic aerosol (SOA) measured in laboratory experiments. Reported timescales for reaching gas-wall partitioning (GWP) equilibrium ( $\tau_{\text{GWE}}$ ) differ by up to three orders of magnitude, however, leading to predicted effects that vary from substantial to negligible. A new technique is demonstrated here in which semi- and low-volatility oxidized organic compounds (saturation concentration  $c^* < 100$  microgram m<sup>-3</sup>) were photochemically generated in rapid bursts in-situ in an 8 m<sup>3</sup> environmental chamber, and their decay due to loss to the walls in the absence of aerosol was measured using a high-resolution chemical ionization mass spectrometer (CIMS) equipped with an “inlet-less” NO<sub>3</sub><sup>-</sup> ion source. Measured  $\tau_{\text{GWE}}$  were 7-13 min for all compounds, with an average relative standard deviation of 33% for replicate experiments. The fraction of each compound that partitioned to the walls at equilibrium follows absorptive partitioning theory with an equivalent wall mass concentration in the range 0.3-10 mg mm<sup>-3</sup>. By comparison,  $\tau_{\text{GWE}}$  measured using a CIMS equipped with a standard low-pressure ion-molecule reaction region were biased high by up to a factor of 4, and the equivalent wall mass concentrations were biased low. Thus, improved ion sources that reduce the contact of compounds with walls are needed for low-pressure CIMS. On the basis of these results, a set of parameters is proposed for modeling GWP in chamber experiments. We applied these findings to fit the results of an ISOPOOH oxidation study in the Caltech chamber in which we reported a new SOA formation mechanism. The effects of relative humidity and temperature on gas-wall partitioning, and wall losses on SOA experiments in which competing aerosol seed particles are generated in the chamber were also explored.

## 7IM.7

**Controlled NO and NO<sub>2</sub> Production via O(1D)-N<sub>2</sub>O Reactions for Use in Oxidation Flow Reactor Studies of SOA Formation Pathways.**

ANDREW LAMBE, Paola Massoli, John B. Nowak, Manjula Canagaratna, Conner Daube, Timothy Onasch, Lindsay Renbaum-Wolff, Gabriel Isaacman-VanWertz, Jesse Kroll, John Jayne, Paul Davidovits, Charles Kolb, Douglas Worsnop, William Brune, *Aerodyne Research, Inc.*

Oxidation flow reactors that use low-pressure mercury lamps to produce hydroxyl (OH) radicals are an emerging technique for studying the oxidative aging of organic aerosols. In these flow reactors, ozone is photolyzed at  $\lambda = 254$  nm to produce O(1D) radicals, which react with H<sub>2</sub>O to produce OH. However, the need to use parts-per-million levels of ozone hinders the ability of flow reactors to simulate NO<sub>x</sub>-dependent SOA formation pathways. Simple addition of NO and/or NO<sub>2</sub> to oxidation flow reactors results in fast conversion of NO<sub>x</sub> to nitric acid, making it difficult to sustain NO<sub>x</sub> levels that are sufficient to compete with hydroperoxy (HO<sub>2</sub>) radicals as a sink for organic peroxy (RO<sub>2</sub>) radicals. Here, we present a new method that is well suited to the characterization of NO<sub>x</sub>-dependent SOA formation pathways in oxidation flow reactors. NO and NO<sub>2</sub> are produced via the reaction  $O(1D)+N_2O \rightarrow 2NO$ , followed by the reaction  $NO+O_3 \rightarrow NO_2+O_2$ . Laboratory measurements coupled with photochemical box model simulations suggest that O(1D)+N<sub>2</sub>O reactions can be used to systematically vary the relative branching ratios of RO<sub>2</sub> + NO and RO<sub>2</sub> + HO<sub>2</sub> reactions over a range of conditions relevant to atmospheric SOA formation. We demonstrate proof of concept using high-resolution time-of-flight chemical ionization mass spectrometer measurements to detect gas-phase oxidation products of isoprene and  $\alpha$ -pinene that have been observed in recent NO<sub>x</sub>-influenced field studies and laboratory chamber experiments. We also detect condensed-phase organonitrate oxidation products of  $\alpha$ -pinene that are formed in the presence of added NO<sub>x</sub> using a high-resolution time-of-flight aerosol mass spectrometer.

## 7NS.1

**Oxidation of BVOCs and SOA Formation above and below a Forest Canopy.** Benjamin Schulze, Henry Wallace, ROBERT GRIFFIN, *Rice University*

Oxidation of biogenic volatile organic compounds (BVOCs) produces organic nitrates (RONO<sub>2</sub>) and secondary organic aerosol (SOA). RONO<sub>2</sub> may be formed via oxidation by nitrate radical (NO<sub>3</sub>) or other oxidants (such as hydroxyl radical, OH) in the presence of nitrogen oxides (NO<sub>x</sub>). NO<sub>3</sub> is especially reactive towards isoprene and monoterpenes such as alpha-pinene but also undergoes rapid photolysis. It is hypothesized that shading provided by forest canopies enhances daytime oxidation of BVOCs by NO<sub>3</sub>. A zero-dimensional model has been developed to investigate oxidation of and SOA production from these two BVOCs in forested areas under rural and polluted cases. Because of the light gradient caused by forest canopy shading, specific attention is paid to conditions both above and below the canopy. Daytime concentrations of NO<sub>3</sub> below the canopy are two-to-three times larger than those above, and relative contributions of NO<sub>3</sub> to daytime alpha-pinene oxidation double under more polluted scenarios. Oxidation of isoprene is almost entirely dominated by reaction with OH. The most significant first-generation RONO<sub>2</sub> formation mechanism varies significantly between scenarios and canopy locations. Nonetheless, in every scenario, daytime production of first-generation RONO<sub>2</sub> from NO<sub>3</sub>-alpha-pinene reactions is more significant below the canopy than above. While SOA mass loadings are moderate (2 micrograms per cubic meter or less), total SOA production is consistently enhanced below the canopy, due to the combined effects of elevated isoprene and reduced NO<sub>x</sub> concentrations relative to above the canopy. Below-canopy daytime production of RONO<sub>2</sub> SOA through NO<sub>3</sub> oxidation of alpha-pinene, while small in absolute terms, is more than double above-canopy production under every scenario. This work emphasizes the probability of daytime oxidation of BVOCs by NO<sub>3</sub>, the relative importance of OH/NO<sub>x</sub> versus NO<sub>3</sub> oxidation in leading to RONO<sub>2</sub> formation, and the need for further investigation of how BVOC and anthropogenic species interact to form SOA.

## 7NS.2

**SOA from Nitrate Radical Oxidation of Monoterpenes: Effects of Temperature, Humidity, Photochemical Aging on Aerosol Mixing and Evaporation.** NGA LEE NG, Christopher Boyd, Theodora Nah, Lu Xu, *Georgia Institute of Technology*

Secondary organic aerosol (SOA) constitutes a substantial fraction of fine particulate matter and has important impacts on climate and human health. The interactions of biogenic VOCs with NO<sub>3</sub> radicals represent a direct way for positively linking anthropogenic and biogenic emissions. Multiple high-time-resolution mass spectrometry organic aerosol measurements were obtained during different seasons at various locations, including urban and rural sites in the greater Atlanta area and Centreville in rural Alabama. Anthropogenic NO<sub>x</sub> is shown to enhance nighttime SOA formation via nitrate radical oxidation of monoterpenes, resulting in the ubiquitous presence of particulate organic nitrates in the southeastern US. Nighttime NO<sub>3</sub> chemistry can contribute up to 22-34% of total measured OA in the southeastern US. Laboratory experiments on nitrate radical oxidation of monoterpenes (*α*-pinene, *β*-pinene, limonene) are conducted in the Georgia Tech Environmental Chamber facility (GTEC) to investigate the formation of SOA and fates of organic nitrates under conditions relevant to the southeastern US. A series of experiments is carried out to investigate the changes in aerosol composition and properties during night-to-day transition, where dilution, temperature/RH changes, and photochemical aging take places. Upon photochemical aging, organic nitrates formed from different precursors exhibit drastically different behaviors, suggesting that they can serve as temporary or permanent NO<sub>x</sub> sinks depending on the monoterpene precursor. Aerosol evaporation is promoted either by isothermal dilution or by increasing the temperature from 25 °C to 40 °C. Results indicate that there is some resistance to aerosol evaporation when temperature is increased. The atmospheric implications of these findings will be discussed.

## 7NS.3

**The Role of Emissions Controls on Aerosol pH over a Decade (2001-2011) in the United States.** PETROS VASILAKOS, Armistead G. Russell, Athanasios Nenes, *Georgia Institute of Technology*

Emission controls, particularly on SO<sub>2</sub>, have long been thought to lead to an increase in the aerosol pH (West et al. 1999). However, despite these controls, recent studies have highlighted the highly acidic nature of aerosol in the present day Southeast United States (Guo et al. 2015), which, in spite the reduction in sulfate, has maintained a relatively constant, acidic pH over time (Weber et al. 2016). The constant pH has been attributed to the buffering effect of ammonia that retains the pH in the SE US between 0 and 2 (Weber et al. 2016). In contrast to SO<sub>2</sub> emissions which are projected to be reduced even further, ammonia emissions from livestock and fertilizers are expected to remain constant or even increase in the future.

In this work, we use a version of CMAQ with extended isoprene chemistry (Pye et al. 2013) and updated model parameters (Vasilakos et al. 2016), to simulate pH over the entire US for the years 2001 and 2011. Simulations will be carried out on a 36x36 km grid covering the entire US, using meteorology from the Weather Research and Forecasting (WRF) model. Biogenic emissions and land use will be provided from the Biogenic Emissions Inventory System version 3.6 (BEIS3.6) using Biogenic Emissions Landuse Database (BELD 4) inputs. Sensitivity studies quantify the importance of pH prediction errors for fine mode ammonium, nitrate and gas-phase counterparts ammonia and nitric acid. Predicted pH fields are evaluated against observations collected from ground-based and airborne field studies, to establish whether simulations are predisposed for under/overpredict of semi-volatile acidic inorganic species. The role of nonvolatile alkaline cations from dust and seasalt and their (potentially) disproportionately strong impact on nitrate partitioning, is presented. We conclude by presenting the importance of pH modulations for reactive N deposition fluxes.

## 7NS.4

**Molecular Characterization of Biogenic SOA Using Online Extractive Electrospray Ionization Mass Spectrometry: On the Fate of Condensed Phase ELVOC.** FELIPE LOPEZ-HILFIKER, Veronika Pospisilova, Ugo Molteni, Mao Xiao, Josef Dommen, Andre Prévôt, Urs Baltensperger, Jay Slowik, *Paul Scherrer Institute*

Recent measurements of the oxidation products from biogenic precursors by chemical ionization mass spectrometry (CIMS) have revealed a large source of extremely low volatility organic molecules (ELVOC) formed at high yield. These molecules can contribute to new particle formation and subsequent particle growth despite their low gas phase abundance. Measurements of particle composition and volatility by CIMS is largely consistent with a significant source of secondary organic aerosol (SOA) formed from the condensation of initially low volatility organic vapors; however, the tendency of these molecules to undergo ionization-induced fragmentation and/or thermal decomposition has to date prevented their direct measurement. As such, the fate of highly oxidized organics formed in the gas phase in the condensed phase remains an open question.

Here, we present the first direct online measurements of individual organic aerosol components at atmospherically relevant particle mass loadings without thermal decomposition or ionization-induced fragmentation, using an extractive electrospray ionization time-of-flight mass spectrometer (EESI-TOF) recently developed at PSI. We focus on the measurement of highly oxidized, low volatility organic molecules and oligomers, which are formed rapidly from biogenic precursors and the fate of these molecules in the particle phase during ageing. To investigate these particle-phase formation and ageing mechanisms the EESI-TOF was deployed at the PSI atmospheric simulation chamber where biogenic precursor compounds were oxidized under a variety of conditions.

Our measurements utilizing the EESI-TOF and a variety of biogenic precursor molecules provide a new level of molecular insight that allows the direct assessment of particle phase oligomerization, fragmentation and ageing reactions. We discuss these individual and combined effects on SOA formation, lifetime and response to atmospheric changes as well as the implications of these findings for measurements of gas-particle partitioning and validation of SOA formation models.

## 7NS.5

**Ozonolysis of alpha-pinene under Atmospherically Relevant Conditions: Impact of NO<sub>x</sub> on Formation of Highly Oxidized Multifunctional Compounds (HOMs).** MATTHIEU RIVA, Otso Peräkylä, Lauriane Quéléver, Liine Heikkinen, Olga Garmash, Mikko Äijälä, Matti Rissanen, Mikael Ehn, *University of Helsinki*

Ozonolysis of alpha-pinene leads to formation of multifunctional gas-phase products including carboxylic acids and high molecular-weight compounds. Recently, highly oxidized multifunctional compounds (HOMs) were identified in the gas-phase in significant concentrations. These HOMs could then condense irreversibly onto aerosol surfaces to produce secondary organic aerosol (SOA). Molecular structures and formation pathways remain, however, uncertain. For instance, it has been suggested that RO<sub>2</sub> + NO reaction can change composition (and possibly SOA yield) even without suppressing autoxidation to a very large degree.

In the present work, ozonolysis of alpha-pinene was systematically examined with varying NO concentrations in an indoor smog chamber. Ammonium sulfate aerosols (acidified and non-acidified) were also injected to further evaluate heterogeneous oxidations of HOMs. Experiments were conducted at room temperature ( $24 \pm 2^\circ\text{C}$ , ~30% of relative humidity) and atmospheric pressure in a 2-m<sup>3</sup> Teflon chamber. Gaseous multi-functional organic compounds were chemically characterized using a range of time-of-flight chemical ionization mass spectrometers (HR-ToF-CIMS) with iodide (I<sup>-</sup>) and nitrate (NO<sub>3</sub><sup>-</sup>) ionization. In addition, particle-phase was chemically characterized using Filter Inlet for Gases and AEROSols (FIGAERO) coupled to an I<sup>-</sup>-HR-ToF-CIMS and a high-resolution time-of-flight aerosol mass spectrometer (HR-ToF-AMS). Hundreds of compound, including highly oxidized products and oligomers, were observed in both gas- and particle-phases. The FIGAERO thermograms of individual SOA constituents formed under various conditions (i.e. NO and aerosol acidity) reveal heterogeneous processes within the oxidation of HOMs leading to increase of oligomer concentrations and SOA formation. Finally, addition of NO into the chamber perturbs formation of HOMs and produces new gas- and particle-phase products.

## 7NS.6

**New Particle Formation from BVOCs and Sulphuric acid in the CLOUD Chamber at Different Levels of NH<sub>3</sub> and NO<sub>x</sub>.**

KATRIANNE LEHTIPALO, Chao Yan, Robert Wagner, Lubna Dada, Jenni Kontkanen, Tuomo Nieminen, Jonathan Duplissy, Hamish Gordon, Jasper Kirkby, Urs Baltensperger, Markku Kulmala, *University of Helsinki*

Both sulphuric acid and oxidation products of biogenic volatile organic compounds (BVOCs) have been previously identified as important precursors for new particle formation in the atmosphere. However, the processes leading to cluster formation and growth are not completely understood in the simultaneous presence of multiple precursor vapors and oxidation pathways. During the CLOUD10 experiment we aimed to replicate the new particle formation process as it is observed at the Hyytiälä SMEAR II station, which is one of the most studied field sites regarding in this respect. Using the CLOUD chamber at CERN we could use atmospherically relevant concentrations of precursors and maintain a high degree of control and a low level of contaminants.

Particle formation in the CLOUD chamber was started from a mixture of the two most abundant monoterpenes found in the boreal forest: alpha-pinene and delta-3-carene. The total monoterpene volume mixing ratios varied from about 150 to 1200 ppt. The experiments were conducted at varying levels of sulphuric acid (from less than  $1 \times 10^5$  cm<sup>-3</sup> up to  $5 \times 10^7$  cm<sup>-3</sup>) and NO<sub>x</sub> (from 0 to 5 ppb). The first experiment series were carried out without ammonia to ensure clean conditions, and later ammonia (up to 3 ppb, but mostly at the level of some hundreds of ppt) was added to the chamber. All the experiments were done first in neutral conditions (without ions present) and then repeated with ionization from galactic cosmic rays (GCR) and/or with additional ionization from the CERN pion-beam to study the fraction of ion-induced nucleation.

A comprehensive suite of instruments including state-of-the-art particle counters, size spectrometers and mass spectrometers were used to detect the forming particles and their precursors. We will present the first results from the "Hyytiälä simulation" in CLOUD and investigate the interactions between different particle formation pathways.

## 7NS.7

**Interaction between SO<sub>2</sub> and Criegee Intermediates in Monoterpene Ozonolysis and Effects on Secondary Organic Aerosol Formation.** JIANHUAI YE, Arthur Chan, *University of Toronto*

Ozonolysis of monoterpenes is an important source of atmospheric biogenic secondary organic aerosol (BSOA). While enhanced BSOA formation has been repeatedly observed under sulfate-rich conditions in both field studies and laboratory experiments, the underlying mechanisms remain poorly understood. In this work, the effect of SO<sub>2</sub> on BSOA formation from monoterpene ozonolysis was investigated. The role of stabilized Criegee biradicals (sCIs) generated from alkene ozonolysis on SO<sub>2</sub> oxidation was examined under different humidity conditions (<5% vs. 50%). Experiments were conducted in a 1 m<sup>3</sup> Teflon chamber. BSOA was produced from ozonolysis of alpha-pinene or limonene in the presence of 30 to 100 ppb of SO<sub>2</sub>. Our results show that BSOA from monoterpene ozonolysis is significantly enhanced in the presence of SO<sub>2</sub> under dry conditions. SOA enhancement increases with increasing the concentration of SO<sub>2</sub>. However, the enhancement becomes negligible as the conditions become more humid. Control experiments show that SO<sub>2</sub> is consumed at timescales consistent with oxidation by sCIs indicating that gaseous SO<sub>2</sub> interacts directly with reactive intermediates during monoterpene ozonolysis. Organosulfate formation is probed by electrospray ionization-ion mobility time of flight mass spectrometer (ESI-IMS/TOF). Our results clearly indicate that the synergy between BSOA and anthropogenic sulphur can occur through SO<sub>2</sub> rather than sulphuric acid, in monoterpene-rich environments. However, humidity plays an important role in modulating this effect.

**8AE.1**

**Understanding Children's Exposure to Trace Metals in Particulate Matter at Home.** JESSICA SAGONA, Stuart Shalat, Zuo Cheng Wang, Maya Ramagopal, Marta Hernandez, Kathleen Black, Gediminas Mainelis, *Rutgers, The State University of New Jersey*

Children's exposure to trace metals is an area of concern; metals such as lead and chromium are known neurotoxicants that are often found in the home. However, most research on estimating exposure has focused on ingestion rather than the inhalation route. In this study, we present inhalation exposure estimates for children in their homes.

Inhalable particulate matter (PM) was collected via Button Aerosol Sampler (SKC, Inc.) during two sampling campaigns that investigated the performance of the Pretoddler Inhalable Particulate Environmental Robotic (PIPER) sampler, a robot designed to replicate changes in children's breathing zones, in New Jersey homes. PM measurements by Button sampler on PIPER were compared to those by a stationary sampler (first campaign) and to those by personal sampler worn by 2-year-olds (second campaign). Fourteen randomly-selected pairs of filters from the first campaign and eleven pairs from the second were analyzed via ICP-MS for 23 metals. Of these, eight metals were consistently found above the detection limit, including lead, chromium, manganese, copper, and nickel.

In the first campaign, initial results indicate that PIPER typically measured slightly higher trace metal concentrations than the stationary sampler, with median lead concentrations in  $\text{ng}/\text{m}^3$  of 16.4 (PIPER) and 11.6 (stationary) and chromium concentrations of 75.2 (PIPER) and 68.8 (stationary). In the second campaign, higher concentrations were measured by the personal sampler than PIPER, with median lead values of 10.0 (personal sampler) vs. 6.4 (PIPER) and chromium values of 81.1 (personal sampler) vs. 74.4 (PIPER).

Our results demonstrate the importance of sampling method when seeking personal exposure estimates for children, as the samplers tended to vary in their measured ranges of metal concentrations. This study also characterizes PM trace metal concentrations in homes, and additional work will focus on identifying nearby sources for each home that might have contributed to the measured metal concentrations.

**8AE.2**

**Aerosol Generation from Rapid Concrete Failure.** Eric Heichelheim, Mija Hubler, LUPITA MONTOYA, *University of Colorado Boulder*

When concrete structures are destroyed through extreme loading conditions, whether artificial or natural, a secondary risk to human health is imposed in addition of the immediate and primary risk of collapse. Suspended dust from failed concrete structures has been linked to negative health impacts, as was the case for first responders to the collapse of the World Trade Center in 2001.

This work investigated how modern concrete admixtures and inclusions can impact the mechanical properties of concrete under dynamic loading. In particular, it investigated the macro-, micro-, and nano- scale fragmentation of concrete and the associated aerosol generated as a function of different admixtures and inclusions. To study this effect, concrete columns were rapidly loaded in a 110-Kip MTS Universal Testing Machine until failure. Aerosol generated during the concrete failure was then sampled using TAS Minivol samplers (Airmetrics, Eugene, OR, USA, 5 L/min). Aerosol was then characterized for size, shape and toxicity.

Four concrete mixes were studied: regular concrete as a control case, fly ash and slag admixtures (to study effects of micro-scale inclusions), and steel-fiber reinforced concrete (to study effects of macro-scale inclusions). Previous studies have shown that concrete fragments follow the Rosin-Rammler distribution as predicted by brittle fracture probabilities. This work determined that such information is not representative of the aerosol particles that are generated, which are of primary importance for health. In particular, the inclusion of large fibers generated a higher concentration of nanoscale fragments. An improved analytical formulation for the probability of small fragment formation is being developed.

**8AE.3**

**Impact of Residential Heating to Temporal/Spatial Variability of Size-segregated Aerosol Mass and Number at the Urban Microscale Level.** JAN BENDL, Jan Hovorka, Tereza Bartonova, Vlasta Svecova, Cecilia Leoni, Miroslav Klán, Lubos Matejcek, *Charles University in Prague*

Wood and coal combustion in local heating are often a major source of air pollution in villages and small cities. PM<sub>x</sub> and PAHs health limits are exceeded especially in winter during inversion situations and unfavorable micro-scale geomorphology like closed valleys. Large spatial variability of PM within urban microscale is common phenomenon due to few heavy polluters. Some people burn low quality fuel and despite law even waste and produce toxic emissions. Nevertheless, very few studies on temporal/spatial variability were made although true PM exposure may differ from fixed-site measuring data.

In Švermov, residential district of Kladno city in Czech Republic, there was perambulation of the length 3.5 km conducted 61 times in February 2016. During the perambulations 5 second data of GPS position, photo time-lapse, PM<sub>10</sub>, PM<sub>2.5</sub>, PM<sub>1</sub> by a Dustrak DRX (TSI), submicrometer particle number concentration (PNC) by P-Trak (TSI), NO<sub>x</sub>, O<sub>3</sub>, temperature and relative humidity by LEO (Ateknea) were recorded. The monitors were positioned in the backpack connected to an omnidirectional vertical inlets protruding about 20 cm from the backpack. Perambulations were conducted usually 3-4 a day for capturing diurnal variability at an average speed of 5 km/h.

For instance, on February 11 average PNC and PM<sub>10</sub> concentration were during morning perambulation 4722 pt/cc and 15 ug/m<sup>-3</sup>, at noon 3427 and 15, at afternoon 11523 and 61 and in the evening 5163 pt/cc and 45 ug/m<sup>-3</sup>. PNC concentration increased up to 10<sup>5</sup> pt/cc close to the main road and in the plumes from the local heating. Comprehensive data analysis is being process.

Mobile measurements allow us to quantify PM and PNC variability due to local home heating within the microscale urban environment.

The study is supported by the Czech Grant Agency (P503/12/G147) and FP7/ENV-2012-308524-2/CITI-SENSE.

**8AE.4**

**Aerosol Emission from Low-cost Metal and Thermoplastic 3-D Fabrication.** JUN WANG, Kevin O'Neill, Jose Muniz, Joshua Pearce, David L. Johnson, *University of Oklahoma*

Three-dimensional (3-D) fabrication is a process that involving the users to access instruments such as 3-D printers, cutters, and engravers. Most of the equipment relies on pyroprocessing to melt and remold the consumables or filaments to a pre-designed shape. A previous study on a low-cost single-nozzle thermoplastic 3-D printer with various filaments indicated that the high-temperature process raised concerns of potential carcinogenic aerosol emission and exposure. The lowered cost of 3-D fabrication devices brought more applications to places where sufficient ventilation and engineering control were often lacking to mitigate the aerosol emission. The objective of this study was to characterize aerosol emission from a series of low-cost 3-D fabrication equipment, namely a dual-nozzle thermoplastic 3-D printer, a mild and stainless steel metal 3-D printer, and a 3-D laser engraver and cutter. The equipment were placed in enclosed chambers and fume generated were measured with various particle sizers and indoor air quality sensors. A scanning mobility particle sizer and aerodynamic particle sizer were employed to examine the particle size distribution in the fine (<0.5 μm) and coarse ranges (<0.5~20 μm), while a GRIMM aerosol spectrometer was used to determine the respirable, thoracic, and inhalable fraction of the aerosol. Particle morphology was recorded via a transmission electron microscope (TEM). The results showed a high emission (~108 to 1010 #/minute of printing time) of particles with mode size in the ultrafine range. The ultrafine aerosols were also visually confirmed in the TEM images. The metallic aerosol compositions from metal 3-D fabrication were similar to the metal filaments. Particulate Cr<sup>6+</sup> concentration in the chamber without ventilation is several folds higher than the permissible exposure limit. The findings suggested that cautious should be taken to avoid overexposure to ultrafine particles while dealing with low-cost metal and thermoplastic 3-D fabrication.

**8AE.5**

**Industry Originated Particles, 36 nm in Diameter, Highly Enriched with PAHs, Significantly Contribute to Human Exposure at a European Air Pollution Hot-spot.** JAN HOVORKA, Cecilia Leoni, Veronika Docekalova, Tomas Cajthaml, Sona Marvanova, *Charles University in Prague*

A European air pollution hot-spot, the residential district of Ostrava-Radvanice and Bartovice, frequently exceeds limits for particulate matter (PM) and benzo[a]pyrene. Of all the PM sizes, the finest fraction, the ultrafine particles (UFPs), deposits most efficiently in the alveolar region of human lungs. This article analyzes highly time-and-space resolved concentration of UFPs acquired by airborne and land-based measurements and UFPs enrichment with heavy ( $MW > 228$  amu) polycyclic aromatic hydrocarbons (PAHs).

Airborne measurement revealed point sources of UFPs in the metallurgical complex close to the district and mapped out UFPs limited horizontal and upward vertical dispersion. Land-based measurements at the residential district recorded frequent simultaneous peaks of UFPs, SO<sub>2</sub>, and CO when downwind from the metallurgical complex, i.e. industrial plumes.

During the plume periods, PAHs concentration in UFPs increased significantly with the relative mass contribution of particles < 36 nm in diameter, enriched with PAH up to 29 mg.g<sup>-1</sup>. Also, particles of 30 – 50 nm were viewed by a transmission electron microscope to constitute the agglomerates of UFPs sampled at the district.

Particles of about 35 nm exhibit the highest pulmonary alveolar deposition amongst UFPs. Therefore, the occurrence of these industry-originated particles, highly enriched with PAHs, significantly contributes to human exposure by polluted air at the hot-spot.

The study is supported by the Czech Grant Agency (P503/12/G147).

**8AE.6**

**An Automated Microenvironmental Aerosol Sampler (AMAS) For Location/Activity Exposure Assessment.** CASEY QUINN, Dan Miller-Lionberg, Jaruwan Mettakoonpitak, John Mehaffy, Sheryl Magzamen, Charles Henry, John Volckens, *Colorado State University*

Existing methods for assessing time-integrated personal exposure are cumbersome and relatively expensive, especially in the context of large-scale epidemiological studies. To address these limitations, we developed an automated microenvironmental aerosol sampler (AMAS). The AMAS is a low-cost, wearable device containing four separate filter channels. A novel aspect of this device is that it collects particulate matter from within distinct personal microenvironments (such as at home, at work, and in transit). The AMAS is about the size of a cell phone, weighs 220 g, and can sample continuously for 32 or 12 hrs on a single charge at 1 or 2 L/min of flow, respectively. The device operates autonomously, using data from on-board sensors (GPS, light intensity, temperature, acceleration) to determine when an individual enters or leaves a given microenvironment and then initiates sampling through one of the four filter channels. A custom-designed manifold utilizing miniature valves was used in conjunction with the AMAS sensor algorithm to control sample flow through a given filter channel. A pilot study was conducted for two weeks with 25 grade-school children to collect samples to demonstrate the feasibility of the sampler and to validate performance. Square-wave anodic stripping voltammetry, electrochemical paper-based analytical devices (ePADs), and image processing were used to quantify levels of zinc, cadmium, and lead collected on the AMAS filters, while particulate black carbon was quantified using optical transmissometry. These analytic techniques provide rapid, low-cost analyses, with method detection limits that are relevant to environmental concentrations: zinc [8.86 ng/m<sup>3</sup> LOD]; cadmium [0.885 ng/m<sup>3</sup> LOD]; lead [0.177 ng/m<sup>3</sup> LOD]. The AMAS and ePAD techniques were evaluated using traditional analytical techniques (ICP-MS) and personal samplers (SKC PEM, BGI OMNI 3000). Preliminary results indicate that the AMAS can be a feasible approach for low-cost, personal exposure assessment across various microenvironments.

**8AE.7**

**Development and Evaluation of an Ultrasonic Personal Aerosol Sampler (UPAS).** JOHN VOLCKENS, Casey Quinn, David Leith, John Mehaffy, Charles Henry, Dan Miller-Lionberg, *Colorado State University*

Assessing personal exposure to air pollution has long proven challenging due to limitations posed by wearable aerosol monitors: cost, noise, and weight. The objective of this work is to develop an ultrasonic personal aerosol sampler (UPAS) to overcome many of these technological limitations. The UPAS is a time-integrated monitor that features a novel micro-pump that is silent during operation. A suite of on-board sensors measure air flow, temperature, pressure, relative humidity, light intensity, and acceleration. Rapid development of the UPAS was possible through recent advances in low-cost electronics, open-source programming, and additive manufacturing. These advances enabled the development of a prototype air sampler that overcomes the cost (bill of materials under \$300), weight (190g), and noise (<45 dB) issues of traditional personal sampling devices. The operating range of the pump spans 4kPa of static pressure head and 3 L/min of flow; the mass flow sensor was accurate within 10% between 0.1 and 3 L/min. The UPAS battery lasted approximately 25 hr at 1.0 L/min and 45 hr at 2.0 L/min. The size cut of the PM<sub>2.5</sub> cyclone agreed well with the published EPA federal reference criterion (within 5% for the majority of ambient particle size distributions). Laboratory tests demonstrate excellent agreement with equivalent federal reference method samplers for gravimetric analysis of PM<sub>2.5</sub> across a broad range of concentrations (20-800 ug/m<sup>3</sup>). A simple linear regression between the UPAS and federal reference samplers gave a slope of 0.996 with an intercept of 3.7 ug/m<sup>3</sup>. The UPAS shows promise for increasing our ability to assess personal PM exposures by reducing the size, weight, and cost of the sampler. As a result, sampling can be conducted at scales that are more relevant to epidemiologic and community-based research.

**8AE.8**

**Indoor-Outdoor Relationship of PM And Health Risk Assessment.** Ruchi Sharma, RAJASEKHAR BALASUBRAMANIAN, *National University of Singapore*

Particulate air pollution is a major environmental problem, especially in highly urbanized cities such as Singapore. Airborne particulate matter (PM) has been linked to adverse health effects, and more strongly than coarser particles because of the ability of the former to penetrate deeper into the respiratory tract and to translocate to other organs. It has been estimated that people spend approximately 80% of their time indoors. Consequently, indoor exposure constitutes a significant fraction of total exposure to atmospheric pollutants for people. Also, the ultrafine particle fraction of PM (PM with size less than 100 nm) has high toxic metal contents, and exposure to such particles could induce a high oxidative stress potential. We carried out a series of systematic studies to characterize the chemical composition, sources, indoor-outdoor relationships of size-fractionated PM and quantify human health risks to aerosol particles in indoor environments equipped with and without "air purifiers". The outcome of the study will be helpful to suggest appropriate mitigation strategies to reduce human exposure to airborne toxic chemical species in PM.

**8AE.9**

**Design and Evaluation of Micro-Well Collector for Personal Aerosol Exposure Monitor.** HE JIAYANG, Makhsoos Sep, Igor Novosselov, *University of Washington*

Personal exposure monitoring is critical for evaluating particulate matter (PM), such as airborne pathogens, allergens, toxins, and their effect human health. High elution volumes, large size of the sampling setup and high power requirements limit the usefulness of the traditional filter collection methods in a variety of applications. We present a novel aerosol collection device (AeroSpec) with small form factor and low power consumption that can be used as a personal exposure monitor. AeroSpec collects PM in a low-cost collection cartridge by aerodynamically concentrating aerosol into a narrow beam that is directed into a micro-well particle trap. The micro-well cartridge is designed to capture airborne PM in the 0.75-5 micron size range and the sampling rates of 1-3 slpm. The primary aim of the design is to reduce the particle collection area for in-situ optical analysis and to increase the concentration of the sample in the elution volume. The combination of the aerodynamic focusing inlet and the optimized angle of the micro-well results in high concentration of collected PM in the submillimeter area inside the micro-well. The low-pressure drop of the collector enables power efficient operation of the AeroSpec sampler and the use of low-power vacuum pump. The micro-well cartridge performance was evaluated using monodisperse aerosols via bulk fluorescence method. Typical collection efficiencies are above 50 % for PM<sub>2.5</sub> at 1 slpm sampling flow rate. The transparent collection substrate and the well-defined collection region independent of particle size allows for in-situ optical analysis of the collected PM. Sample elution can be performed via standard pipette tip interface; the elution volume is 10 to 20 microliters.

**8AE.10**

**Size-Selective Traceable Aerosol Particles to Assess Aerosol Transport in Field Tests.** CYNTHIA J. KAESER, George R. Farquar, Matthias Frank, A. Daniel Jones, Elizabeth K. Wheeler, *Lawrence Livermore National Laboratory*

In the event of an unplanned release of hazardous aerosols, health officials must know how quickly and far from the source the aerosol could spread in order to adequately warn the public. These unwanted aerosols may be composed of a range of particle sizes and their transport after release will depend on the sizes present. Real-life environments that are at high risk for such an event are often complicated by complex air patterns and the movement of people. To provide accurate information for emergency plans, field tests can be performed in these high-risk locations using harmless, traceable aerosols of multiple sizes.

DNA Tagged Reagents for Aerosol eXperiments (DNATrax) has been shown to be a safe and effective material for tracking aerosol transport in real-life locations (Harding, 2016). Safe for human exposure with single-digit particle limits of detection, DNATrax particles are within the inhalable range (aerodynamic diameter of 1-10 micro-meter). However, the transport of particles can vary extensively even within this size range. It is then desirable to have particles of differing, non-overlapping size distributions, each labeled with a distinct DNA tag. These would be released simultaneously with the DNA tag used to differentiate the particles of each size from each other at the end of the experiment. To accomplish this, production protocols for DNATrax were optimized to provide the distinct size distributions desired. This presentation will outline these production alterations and highlight additional data acquired during the material preparation for a field test in a major U.S. city.

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Harding, R.N., et al. (2016) Unique DNA-Barcoded Aerosol Test Particles for Studying Aerosol Transport, *Aerosol Science and Technology*, 50, 429-435.

**8AE.11**

**Quantitative Analysis of Nanoparticle Size Distribution with Scanning Electron Microscope for Personal Exposure Measurement.** MAROMU YAMADA, Sheng-Chieh Chen, David Y. H. Pui, *University of Minnesota*

Personal exposure assessment to nanomaterial particles is strongly needed in occupational health field. In workplaces handling nanomaterials, direct-reading instruments and gravimetric/chemical analyses are generally applied to quantitative analyses of the nanomaterial particles. However, there are some problems in these measurements, e.g. the direct-reading instruments are not able to distinguish nanomaterials from ambient nanoparticles, gravimetric/chemical analyses require large volume of aerosol samples, and only limited morphological information can be obtained. Therefore, in this study, a new approach for quantitative analysis of nanomaterial particle concentration and their number size distribution with a scanning electron microscope (SEM) is investigated for accurate personal exposure measurements. An active personal nanoparticle sampler (PENS) composed of a micro-orifice impactor (MOI) and a subsequent 25-mm Nuclepore filter is applied for the nanoparticle samplings. Potassium chloride and silver particles are used for evaluating cutoff size of the MOI and collection efficiency of the Nuclepore filters. Cutoff size of the impactor can be varied from 400 to 100 nm depending on the operation flow rate from 0.5 to 2.0 LPM. Surface-collection efficiency of the Nuclepore filter for nanoparticles was confirmed and compared with previously suggested surface-collection efficiency models. These results obtained provide information for a method of personal exposure measurements by using the PENS as well as for considering further methodology of exposure assessment with SEM.

**8BA.1**

**Assessing the Biological Threat Posed by Suicide Bombers.** Jerry Cabalo, KATELYNN STAFFORD, *Excet, Inc/Edgewood Chemical Biological Center*

In order to assess the biological threat posed by suicide bombers, we exploded ballistic gelatin blocks using *Bacillus atrophaeus* (BG) spores as an organism simulant in increasing scaled size in three tests. The results of our test shows that 1) organisms can survive the blast, and 2) be widely dispersed in both aerosol and visible remains of the bomber. Our results show an aerosol threat. We detected living organisms in large pieces of gel as well as on collection tiles without ANY visible contamination. Significant aerosol concentrations of ballistic gelatin were detected by a UV-fluorescence based particle counter.

**8BA.2**

**Droplet Microfluidics Detector for Bioaerosols.** BRIAN DAMIT, *Johns Hopkins University Applied Physics Laboratory*

Effective detection of bioaerosols is important in fields ranging from environmental health monitoring to biosurveillance. Current detectors are limited by slow response time and expensive consumption of reagents and these weaknesses have compelled the development of new technologies. In this work, a detector was developed which applies the principles of droplet microfluidics to bioaerosol detection. Droplet microfluidics is a subfield of microfluidics based on the creation of nanoliter/femtoliter droplets containing compartmentalized reagents and boasts enhanced assays and easy fluidic manipulations. The bioaerosol detector here functions by precisely focusing aerosols directly into these droplets, and thus harness the benefits offered by a droplet microfluidics platform.

A breadboard detector system, which consisted of an aerodynamic focusing lens, aerosol-focusing nozzle, custom microfluidic droplet chip, and fluorescence microscope, was constructed. Computational fluid dynamic simulations and Lagrangian particle tracking modeling were completed to identify the optimal conditions for aerosol focusing into the droplets. Preliminary experiments, wherein test PSL aerosols were deposited onto solid substrates, demonstrated sub 200-micron spot diameters for aerodynamic sizes of 2-5 micron. After obtaining fine aerosol focusing, collection of aerosols in the droplets was achieved by positioning the chip below the nozzle, forming a pinned air-liquid interface at the chip surface, and then focusing test aerosols into that interface. Real-time inspection via microscopy confirmed aerosol capture at the interface.

Finally, to show proof-of-concept, a simple droplet propidium iodide (PI) assay was performed: the system was able to distinguish between *E. coli* and non-biological aerosols collected in a microfluidic droplet within 20 s of PI incubation. Overall, this work successfully established the technique of direct collection of aerosols into a convenient droplet microfluidic platform for the purpose of rapid bioaerosol detection.

**8BA.4**

**Capture Efficiency of Filters Against Airborne Pig Pathogen Models in an ASHRAE Standard 52.2 Test Duct.** VALÉRIE LÉTOURNEAU, Marie-Aude Ricard, Jean-Gabriel Turgeon, Laura Batista, Caroline Duchaine, *Université Laval, Canada*

Airborne transmission of pig pathogens such as the Porcine reproductive and respiratory syndrome virus (PRRSv) may be reduced in filtered buildings according to some field studies. However, the effectiveness against viruses and bacteria of filter systems need to be studied in an environmentally controlled and standardized environment. The objective of the study is to evaluate in an ASHRAE Standard 52.2-2012 test duct the capture efficiency of five combinations of MERV rated pre-filter and filter for Influenza virus, PRRSv and *Streptococcus suis* serotype 2 models. A Fluidized Bed Aerosol Generator (Model 3400A, TSI) and a 24-jet Collision Nebulizer (BGI) will be used conjointly or not to aerosolize Arizona road dust (ISO 12103-1, A2 Fine Test Dust, Powder Technology Inc), phages Phi6 (Influenza virus and PRRSv model), and *Streptococcus thermophilus* (*Streptococcus suis* serotype 2 model). Agglomeration of airborne particles coming from the two aerosol generators will take place in a mixing chamber that will be connected to the aerosol injection line of the test duct. Airborne particles will be counted by connecting two Optical Particle Sizers (sampling rate: 1L/min, Model 3330, TSI) both upstream and downstream of the tested filter system. AGI-30 impingers (sampling rate: 12.5L/min, All Glass Incorporated) will be used to sample the airborne virus and bacteria in 20mL of buffer. Samples taken from upstream and downstream of the tested filter system will be analyzed by culture and PCR to quantify viable/infectious and total microbial models, respectively. The herein study highlights the challenges of artificially reproducing the size distribution of environmental airborne particles and its effect on the capture efficiency of filters against virus and bacteria as well as using microbial models in a non-biocontained working space.

**8BA.5**

**Microbial Ice Nucleators Scavenged from the Atmosphere During Simulated Rain Events.** Regina Hanlon, Craig Powers, Kevin Failor, Boris Vinatzer, DAVID SCHMALE, *Virginia Tech*

Some microorganisms associated with rain may catalyze the nucleation of ice crystals at significantly warmer temperatures than would normally be required for ice formation, suggesting that they may play an important role in the onset of precipitation. Rain samples collected near the surface of the earth contain an array of microbial ice nucleators, but little is known about their source(s) and life history. We conducted a series of field experiments to test the hypothesis that microbial ice nucleators are scavenged from the atmosphere by rainfall. Thirty-three simulated rain events (SREs) were conducted over four months (Nov 2014, Dec 2014, April 2015, and June 2015) off the side of the Smart Road Bridge in Blacksburg, VA, USA. In each event, sterile water was dispensed over the side of the bridge and recovered in sterile containers at the bottom (a distance of ~55m). Microbes scavenged from the simulated rain events were cultured on six different types of agar media (R2A, TSA, CA; +/-cycloheximide), and the ice nucleation activity of the resulting colonies was examined. Microbial ice nucleators were cultured from 94% (31/33) of the SREs, and represented 1.4% (121/8871) of the total number of colonies assayed. This percentage is similar to the percentage of culturable microbial ice nucleators occurring in about half of the natural rain events studied in Blacksburg, VA, USA. Mean CFUs scavenged by simulated rain ranged from 2 to 267 CFUs/mL. Sequence-assisted identification of the repeatable microbial ice nucleators that were scavenged from the atmosphere showed a number of unique prokaryotic and eukaryotic taxa. This work expands our knowledge of the scavenging properties of rainfall, and suggests that at least some ice nucleators in natural precipitation events may have been scrubbed from the atmosphere during rainfall, and thus are not likely to be involved in the onset of precipitation.

**8BA.6**

**Fluorescence and Sizing Properties of Individual Particles Associated with Dust and Non-Dust Events, Contrasting Cyprus and Barbados.** NICOLE SAVAGE, Christopher Pöhlker, Jean Sciare, J. Alex Huffman, *University of Denver, CO*

Bioaerosols can act as seeds for ice nucleation thus affecting cloud formation and precipitation. In recent years, advancements in chemical and physical detection of bioaerosols have allowed the characterization of airborne biological particles much more quickly and cost effectively than by previous techniques. One such instrument is the Wideband Integrated Bioaerosol Sensor (WIBS) licensed by Droplet Measurement Technologies, which uses single particle fluorescence spectroscopy to characterize biological particles.

Cyprus is at the crossroads of 3 continents and sees aerosol events transported long distances from both natural and anthropogenic sources, including pollution from Western Europe, Eastern Europe, and the Middle East, sea salt from the Mediterranean Sea, and dust from large deserts in Africa and the Middle East. The WIBS was used to investigate the properties of bioaerosols associated with dust events originating from various geographical locations. Initial fluorescence and sizing properties of individual particles observed by the WIBS will be reported. We will contrast the aerosol properties during dust and non-dust periods to estimate the amount of fluorescent biological material that may be lofted with the dust and transported across long distances. We will also discuss the interference the dust may introduce to fluorescent aerosol characterization.

The WIBS was also operated for several months at a coastal site in Barbados to observe long-range transport of dust. Approximately 800 Tg yr<sup>-1</sup> of soil dust is transported from North Africa and brought west over the Atlantic Ocean, which may influence cloud formation properties in the region. We will show initial results and compare fluorescent particle properties between Cyprus and Barbados air masses.

**8BA.7**

**Understanding the Link between Meteorology and Speciated Abundance of Bioaerosols in an Urban Environment: A Comparison between Flow Cytometry and Real-Time Autofluorescence Measurements.** ARNALDO NEGRON-MARTY, Natasha DeLeon-Rodriguez, Samantha M. Waters, Luke Ziemba, Bruce Anderson, Michael Bergin, Kostas Konstantinidis, Athanasios Nenes, *Georgia Institute of Technology*

The abundance and speciation of primary biological atmospheric particles (PBAP) has been of great interest due to their potential impact on human health, cloud formation and contribution to atmospheric nutrient deposition. During this study state-of-the-art sampling techniques and protocols have been developed and combined with the speciation of PBAP by flow cytometry (FCM). An effective FCM protocol has been developed to identify and quantify speciated bioaerosols populations. In addition, a Wideband Integrated Bioaerosol Sensor (WIBS) has been used to understand the temporal variability of the PBAP, by measuring the autofluorescence of the atmospheric particles. The techniques developed here have been applied to understand the PBAP variability and abundance in downtown Atlanta under different meteorological conditions. FCM results show the presence of a low nucleic acid (LNA) and a high nucleic acid (HNA) content subpopulation. The contribution of each subpopulation to the total biological atmospheric particles (TBAP) varies depending on the predominant meteorological conditions. Results suggest the HNA subpopulation, named fungal spores, dominates the composition of the TBAP during humid and warm days after rain events. However, during dry episodes the HNA subpopulation is diminished and the LNA subpopulation dominates the composition of the TBAP in downtown Atlanta. Also, WIBS and FCM results qualitatively agree in the behavior of the LNA and HNA subpopulations by showing similar size distributions during specific meteorological events. Our finding suggests Atlanta average PBAP concentration is around 10,000 - 80,000 particles per cubic meter during Spring, where WIBS represents the lower bound and FCM the upper bound of the quantification. Additional FCM experiments were performed with different types of pollen, fungi and bacteria to better understand the scattering and fluorescence properties of microorganisms and to support atmospheric samples observations.

**8BA.8**

**Making the "Invisible" Visible: Aerosol Collection into a Liquid followed by Concentration of the Sample for Rapid Microbiological Methods.** DAVID ALBURTY, Michael Hornback, Andrew Page, Ann Packingham, *InnovaPrep LLC*

A tangential slit wetted cyclone (SpinCon II, InnovaPrep) was used to collect aerosolized washed *Bacillus atrophaeus* endospores from an aerosol test chamber at low aerosol concentrations into ~10 mL of sterile water. A one mL aliquot of the liquid sample was split for analysis. Half of the sample was used for traditional culture, whereas the other half mL was prepared for analysis using bead beating (OmniLyse, Claremont Biosolutions) and analyzed by qPCR (Step One, Applied Biosystems). In parallel, the remaining portion of the liquid sample was concentrated (Concentrating Pipette, InnovaPrep) and eluted in 250 microliters of clean buffer. The concentrated sample was split, with half used for traditional culture, and half prepared for analysis using bead beating and analyzed by qPCR. The results were compared and showed that a concentration factor of ~24X was applied to the initially collected sample using this process. Application of known collection and retention efficiencies (Murowchick, 2015) of the wetted cyclone are summarized for application to the design of environmental aerosol studies or for biodefense purposes.

**8BA.9****Spectral Intensity Bioaerosol Sensor (SIBS): Description and Updated Initial Characterization of a Novel Commercial Instrument for Spectrally-Resolved Fluorescence Measurements of Individual Particles.**

NICOLE SAVAGE, Tobias Könnemann, Gary Granger, Gavin McMeeking, Hang Su, Petya Yordanova, Roman Frohlich, Ulrich Poeschl, Christopher Pöhlker, J. Alex Huffman, *University of Denver, CO*

Until recently the understanding of bioaerosol properties had been limited by the lack of instrumentation capable of characterizing biological particles with high time and size resolution. The Wideband Integrated Bioaerosol Sensor (WIBS) provides information about fluorescence of individual particles in two excitation and two emission channels. The Spectral Intensity Bioaerosol Sensor (SIBS) is a new instrument developed by Droplet Measurement Technologies (DMT) that improves upon the spectral resolution of the WIBS and other commercial bioaerosol sensors by providing higher resolution spectral information. The SIBS measures time-resolved fluorescence following sequential excitation at 280 and 370 nm over 16 emission channels spanning a range of approximately 288-734 nm. The instrument provides single particle fluorescence measurements, fluorescence lifetime, an asymmetry factor, and particle size for each interrogated particle.

We performed an initial instrument comparison between the SIBS, WIBS, and Ultraviolet Aerodynamic Particle Sizer (UVAPS) instruments using various non-biological and bioparticle standards such as fungal spores, metabolic compounds, humic and fulvic acids, amino acids, and dust. The first round of characterization began in the summer of 2015, and preliminary results were presented in a poster at the AAAR conference 2015. During the initial study we realized that the prototype instrument required significant technical improvements before it was deployable. Since that point the instrument has received several major modifications and upgrades including the addition of a quadrant photomultiplier tube detector (PMT) for asymmetry analysis, a cooled PMT (Hamamatsu), and a modified control board to reduce electrical and thermal noise in fluorescence detection. We have repeated characterization experiments and will report particle sizing and fluorescence spectral properties observed by the SIBS and other instruments.

**8BA.10****Investigation of Possible Transmission of Infectious Diseases via Contaminated Cell Phones.** CAIJIA XU, Maosheng Yao, *Peking University*

In recent years, smartphones are widely used in the world and have become a life necessity. Previous studies focused on the concentration, species and pathogenicity of bacteria on the smartphone screens in clinical environment. However, smartphones may also be a source of pathogenic bacteria in daily life. People who have a fever or cold may release pathogens to their smartphone screens by coughing, sneezing or touching. Accordingly, the smartphones become a pathogen carrier and pose a health threat to friends or family members. In this study, smartphone screen swabs and throat swabs from patients with fever or cold were taken. The swab was eluted with 1.5 mL sterile water and DNA was extracted from the elution. Then loop-mediated isothermal amplification (LAMP) was used to detect common respiratory tract pathogens such as *Haemophilus influenzae*, Methicillin-resistant *Staphylococcus aureus* and so on. Our preliminary results showed nearly 10% of smartphones from flu patients studied were contaminated by *Haemophilus influenzae*. The results indicated that cell phone from flu patient could pose potential health risks to other healthy people. Further improvement of the method including washing bacteria from the cell phone can also lead to an innovative method for screening infectious agents for flu patient.

**8BA.11**

**Fine Variability of Pollens, Fungal Spores and Bacteria during Spring 2016 in Cyprus Island.** DOMINIQUE BAISNEE, Roland Sarda-Esteve, Francois Fenaille, Minh Thang Le, Jean Sciare, Iasonas Stavroulas, Michel Thibaudon, Marc Peyraut, Christophe Bossuet, *CEA*

In the frame of Bio Chemical Collectors (BCC) research project from the French Atomic Energy Commission (CEA), we have deployed a new experimental procedure for the collection and the analysis of atmospheric Bioaerosols on membrane filters without culture. This experimental procedure has been applied during the spring 2016 in Cyprus Island from March 29 to April 28, at the Cyprus Atmospheric Observatory (CAO) at Agia Marina Xyliatou. For the collection and detection of pollen and fungal spores every two hours we used a spore trap Hirst Type (LANZONI, It). For the collection, detection and analysis of bacteria every 2 hours we used a sequential sampler (LECKEL, 47/50) at a flow of 2.3m<sup>3</sup>/h. To evaluate the presence of bacteria in the Particulate Matter below 1 micron (PM<sub>1</sub>) we used 47 mm Sartorius Gelatine Filter with a pore size of 3µm. The samples were cultivated on 3 separate and specific substrates for the identification of bacterial species. For the total bacteria in the Particulate Matter below 10 microns (PM<sub>10</sub>) in we used 47 mm Nuclepore membrane with a pore size of 2µm. The analysis of total bacteria has been done by a new analytical method developed within this research program. This method consists in the detection of Muramic Acid which is a specific tracer of bacteria by Liquide Chromatography coupled with a High Resolution Mass Spectrometer (LC HS MS/MS). The final study has been done in cooperation with the Cyprus institute for the characterization of atmospheric ice nucleating particle (INP) in the frame of the EU-funded project : Impact of Biogenic versus Anthropogenic emissions on Clouds and Climate: towards a Holistic UnderStanding (BACCHUS).

This work is supported by the CBRN-E R&D research program from Joint ministerial program of R&D against CBRN-E threats.

**8BA.12**

**Comparison of RNA Analyses with Plaque Assays for Evaluating Virus Aerosol Collection Efficiency.** Xiao Jiang, Maohua Pan, Susanne Hering, John Lednicky, CHANG-YU WU, Hugh Fan, *University of Florida*

The spread of virus-induced infectious diseases through airborne transmission is a global concern for economic and medical reasons. To better understand virus transmission modes, it is essential to have an effective aerosol collector such as the growth tube collector (GTC) system that utilizes water-based laminar-flow condensation for collecting virus-containing aerosols. In this work we characterized the GTC system using bacteriophage MS2 as a surrogate for small RNA viruses. With the methods of RNA extraction and reverse-transcriptase polymerase chain reaction (RT-PCR) and the plaque assay (culturing collected virus samples), we evaluated the GTC system for its virus collection efficiency, and compared it with a commercially available apparatus SKC® Biosampler. The plaque assay reported only viable viruses collected whereas RT-PCR analyzed total viruses, including those viruses inactivated during collection. The results show that the GTC had collection efficiency of viable viruses between 0.24 – 1.8% and total collection efficiency between 18.3 – 79.0%, which was 1 - 2 orders of magnitude higher than the SKC® Biosampler. The results illustrate that the nebulization process using the Collison nebulizer deactivated the majority of MS2 viruses. Higher relative humidity (RH) significantly increased both the total collection efficiency and the efficiency for viable viruses of the GTC while its effect on the collection efficiency of SKC® Biosampler was not significant.

**8BA.13**

**Analysis of Optical Properties of Nitrated Proteins Potentially Relevant to the Atmosphere.** BENJAMIN E. SWANSON, Kyle Pierce, Amani Alhalwani, Emma Biesada, Anna Dondero, Marie Gosselin, Nicole Savage, J. Alex Huffman, *University of Denver*

Due to urbanization, many areas around the world are experiencing higher levels of anthropogenic pollution that exist in many forms. Secondary gas-phase pollutants NO<sub>2</sub> and O<sub>3</sub> have been shown to be able to react with tyrosine residues of proteins [e.g. 1], introducing the possibility that these modified proteins could exacerbate environmental allergies for people living in urban areas [2]. Recent work has shown that O<sub>3</sub> by itself can modify proteins on the surface of airborne biological particles and that fluorescence-related detection can be influenced in polluted environments [e.g. 3]. We have investigated the effect of protein nitration using tetranitromethane (TNM) as a surrogate for the tyrosine-specific gas-phase nitration induced by NO<sub>2</sub> and O<sub>3</sub> and peroxyne (PN) as a surrogate for non-specific nitration induced within human systems. We show the resultant changes in UV-vis absorption spectra and fluorescence spectra of four protein types and show how detection using a WIBS-4A (wideband in situ bioaerosol sensor) is reduced after nitration.

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**8BA.14**

**Airborne Inactivation of Enveloped and Non-enveloped Viruses by a Packed Bed Non-thermal Plasma.** TIAN XIA, Abby Kleinheksel, Eric Monsu Lee, Zhong Qiao, Krista Wigginton, Herek Clack, *University of Michigan*

Transmitted diseases are one of the greatest threats to modern agriculture and food security. They reduce crop yields, diminish animal productivity and increase animal loss from increased mortality and culls during disease outbreaks. It is believed that the prevention of infectious diseases relating to agricultural activities will become increasingly important to insure future food production. While much research has focused on waterborne pathogen inactivation, the same does not hold true for airborne pathogens, particularly for conditions where the objective is a technology capable of airstream disinfection.

For the purpose of developing a novel airstream disinfection technology and contributing to the scientific understanding of spontaneous inactivation of airborne pathogens in a plasma environment, a dielectric barrier discharge (DBD) non-thermal plasma reactor was designed and constructed in this study and its airstream disinfection efficiency was examined. Two virus species, MS2 and Phi6, were aerosolized by a nebulizer and suspended in an air flow that passed through the reactor. Two impingers sampled the virus-loaded air flow at both upstream and downstream positions in the reactor, and the samples were analyzed by plaque assay and quantitative Polymerase Chain Reaction (qPCR) to determine the active virus number concentration and total virus genome copies. A commercial power meter was used to measure the power consumption of the system. An ozone filter was installed downstream of the reactor and ozone concentration was measured both upstream and downstream of the filter. The results indicate that this preliminary reactor design can achieve up to three-log reduction in infective virus by inactivation and filtration, with volumetric energy consumption (J/L) significantly lower than that of HEPA filtration only. Unfiltered downstream ozone concentrations were not substantially higher than ambient concentrations and the ozone filter effectively counteracted such increases. With further optimization, non-thermal plasma can be a viable technology for airstream disinfection and prevention of airborne disease transmission.

**8CA.1****Comparison of Concentration of Carbonyl Compounds in Two Periods (2012-2013 vs 2014-2015) in Tijuana Airshed**

**B. C. DEISY SUGEY TOLEDO ARANGURE**, Guillermo Rodríguez-Ventura, Ernesto Velez-Lopez, Alejandro Gomez, Jesus Guerrero-García, Mariela Ruiz, Bernabe Adolfo Ochoa Morimoto, Yazmin Adilene Montoya Camacho, Alejandra Jaramillo Bernal, Melvis Vega Garcia, Fernando Ruiz Patiño, *Universidad Autonoma de Baja California, Tijuana, Mexico*

Considering environmental aspects, Tijuana is one of the most affected by air pollution, this is due to the industrial and commercial area of the region, records Showing Ministry of Environmental Protection (SPA) of Baja California, specifically in the municipalities of Tijuana, Rosarito and Mexicali are in red dot Pollution (SPA, 2012-2020).

In Tijuana, Baja California, there is a monitoring program for air quality criteria pollutants (SPA, 2012-2020), with five monitoring stations for air basin -Rosarito Tijuana, reports of PM10 concentrations are published, PM2.5, ozone (O<sub>3</sub>), nitrogen oxides (NO<sub>x</sub>), sulfur oxide (SO<sub>x</sub>).

The method used is US EPA.- TO -11 Ambient air is sucked through Cartridges Sep- Pak silica chromatographic grade. These are coated with 2,4 dinitrophenylhydrazine (DNPH) acidified as derivatizing agent. (The sampling rate was 0.7L/m for a period of 24 hours.) (SOP MLD 022,2001).

For this, a comparative study of the levels of concentration of carbonyl compounds found in the period (1) 2012-2013 vs period (2) 2014-2015 (Method TO- 11A) was performed. The results obtained during the first period show that formaldehyde is the most abundant compound [ 6.14 mg/m<sup>3</sup>], followed by acetaldehyde [2.7µg/m<sup>3</sup>] and acetone [1,63µg/m<sup>3</sup>], for the second period was the most abundant compound formaldehyde [8.52 mg/m<sup>3</sup>], followed by acetaldehyde [6.64 mg/m<sup>3</sup>] and acetone [1,92µg/m<sup>3</sup>]. It can be concluded that the concentration levels followed the same pattern, only for the second period levels increased significantly.

**8CA.2**

**Reduction of Fe(III) by Soot.** Hector Casique, Ashleen Reddy, Casey Neumann, ANNE JOHANSEN, *Central Washington University*

Combustion of fuels leads to the emission of carbonaceous soot particles that also contain organic molecules and trace metals. Despite indications that quinone-like structures and ferrous iron contribute to soot toxicity, not much is known about how these compounds are produced during combustion and after emission into the atmosphere. The purpose of this research is to study model iron-soot systems under conditions encountered in the tail pipe and in the atmosphere in order to increase our understanding of the iron redox processes that control iron speciation and surface functional groups of the soot. Wet-chemical as well as spectroscopic techniques are used to determine changes in iron speciation and soot characteristics in a variety of settings. Results show that under reducing atmospheric environments as well as in sunlight, iron is effectively reduced in the presence of soot. These results indicate that the toxicity of soot may depend on tailpipe conditions as well as ageing of aerosol particles before inhalation.

**8CA.3**

**Isolation and Quantification of Black Carbon to Study Climate Impacts.** ALLISON AIKEN, Manvendra Dubey, Rahul Zaveri, John Shilling, Alla Zelenyuk, Claudio Mazzoleni, Gavin McMeeking, Ezra Levin, Paul DeMott, Sonia Kreidenweis, *Los Alamos National Lab*

Absorbing aerosols (AA) represent a large uncertainty in climate models today. While refractory black carbon (rBC) is historically the most studied AA, the absorption enhancements (Eabs) assumed in climate models remain un-validated and depend strongly on morphologies and composition. When using core-shell Mie Theory, Eabs can be as large as a factor of 2 for non-absorbing coatings on a rBC core. Ambient measurements from field campaigns indicate that rBC Eabs depend strongly on source types (Cappa et al., 2012, Liu et al., 2015). rBC absorption is difficult to constrain in ambient data due to the presence of other absorbing species, e.g. brown carbon, absorbing dusts. For this reason, we present two measurement techniques to isolate physical and optical properties specific to rBC. The first well-established method using a thermal denuder for the removal of non-refractory species employs laser-induced incandescence (LII) in the SP2 to detect rBC and photoacoustic spectroscopy to directly measure aerosol absorption. rBC mass and size distributions are coupled with absorption measurements to directly quantify rBC optical properties from both lab and ambient studies. The second technique is a new method that uses the laser-induced vaporization (LIV) that occurs within the SP2 to remove the incandescent particles, dominated by rBC for ambient aerosols. For the first method (rBC Isolation) rBC-specific mass absorption coefficients (MAC's), single scatter albedo (SSA) and absorption enhancements (Eabs) are measured directly for SOA coating experiments on mobility-diameter selected diesel soot cores. Measurements are also compared with Mie theory calculations. Results from both ambient and laboratory data, including urban and biomass burning sources, will be presented indicating the importance of regional and source-specific studies. The second method (rBC Removal) was recently developed to isolate the effects of rBC by removing rBC from mixed aerosol samples (Levin et al., 2014). Here the SP2 is repurposed as a pre-treatment, similar to how the thermal denuder is used in the first method. The LII and the subsequent LIV that occur within the SP2 are used to remove the particles that incandesce. Removal rates and the efficacy of the method are presented based on laboratory quantification using the rBC surrogate Aquadag and a second SP2 for detection of the remaining incandescent particles (Aiken et al., 2016). Removal of Aquadag is efficient for particles >100 nm mass-equivalent diameter (d<sub>me</sub>), enabling application for microphysical studies. However, the removal of particles ≤100 nm d<sub>me</sub> is less efficient due to the formation of small particles by fragmentation and recondensation of the volatilized material. In addition, incomplete vaporization that can also occur for smaller rBC particles in the SP2 can also contribute to the particles that remain after LII. While small in mass, the particles remaining after undergoing LII and LIV in the SP2 have a significant effect on the residual absorption and incandescent particle number remaining. Therefore and in summary, future work is required before the rBC removal technique can be used as a pre-treatment for wide-ranging applications similar to how the thermal denuder is employed.

**8CA.4**

**Indonesian Peatland Fires Contribution to Haze Pollution over Singapore in 2015.** SRI HAPSARI BUDISULISTIORINI, Matthieu Riva, Michael Williams, Takuma Miyakawa, Jing Chen, Jason Surratt, Mikinori Kuwata, *Nanyang Technological University*

Transboundary haze from widespread fires in the forests and peatlands of Indonesia that has been recurring in the last decade, significantly elevated particulate matter (PM) concentration in the Southeast Asia, particularly during the 2015 El Niño. Previous studies have investigated chemical composition of particles emitted during peatland fires, however, they were limited to time-integrated samples and number of identified compounds. During October 10-31, 2015, Aerodyne Time-of-Flight Aerosol Chemical Speciation Monitor (ToF-ACSM) was deployed for real-time chemical characterization of ambient submicron PM (NR-PM<sub>1</sub>) in Singapore. Simultaneously, PM<sub>2.5</sub> samples were collected for molecular-level organic aerosol (OA) constituents, organic carbon (OC), elemental carbon (EC) and water soluble OC (WSOC). OA molecular-level tracers were quantified by gas chromatography interfaced to electron ionization mass spectrometry (GC/EI-MS) and ultra-performance liquid chromatography interfaced to high-resolution quadrupole time-of-flight mass spectrometer equipped with electrospray ionization operated in negative ion mode (UPLC/(-)ESI-HR-Q-TOFMS). Aerosol size distributions were measured by the NanoScan Scanning Mobility Particle Sizer and Optical Particle Sizer. OA and SO<sub>4</sub><sup>2-</sup> are dominant components of the haze particles, accounting for 77% and 12% of the total NR-PM<sub>1</sub> mass, respectively. OA mass mainly composes of OC, giving ratio of ~1.5. OA is generally oxidized as indicated by prevalent contribution of ion signals at m/z 44 (mostly CO<sub>2</sub><sup>+</sup>) compared to m/z 43 (mostly C<sub>2</sub>H<sub>3</sub>O<sup>+</sup>). However, during a highly elevated NR-PM<sub>1</sub> period, OA is less oxidized as showed by intense signals at m/z 43. OA from the TOF-ACSM were analyzed for factor analysis using positive matrix factorization (PMF). The biomass burning OA (BBOA) factor is confirmed with known biomass burning tracers (i.e. levoglucosan and mannosan). Significant amount of nitroaromatics were identified, indicating the formation of brown carbon (BrC) chromophores during wildfires.

**8CA.5**

**Analysis into the Microphysical Properties and Behaviour of Black Carbon Aerosol.** JAMES BROOKS, *University of Manchester*

Black Carbon (BC) aerosol is a carbonaceous material formed during combustion of fossil fuels, amongst other carbon sources. BC is often referred to as soot, and is characterised by strong visible light absorption, giving it a large radiative forcing potential. Despite BC being studied for many years now, its definition and understanding remains ambiguous due to the quality of different measurement techniques. Filter based methods have been used extensively, but include inherent inaccuracies and sampling issues (Bond et al, 2013). The use of an instrument based on laser induced incandescence (LII) has sought to eliminate such inaccuracies and has become much more common in BC measurement and detection (Moteki and Kondo, 2010). The method of LII used in the research as part of my PhD will be a Single Particle Soot Photometer (SP2), which will provide various microphysical and optical properties of BC aerosol. A beam of BC particles, on a particle-by-particle basis, will pass through a 1064nm laser beam and be heated up to temperatures of 4000K. At this high temperature, the BC particle will incandesce (vaporize) and will give information about its mass, size, composition and mixing state.

When freshly emitted, BC-containing particles are generally hydrophobic (don't readily mix with water) but with time they become hydrophilic (interact with water) through aging, which have impacts on the optical properties and mixing state of the particles (Ohata et al, 2016). The measuring of BC mixing state is not sufficient across the Earth, so large uncertainties surrounding BC climate forcing exist (Taylor et al, 2015; Willis and Healy, 2015).

I will be operating the SP2 instrument, amongst others, as an instrument-operator on-board the FAAM BAe-146 Research Aircraft, carrying out fieldwork on two campaigns. Firstly SWAAMI (South-West Asian Aerosol Monsoon Interaction) studying BC and dust properties across India, and secondly CLARIFY-2016 (Cloud-Aerosol-Radiation Interaction and Forcing – Year 2016) looking at the interaction of biomass-burning aerosol and clouds over the SE Atlantic. I will present preliminary results, in a poster format, from both campaigns.

**8CA.6**

**Effects of Secondary Organic Aerosol coating on the Morphological Properties of Soot Aggregates from Three Sources.** KAISER LEUNG, Elijah G. Schnitzler, Wolfgang Jaeger, Jason S. Olfert, *University of Alberta*

Soot aggregates are a large contributor to global climate change and have different morphological properties such as primary particle size, effective density, and mobility diameters. The purpose of this study is to determine whether soot from different sources with different initial morphological properties will restructure differently when coated with secondary organic aerosols (SOA). Monodispersed soot aggregates from a diesel engine generator, an inverted diffusion burner, and a McKenna burner underwent restructuring due to SOA derived from p-xylene in photo-oxidation chamber experiments. Soot aggregates were generated by a diesel Yanmar YDG3700 generator, combustion of methane using an inverted diffusion burner, or combustion of ethylene using a McKenna burner. All sources were treated to eliminate any volatile organic chemicals (VOCs) present, size-selected by differential mobility analyzer, injected into a smog chamber, and exposed to the oxidation products of p-xylene to form SOA coatings. The mobility diameter collected for the diesel generator were 70 nm, 100 nm, and 150 nm and the sizes collected for both the inverted burner and McKenna burner were 100 nm, 150 nm, 200 nm, and 250 nm. As the initial mobility diameter increased, the calculated percentage of diameter change also increased; with the diesel soot collapsing from a range of 1.2% to 11.8%, the inverted burner from 3.0% to 27.8%, and the McKenna burner from 0.8% to 16.0%. For comparable initial mobility diameters, the soot from the diesel generator collapsed significantly more relative to the inverted and McKenna burner. Effective density was also calculated for each source and it was determined that the soot aggregates from the diesel generator were the lowest, ranging from 0.38 to 0.47 kg/m<sup>3</sup>. For similar initial mobility diameters the effective density for the McKenna burner ranged from 0.50 to 0.689 kg/m<sup>3</sup> and for the inverted burner ranged from 0.66 to 0.74 kg/m<sup>3</sup>.

**8CA.7****CARES 2010: Diurnal Variation in the Mixing State of Black Carbon Aerosols in Sacramento, CA. R.**

SUBRAMANIAN, Janarjan Bhandari, Noopur Sharma, Swarup China, Claudio Mazzoleni, Rahul Zaveri, *Carnegie Mellon University*

Direct radiative forcing by BC-containing aerosols (BCA) is affected by the relative fraction of non-BC material and particle morphology – collectively referred to as “mixing state”. In June 2010, as part of the CARES field campaign, a DMT single particle soot photometer (SP2) was deployed in the Sacramento, CA urban area. The SP2 detects single particle BC masses over 0.5 fg, and also provides information on the BC mixing state at the single-particle-level for a narrower range of aerosol sizes. The SP2 deployed at CARES reported mixing state information for BCA larger than ~170 nm optical diameter. The mixing state can be represented using either the incandescent lag, or the coating thickness assuming core-shell morphology and using the Leading Edge Only (LEO) optimization technique. The incandescent lag method shows a diurnal variation in the BC mixing state, with a greater fraction of thickly-coated BCA in the afternoon (~17%) than in the morning (~11%). However, preliminary results with LEO are not as clear. Our investigations will examine the relationship between the binary classification of the incandescent lag method and the more quantitative LEO technique. These results will be compared to SEM images collected at the site over periods ranging from 2-6 hours.

**8CA.8****Black and Brown Carbon at Duke Forest, A Biogenic Environment Impacted by Urban Influence. R.**

SUBRAMANIAN, Antonios Tasoglou, Spyros Pandis, Andrey Khlystov, *Carnegie Mellon University*

Black carbon (BC) is a significant climate warming agent, while light-absorbing organic carbon, called brown carbon (BrC), also impacts the atmospheric radiative balance. There is strong evidence that the optical properties of ambient aerosols, especially BC, are affected by biogenic secondary organic aerosol (SOA) through the lensing effect (coating of BC cores by semivolatile SOA), in addition to the potential formation of BrC from biogenic emissions influenced by anthropogenic sources. To evaluate these effects, measurements of ambient aerosol optical properties and chemical composition were made at Duke Forest (Chapel Hill, NC) during summer 2015, using photoacoustic extinctionimeters (DMT PAX, 405 nm and 532 nm), a seven-wavelength Aethalometer, a steam-jet aerosol collector (SJAC), and a single particle soot photometer (SP2). For absorption and BC measurements, the sample was cycled between a dry line and a dry/thermally-denuded line. We found strong evidence for non-BC light absorption at Duke Forest that appears linked to a low-volatility aerosol component. For example, the Aethalometer readings at Duke Forest showed greater near-UV and blue absorption compared to absorption at 880 nm, than can be accounted for by an inverse wavelength dependence, as would be the case if BC was the only absorbing agent. On some afternoons, the blue PAX also recorded significant aerosol light absorption, which was not associated with BC. We also saw a diurnal pattern in the BC light absorption enhancement ( $E_{\text{abs}}$ ), which was greater at night than during the day. Hourly samples collected with the SJAC are being analyzed offline for aerosol chemical composition, to gain insight into the relationship of non-BC light absorption to aerosol chemistry and sources.

**8CA.9**

**The Effect of Aging on Brown Carbon Optical Properties Emitted from Biomass Pyrolysis.** MARIAM FAWAZ, Benjamin Brem, Tami Bond, *University of Illinois at Urbana Champaign*

Brown carbon is the light absorbing organic aerosol component of organic carbon. To date, few studies have touched on the optical properties of freshly emitted brown carbon; even fewer have examined the effect of the particle aging in the atmosphere on the optical properties. Aging, occurring during the lifetime of particles in the atmosphere, ranges from hours to days, where particles undergo physical and chemical reactions that alter their physicochemical properties. In this work, we study the effect of atmospheric aging on brown carbon light absorption, and report, under laboratory settings, the optical properties of freshly emitted organic aerosols and aged organic aerosols from biomass pyrolysis. We measure the light extinction, light scattering, and light absorption coefficient of organic carbon at three wavelengths (460 nm, 520 nm, and 670 nm). We use a short pathlength extinction cell to measure light extinction, a nephelometer to measure light scattering and we calculate light absorption as the difference between extinction and scattering. Brown carbon was aged by exposing the particles to atmospherically relevant concentrations of ozone ( $O_3$ ) and ammonia ( $NH_3$ ). We show that the  $O_3$  and  $NH_3$  treatments increase the absorption coefficient of brown carbon by an average of 20% and 250% respectively. Aged brown carbon aerosols absorb more light than when freshly emitted; thus, the effect of the aging processes exacerbate the impact of brown carbon concentrations in the atmosphere on global radiative forcing.

**8CA.11**

**Chemical Characterization of Water Soluble Organic Matter in Rural and Contrasting Urban Environments in the Southeastern United States.** LU XU, Hongyu Guo, Rodney J. Weber, Nga Lee Ng, *Georgia Institute of Technology*

Water-soluble organic matter (WSOM) is an important component of atmospheric particles. WSOM can alter the hygroscopicity of particles, affect particle water content, and further influence climate. However, the chemical composition of WSOM is not clear. In this study, we coupled a Particle-Into-Liquid-Sampler to a High-Resolution Time-of-Flight Mass Spectrometer (denoted as PILS-AMS) to continuously measure the chemical composition of WSOM in two contrasting environments, rural Centreville in Alabama (part of the Southeast Oxidant and Aerosol Study) and urban Atlanta in Georgia in summer, 2013. Our measurements showed that about 90% and 80% of OM is water-soluble in rural and urban sites, respectively. The fact that the majority of OM is water-soluble is consistent with our previous finding that OM in the southeast US in summer is mainly secondary. Positive Matrix Factorization (PMF) analysis was performed on both ambient total OM and WSOM for source apportionment. Based on comparison between ambient total OM and WSOM, we found that primary OM from vehicle emissions and cooking is not water-soluble. PMF factors representing secondary OM show different water solubility, which will be discussed in detail in the presentation. Studying the water solubility of OM subtypes largely improves our understanding of the sources of PMF factors.

**8CA.12****Chemical Characterization of Atmospheric Semivolatile Organic Compounds in the Greater Toronto Area.**

MANPREET TAKHAR, Mohammad Asif Iqbal, Arthur Chan, *University of Toronto*

Semivolatile organic compounds (SVOCs) are important for aerosol formation and air quality. Once released, SVOCs partition between gas- and particle-phases depending on atmospheric conditions such as temperature and total organic aerosol mass. Our main goal is to characterize the gas-phase and particle-phase organics present in  $PM_{2.5}$  and relate the composition to sources and processes. Samples were collected using an Integrated Organic Gas and Particle Sampler, which includes a denuder-based gas sampler and a filter pack. Gas-phase organics were collected via sorption to the XAD-4 resin coated denuders, and particle-phase organics were collected on quartz fiber filters backed by sorbent impregnated filters (SIFs). Denuder and filter samples were collected during the 2015 Pan Am Games held in Toronto and analyzed by thermal desorption-gas chromatography mass spectrometry (TD-GC/MS) with in situ derivatization for polar organics. SVOCs like alkanes, carbonyls and fatty acid methyl esters were observed to partition between gas- and particle-phases. Volatile polycyclic aromatic hydrocarbons (PAHs) were found predominantly in the gas-phase while polycyclic aromatic compounds like quinoline, furanone, lactone, and nitriles were observed in the particle-phase. Concentrations of PAHs show positive correlation with temperature likely due to an evaporative source present in the atmosphere, whereas alkanes concentrations show no temperature dependence. Furthermore, SIFs contain both lighter and heavier alkanes likely due to breakthrough from denuders and/or evaporation from quartz filters. Polar SVOCs like levoglucosan and abietic acid which are markers for biomass burning were observed. Also, compounds like cholesterol and fatty acids, which are representative of meat cooking emissions, are characterized using in situ derivatization GC/MS. Gas-particle partitioning, volatility distribution, and fraction of organic carbon and elemental carbon present in  $PM_{2.5}$  will also be discussed.

**8CA.13****Sources and Evolution of Wintertime Organic Aerosol in the Northeastern US.**

JASON SCHRODER, Pedro Campuzano-Jost, Douglas Day, Nicola Blake, Alan Hills, Rebecca Hornbrook, Eric Apel, Andrew Weinheimer, Teresa Campos, Viral Shah, Kelsey Larson, Jaegle Lyatt, Jose-Luis Jimenez, *CIRES, University of Colorado, Boulder*

Most recent aircraft field studies have been conducted in summer, and thus wintertime aerosol sources and chemistry are comparatively poorly understood. The WINTER aircraft campaign was a recent field experiment to probe the sources and evolution of gas pollutants and aerosols in Northeast US urban and industrial plumes during the winter. A highly customized Aerodyne high-resolution aerosol mass spectrometer (AMS) was flown on the NSF/NCAR C-130 to characterize submicron aerosol composition and evolution. Thirteen research flights were conducted covering a wide range of conditions, including rural, urban, and marine environments during day and night. Organic aerosol (OA) was an important component of the submicron aerosol in the boundary layer. The fraction of OA measured during WINTER was smaller (35-40%) than in recent US summer campaigns (~60-70%). The distribution of OA oxygenation (O:C) is broader when compared to other recent summer and spring time studies, and shows a larger fraction of less oxygenated OA, suggesting more primary emission are present during winter. However, when compared to a recent GEOS-Chem version the measured wintertime OA is substantially more oxidized. A case study of urban outflow from NYC is used to investigate wintertime evolution of OA. Based on positive matrix factorization analysis; the NYC OA outflow has a substantial amount of primary biomass burning OA (~50%), a relatively constant concentration of hydrocarbon like OA (ie primary urban), when dilution is accounted for. A rapid increase in oxidized OA (OOA, a surrogate for secondary OA) is observed with distance from NYC, indicating that the SOA production from polluted sources is faster than expected in wintertime.

**8CA.14**

**Secondary Organic Carbon (SOC) Estimation Using Several Indirect Techniques and the Evaluation of Their Uncertainties.** DEEPCHANDRA SRIVASTAVA, Olivier Favez, Nicolas Bonnaire, Emilie Perraudin, Valérie Gros, Eric Villenave, Alexandre Albinet, *INERIS/EPOC, Université Bordeaux, France*

Knowledge of the relative contribution of primary and secondary organic aerosol fractions is important in formulating effective control measurements for ambient particulate matter (PM), and the main part of Organic Aerosol (OA) in urban and rural atmospheres is found to be of secondary origin. However, its exact contribution still remains uncertain despite intensive efforts undertaken during the last decades to characterize and understand the chemistry leading to Secondary Organic Aerosol (SOA). Indeed, there is still no direct way to separate secondary to primary organic aerosol fractions. Quantification of Secondary Organic Carbon (SOC) is furthermore difficult because of our limited understanding of the molecular composition of SOC and because of the presence of a large, but unknown, number of secondary organic products. This study has been purposely carried out to estimate the contribution of SOC fraction to OA content, by using various semi-direct and indirect methodologies and evaluate associated uncertainties involved in the following outcomes. Measurements were conducted at SIRTAL-LSCE, a well arranged atmospheric site in the vicinity of Paris (France), over a period from 6 to 24 March 2015. This was accomplished by utilizing information obtained from intensive filter measurements conducted at every 4 hours. SOC estimations were proposed using Positive Matrix Factorization applied to Aerosol Chemical Speciation Monitor (ACSM) measurements as well as using off-line data analyses, such as EC-, WSOC-, and SOA tracer-based methods. Results might also assert the photochemical origin of SOA, although the relative contribution to the OC and the SOA formation may differ during the chosen period. Large discrepancies were accounted for in the SOC estimations furnished using different techniques. Results imply that cautions should be taken while estimating SOC. Discussion will lead to profound information about the limitations and challenges associated to SOC estimations using different techniques.

**8CA.15**

**Near-source Evolution of Black Carbon Mixing States: Three-dimensional Source-oriented Model Evaluation.** ALESHKA CARRION-MATTA, Bo Yang, Hitoshi Matsui, K. Max Zhang, *Cornell University*

Black carbon particles have been linked to global warming due to their physicochemical and optical properties. Mixing states of these particles are known to influence absorption efficiency and CCN activity. Spatial evolution of black carbon particles has been studied in global and regional models, which rely on realistic parameterization of source emissions. Recent studies have shown the importance of initial size distributions and mixing states in order to estimate black carbon particles radiative effects. Sensitivity simulations showed that optical and radiative variables were highly sensitive to aerosol size and mixing state initial values. Yet, few models can successfully resolve initial aerosol size distribution, number concentration and mixing state; and better representation of these features are needed. In this study, we coupled source-oriented aerosol dynamic processes with transport of black carbon particles from its sources to ambient background, simulated using computational fluid dynamics model (CFD). This model predicts size distribution, chemical composition and mixing state of black carbon particles at meter-scale resolution spatially. Outcomes from this study can potentially lead to better parameterization of appropriate initial size distributions and mixing states in the emission profiles for global and regional models.

**8CA.16**

**A Two-Year Study of Carbonaceous Aerosols in Ambient PM<sub>2.5</sub> at a Regional Background Site for Western Yangtze River Delta, China.** DONG CHEN, Hongfei Cui, Yu Zhao, *Nanjing University*

To analyze the characteristics of regional background carbonaceous aerosols in western Yangtze River Delta (YRD), hourly organic carbon (OC) and elemental carbon (EC) in fine particulate matter (PM<sub>2.5</sub>) were measured with a semi-continuous carbon analyzer at a suburban site in upwind Nanjing from June 2013 to May 2015. Relatively low OC, EC and OC/EC were observed compared to other studies conducted in Nanjing. The reasons include the limited primary emissions around the observation site, the improved emission controls in recent years, large contribution of traffic sources, and the use of denuder to reduce positive artifact in OC measurement. Resulting from the stable atmosphere conditions, the highest concentrations of carbonaceous aerosols were found in both winters, with average OC and EC observed at  $11.8 \pm 10.0$  and  $5.9 \pm 3.4 \mu\text{g}/\text{m}^3$  for the first one, and  $8.1 \pm 5$  and  $4.5 \pm 2.4 \mu\text{g}/\text{m}^3$  for the second one, respectively. Compared to 2013, reduced OC and EC were found in summer and autumn 2014, demonstrating the benefits of emission control policies implemented for the Nanjing Youth Olympic. Good correlation between OC and EC was found in winter indicating the common sources including traffic and coal combustion. Using the EC-tracer method, the highest SOC concentrations of each year were estimated in autumn for 2013-2014 ( $4.5 \mu\text{g}/\text{m}^3$ ) and in spring for 2014-2015 ( $2.4 \mu\text{g}/\text{m}^3$ ), while the largest SOC/OC appeared in summer attributed mainly to the enhanced oxidation rate for SOC generation from high temperature. For the hazy event in winter 2013, the back trajectories of air masses suggested that heavy pollution were from eastern Jiangsu, northern Anhui and Jiangsu, downtown Nanjing, and Shanghai. Secondary aerosol formation played an important role indicating by the mass fraction of OC and increased OC/EC in PM<sub>2.5</sub>. In the harvest season, biomass burning was estimated to contribute 51% and 16 % of OC and EC concentrations, respectively.

**8CA.17**

**Characterization of Time-Resolved Atmospheric Aerosol Using an Automated Raman Spectrometer and a Multi-wavelength Aethelometer.** STEVEN HILL, David Doughty, Alan Wetmore, Deryck James, *US Army Research Lab*

An automated aerosol Raman spectrometer (ARS) was used to measure Raman spectra of atmospheric aerosol at 15 minute time resolution for several days in the Washington, DC metropolitan area of the United States. We present and discuss time-resolved results of Raman spectra with emphasis on comparing results related to black and brown carbon as indicated by the D and G peaks in the single-particle Raman spectra and by multi-wavelength light absorption as measured by an aethelometer (Magee Scientific, AE-33). The ARS used (a REBS made by Battelle) automatically samples aerosol and measures individual particle-Raman spectra from these aerosols. Relations to local and regional winds are noted.

**8CA.18**

**The Aerosol Radiative Effects and Global Burden of Mortality from Uncontrolled Combustion of Domestic Waste.** JOHN KODROS, Bonne Ford, David Ridley, Rachel Cucinotta, Christine Wiedinmyer, Ryan Gan, Sheryl Magzamen, Jeffrey R. Pierce, *Colorado State University*

Open combustion of domestic waste (i.e. trash) is a potentially significant source of pollutants in developing countries; however, it is not currently included in many emission inventories. Globally, open waste burning emits  $9.2 \text{ Tg yr}^{-1}$  of organic aerosol and  $0.6 \text{ Tg yr}^{-1}$  of black carbon (Wiedinmyer et al., 2014). The proximity to largely populated urban areas has created concerns for both local air quality and climate. We incorporate the Wiedinmyer et al. (2014) open waste burning inventory into GEOS-Chem-TOMAS, a chemical transport model with online aerosol microphysics, and estimate the direct radiative effect (DRE), cloud-albedo indirect effect (AIE), and premature mortality due to chronic exposure to  $\text{PM}_{2.5}$ . Owing to uncertainties regarding aerosol optical properties as well as emission mass and size distributions, we estimate the globally averaged DRE to range from  $-40 \text{ mW m}^{-2}$  to  $+4 \text{ mW m}^{-2}$  and the AIE to range from  $-4 \text{ mW m}^{-2}$  to  $-49 \text{ mW m}^{-2}$ . In the source regions of Southeast Asia, Western Africa, and Central America, these radiative effects exceed  $-0.4 \text{ W m}^{-2}$ . We estimate chronic exposure to ambient  $\text{PM}_{2.5}$  from domestic-waste combustion to cause 284,000 adult mortalities per year, most of which occur in developing countries. Exposure to  $\text{PM}_{2.5}$  increases the risk of premature mortality by more than 0.5% for greater than 50% of the population. This estimate equates to approximately 9% of the adult mortalities from  $\text{PM}_{2.5}$  exposure reported in the Global Burden of Disease Study 2010.

Wiedinmyer, C., Yokelson, R. J. and Gullett, B. K.: Global emissions of trace gases, particulate matter, and hazardous air pollutants from open burning of domestic waste., *Environ. Sci. Technol.*, 48(16), 9523–30, doi:10.1021/es502250z, 2014.

**8CA.19**

**Molecular Composition of Biomass Burning Aerosol from Household Cookstoves in Rural Haryana, India.** Lauren Fleming, SERGEY NIZKORODOV, Donald Blake, Robert Weltman, Rufus Edwards, Peng Lin, Alexander Laskin, Julia Laskin, Kirk Smith, Narendra Arora, Sneha Gautam, Ankit Yadav, *University of California, Irvine*

Emissions of air pollutants from biomass-burning cookstoves in India have proven to be significant on regional scales. However, the extent of competition between the primary particle evaporation, which reduces the  $\text{PM}_{2.5}$  mass, and chemical oxidation of VOC components in smoke, which increases the  $\text{PM}_{2.5}$  mass by forming secondary pollutants, is poorly understood. To better constrain the contribution of primary and secondary aerosols to the aged cookstove smoke, we collected particulate matter and whole air samples from prescribed cooking activities using traditional cookstoves in Palwal District, Haryana, India. The fuel sources included brushwood and dung. The whole air samples were analyzed using gas chromatography methods to determine the distribution of non-methane volatile organic compounds in fresh smoke. The molecular composition of the particulate organic compounds was characterized using nanospray desorption electrospray ionization (nano-DESI) high-resolution mass spectrometry. Nitrogen-containing compounds were found to dominate the nano-DESI-MS signal in dung smoke samples, while the majority of detected compounds from brushwood smoke did not contain nitrogen. The results of this study will be used as an input to a model that describes secondary chemical processing of smoke, and will serve as basis for determining the effect of replacement of traditional cookstoves with more modern alternatives.

**8CA.20**

**Light Absorbing Organic Carbon Aerosol Emissions from Cookstoves in India.** APOORVA PANDEY, Sameer Patel, Pratim Biswas, Shamsh Pervez, Judith Chow, John Watson, Rajan Chakrabarty, *Washington University in St Louis*

Combustion of solid biomass in traditional cookstoves in south Asia is the largest source of carbonaceous aerosols emissions in the region. Currently, there is a high level of uncertainty in the estimated aerosol direct forcing over this region from the underlying uncertainties and discrepancies in inputs to climate models. As a step towards resolving these discrepancies, our objectives were to (1) develop particulate emission factors for in-field operation of traditional biomass cookstoves, and (2) estimate wavelength dependent Mass Absorption Cross-sections (MAC) of the emitted aerosols and their light absorbing organic carbon (LAOC) components.

A field study was conducted in Raipur, Chhattisgarh (a central Indian state) in December 2015. Common types of biomass fuel—fuel-wood, agricultural residue and cow dung — from different regions of India were used in a traditional mud stove to prepare typical meals in a household kitchen. Emissions were sampled with an eight-armed probe and analyzed using a portable mobility particle sizer, a TSI SidePak and a TESTO gas analyzer. Particle samples were collected on Teflon and quartz fiber filters during the ignition, steady flaming and smoldering phases of the combustion cycle. The Teflon filters were used for gravimetric analysis and UV-vis spectrophotometry on the filter deposits and their extracts in water and acetone. Thermo-optical (IMPROVE-TOR) analysis on the quartz filters yielded the elemental and organic carbon fractions. Emission factors (PM<sub>2.5</sub>, EC, OC and CO) were calculated using the carbon balance method. Filter transmission spectra were used to calculate the total aerosol MAC, which was apportioned to Black Carbon and LAOC using the two-component model. The total contribution of LAOC to aerosol light absorption was estimated by integrating its absorption coefficient with solar irradiance in the 300-900 nm wavelength range.

**8CA.21**

**Fractal Scaling of Coated Soot Aggregates.** WILLIAM HEINSON, Rajan Chakrabarty, *Washington University in St. Louis*

Soot Aggregates (SAs) in the atmosphere significantly influence the earth's radiation balance and climate, visibility, and public health. They are formed from high-temperature, incomplete combustion of fossil and biomass fuels via diffusion-limited aggregation of spherical monomers. Real-world combustion sources, such as wildfires and engines, operate in fuel-rich conditions and co-emit large amounts of gas-phase organic compounds along with SAs. These compounds, either upon cooling or after undergoing atmospheric processing, get deposited on the aggregate surfaces as layers of external coating. Recent studies have shown SAs can contain significant amounts of surface coatings of organic compounds which obfuscate their native fractal morphology and make them visually appear as "near-spherical". Depending on the amount of coating mass, the morphologies of SAs are currently parameterized using mass fractal dimension ( $D_f$ ) values in the range of  $1.8 \leq D_f \leq 3.0$ . Here we perform detailed three-dimensional morphological characterization of simulated surface coated aggregates that mimic atmospheric SAs. We show that  $D_f$  remains invariant at 1.8 with increasing coating mass. We find coating to affect only the fractal prefactor, an understudied parameter which controls the aggregate shape anisotropy and local packing fraction of monomers. We provide revised scaling relationships to enable better representation of SA morphologies in climate models.

**8CA.22****Mass-specific Extinction and Absorption Spectra of Particles from Kerosene-fueled Simple Wick Lamps.**

CHRISTOPHER ZANGMEISTER, James Radney, Courtney Grimes, Jessica Young, Rian You, Russell Dickerson, Michael Zachariah, *National Institute of Standards and Technology*

A recent global survey reported more than  $3.25 \times 10^8$  kerosene-fueled simple wick lamps are in routine use consuming greater than  $7.0 \times 10^{10}$  L of kerosene and producing  $6 \times 10^{12}$  g of particulate emissions per year. To date little is known about the optical properties of particles produced from simple wick lamps and how these sources impact localized climate forcing. In this study we quantitatively measure absorption spectra and extinction from particles emitted from kerosene-fueled simple wick lamps. Data was collected in-situ of mass- and mobility-selected particles using a single wavelength cavity ringdown spectrometer and a broadband photoacoustic spectrometer, respectively. Lamps were sourced from both East Africa and the United States. The mass-specific absorption and extinction cross-sections – MAC and MEC – at  $\lambda = 660$  nm were  $12.1 \pm 1.0$  m<sup>2</sup> g<sup>-1</sup> and  $14.6 \pm 1.4$  m<sup>2</sup> g<sup>-1</sup> yielding a single scattering albedo of  $0.17 \pm 0.03$ ; all uncertainties are  $2\sigma$ . Absorption spectra were measured from  $\lambda = 500$  nm to 840 nm for aerosols with a mobility diameter of 500 nm. The measured absorption Ångström exponent (AAE) was  $0.89 \pm 0.10$  and independent of particle mass. The MAC at  $\lambda = 550$  nm was  $16.5 \pm 1.5$  m<sup>2</sup> g<sup>-1</sup>, 2.5 times higher than previous measurements from kerosene-fueled simple wick lamps. The measured results are discussed for their potential impacts on localized climate forcing.

**8CA.23****Evaluation of the Absorption Ångström Exponents for Traffic and Wood Burning in the Aethalometer Based Source Apportionment Using Radiocarbon Measurements of Ambient Aerosol.**

ANDRE PRÉVÔT, Peter Zotter, Hanna Herich, Martin Gysel, Imad El Haddad, Yanlin Zhang, Grisa Mocnik, Christoph Hueglin, Urs Baltensperger, Soenke Szidat, *Paul Scherrer Institute*

Black carbon (BC) measured by a multi-wavelength Aethalometer can be apportioned to traffic and wood burning. The method is based on the differences in the wavelength dependence of the aerosol absorption for these two sources (Sandradewi et al. 2008). This dependence is typically parameterized by the Ångström absorption exponent ( $\alpha$ ). While the spectral dependence of the traffic-related BC light absorption is low, wood smoke particles are characterized by enhanced light absorption in the blue and near ultraviolet. Source apportionment results using this methodology are hence strongly dependent on the  $\alpha$ -values assumed for the pure emissions from these two sources (traffic  $\alpha_{TR}$ , and wood burning  $\alpha_{WB}$ ). Most studies use a single  $\alpha_{TR}$  and  $\alpha_{WB}$  pair in the Aethalometer model, derived from previous work. However, an accurate determination of the source specific  $\alpha$ -values is currently lacking, and in some recent publications the applicability of the Aethalometer model was questioned.

The best combination of  $\alpha_{TR}$  and  $\alpha_{WB}$  (0.9 and 1.68, respectively) was obtained by fitting the Aethalometer model outputs against the fossil fraction of EC (EC<sub>f</sub>/EC) derived from 14C measurements. Aethalometer and 14C source apportionment results are well correlated ( $r = 0.81$ ) and the fitting residuals exhibit only a minor positive bias of 1.6% and an average precision of 9.3%. This indicates that the Aethalometer model reproduces reasonably well the 14C results for all stations investigated in this study using our best estimate of a single  $\alpha_{WB}$  and  $\alpha_{TR}$  pair. We also show that  $\alpha_{WB}$  and  $\alpha_{TR}$  values previously used in literature (~2) significant residuals and biases. Therefore we recommend to use the best  $\alpha$  combination as obtained here ( $\alpha_{TR} = 0.9$  and  $\alpha_{WB} = 1.68$ ) in future studies when no or only limited additional information are available.

Sandradewi et al. (2008) Environ. Sci. Technol. 42, 3316-3323.

**8CA.24**

**Fourier-Transform Infrared Determination of Organic and Elemental Carbon in the Chemical Speciation Network by Partial Least-Squares: The Importance of Spectra Pretreatment on Factor Interpretation.** ANDREW WEAKLEY, Ann Dillner, Satoshi Takahama, *University of California, Davis*

Organic and elemental carbon (OC, EC) are major constituents in urban ambient fine aerosols (PM<sub>2.5</sub>) and quantified in the EPA's Chemical Speciation Network (CSN). Presently, OC and EC are determined by subjecting PM<sub>2.5</sub> collected on quartz substrates to destructive thermal analysis using thermal optical reflectance (TOR). Recently, it was demonstrated that the quantity of TOR OC and EC is non-destructively determinable using a partial least-squares (PLS) regression with Fourier-transform infrared (FT-IR) spectra. Here, a PLS regression correlates the infrared absorption of PM<sub>2.5</sub> on collocated polytetrafluoroethylene (PTFE) filters to their corresponding TOR OC and EC measurements. The optimal prediction of TOR OC involves second derivative transforming spectra to suppress PTFE scattering and amplify the signal-to-background ratio of organic functional groups. Next, the PLS model is trained to use only infrared absorption (indexed on specific wavenumbers) best correlated to the TOR OC measurement. Judiciously selecting wavenumbers for calibration using the backward Monte Carlo unimportant variable elimination (BMCUVE) algorithm resulted in an accurate and parsimonious (few-component) PLS model. Further analysis indicated that a single PLS component (factor) modeled the average extinction of mid-infrared radiation by OC functional groups. Furthermore, the FT-IR OC method matched the accuracy and precision of parallel TOR OC measurements when predicting independent testing samples not used for calibration. Determination of TOR EC by PLS followed a similar procedure, with method repeatability again demonstrated using test samples. We also provide a first demonstration of transferability of calibration models for TOR OC and EC prediction developed from CSN spectra to samples collected in the Federal Reference Method (FRM). Preliminary results indicate that appropriately pretreating FT-IR spectra prior calibration and prediction is vital to the successful, interpretable, repeatable, and potentially transferable prediction of TOR OC and EC by the FT-IR method.

**8CA.25**

**Spatial and Temporal Trends of Aerosol and Precipitation Chemistry at Four Sites in South Korea, 1997-2015.** BEOMCHEOL SHIN, Jo Wan Cha, Sang-bum Ryoo, *NIMS, KMA*

Comparison between rainwater and aerosol components reveals some information about common sources of these components. Na<sup>+</sup> and Mg<sup>2+</sup> are sea salt elements in both rain and aerosol. Mg<sup>2+</sup>, Ca<sup>2+</sup>, and Na<sup>+</sup> are associated with crustal origin. Similarly the anthropogenic constituents SO<sub>4</sub><sup>2-</sup>, NH<sub>4</sub><sup>+</sup> and K<sup>+</sup> indicate similar source of origin, namely, they were incorporated into cloud droplet and transported to other location. In this work, we investigate the annual profiles of rain/snow water accumulation, precipitation pH, and composition of precipitation and aerosol particles. Precipitation accumulation occurs mostly during the monsoon season (July-September). Rain and snow pH levels are usually between 4-6, with crustal-derived species playing a major role in acid neutralization. These species (Ca<sup>2+</sup>, Mg<sup>2+</sup>, K<sup>+</sup>, Na<sup>+</sup>) exhibit their lowest concentrations during summer and their highest concentrations in the other seasons in both PM<sub>2.5</sub> and precipitation due mostly to dust. And how these species are best correlated with each other in rain and snow will also be discussed.

And the trends of sulfate, nitrate, and ammonium in precipitation can indicate changes in the mixture of gases and particles scavenged by precipitation, possibly reflecting changes in emissions, atmospheric chemical transformations, and weather patterns. We characterizes the spatial and temporal patterns of aerosol and precipitation composition at four sites across South Korea between 1997 and 2015 by Mann-Kendall statistical test. Analyses were performed on concentrations of ammonium, sulfate, nitrate, dissolved inorganic nitrogen (DIN, sum of nitrogen from nitrate and ammonium), and earth crustal cations (ECC, sum of calcium, magnesium, and potassium). And the most influential species towards rain and snow water pH will be presented.

**8CA.26**

**Water-soluble PM<sub>2.5</sub> Composition and Particle Water Content During Wintertime in Fresno, California: Results from DISCOVER-AQ 2013.** CAROLINE PARWORTH, Dominique Young, Hwajin Kim, Sonya Collier, Qi Zhang, *University of California, Davis*

The chemical composition and concentration of ionic PM<sub>2.5</sub> and gas-phase species were measured from January – February, 2013 in Fresno, CA with a Particle-Into-Liquid Sampler with Ion Chromatography (PILS-IC) and annular denuders. The average ( $\pm 1\sigma$ ) ionic PM<sub>2.5</sub> mass concentration was 17.4 ( $\pm 10.9$ ) micro-grams m<sup>-3</sup>, such that NO<sub>3</sub><sup>-</sup> dominated followed by NH<sub>4</sub><sup>+</sup>, SO<sub>4</sub><sup>2-</sup>, Cl<sup>-</sup>, K<sup>+</sup>, NO<sub>2</sub><sup>-</sup>, Na<sup>+</sup>, Ca<sup>2+</sup>, formate, glycolate, and F<sup>-</sup>. Residential wood burning may be a dominant source of glycolate, and mixed sources of formate include vehicles and wood burning. Several amines were identified including methylamine (CH<sub>3</sub>NH<sub>3</sub><sup>+</sup>) being the most abundant followed by triethanolamine ((HOCH<sub>2</sub>CH<sub>2</sub>)<sub>3</sub>NH<sup>+</sup>), ethanolamine (HOCH<sub>2</sub>CH<sub>2</sub>NH<sub>3</sub><sup>+</sup>), dimethylamine ((CH<sub>3</sub>)<sub>2</sub>NH<sub>2</sub><sup>+</sup>), and ethylamine (CH<sub>3</sub>CH<sub>2</sub>NH<sub>3</sub><sup>+</sup>). Regional sources of amines are likely, and amines are not expected to be important atmospheric bases compared to NH<sub>4</sub><sup>+</sup> during this study. PM<sub>2.5</sub> K<sup>+</sup> was identified as an external tracer for residential wood burning in this region. PM<sub>2.5</sub> Na<sup>+</sup>, Cl<sup>-</sup>, and (CH<sub>3</sub>)<sub>2</sub>NH<sub>2</sub><sup>+</sup> mass concentrations enhanced during a strong sea-breeze event, with Na<sup>+</sup> serving as an external tracer for sea spray aerosol. NH<sub>3</sub> exceeded HNO<sub>3</sub> mass concentrations, such that NH<sub>4</sub>NO<sub>3</sub> is predicted to be limited by HNO<sub>3</sub> availability. Particle water was calculated, such that inorganic particle water was approximated using E-AIM theory and organic particle water was approximated with kappa-Kohler theory. The average ( $\pm 1\sigma$ ) total particle water mass concentration was 22.8 ( $\pm 21.8$ ) micro-grams m<sup>-3</sup> such that inorganic particle water dominated total particle water mass (87%). Particle water mass was the greatest during early morning and night hours.

**8CA.27**

**Trends of Macronutrients in Fractionated Particulate Matter in Rooster House.** NANH LOVANH, John Loughrin, Philip Silva, *USDA-ARS*

The persistence and long life expectancy of ammonia, odors and toxic pollutants from poultry houses may be due to the ability of suspended particulate matters (SPM) to serve as carriers for odorous compounds such as ammonium ions and volatile organic compounds. SPM is generated from the feed, animal manure, and the birds themselves. A large portion of odor associated with exhaust air from poultry houses is SPM that have absorbed odors from within the houses. Understanding the fate and transport processes of particulate emissions in poultry house is a necessary first step in utilizing the appropriate abatement strategies. In this study, the examination of the macronutrients such as sodium, potassium, calcium and magnesium distributions in SPM in a rooster house was carried out. Fractionated SPM (2.5 micro-meter, 10.0 micro-meter, and total inhalable fraction or TIH) were collected from a rooster house using particle trap impactors. The SPM from the particle trap impactors were extracted and analyzed for various chemical species using ion chromatography (IC) and high performance liquid chromatography. The results showed that macronutrients were highly concentrated in the smaller SPM than the larger size particles. In addition, the concentrations of macronutrients were observed to increase over the life of the flock. Furthermore, a marked increase in SPM concentrations was observed during non-feeding periods used to increase leanness in birds. During the 25 weeks of growth, the average concentration differences between feeding and non-feeding periods for PM<sub>2.5</sub>, PM<sub>10</sub>, and TIH were 58%, 104%, and 149%, respectively.

**8CA.28****Seasonal Variation and Characteristics of Carbonaceous Aerosol in PM<sub>2.5</sub> of the Background Atmosphere in Korea.**

JiYI LEE, Jong Sik Lee, Yu Woon Jang, Eun Sil Kim, Yong Pyo Kim, Chang Hoon Jung, *Chosun University*

Routine measurements of organic carbon (OC), elemental carbon (EC), water-soluble organic carbon (WSOC) and Humic Like Substance-Carbon (HULIS-C) in PM<sub>2.5</sub> were carried out at Anmyeon Island (AI) to understand seasonal variation and the level of carbonaceous aerosol concentrations at a background area in Korea between 2015 and 2016. Annual average concentrations of OC and EC were  $4.47 \pm 3.04 \mu\text{g}/\text{m}^3$  and  $0.41 \pm 0.18 \mu\text{g}/\text{m}^3$ , respectively. OC and EC concentrations showed same seasonal variation with summer minimum and fall maximum, while, the composition of OC and EC was consistent (90% of OC and 10% of EC in carbonaceous aerosol). The average concentrations of WSOC and WISOC were  $2.54 \pm 1.74 \mu\text{g}/\text{m}^3$  and  $1.93 \pm 1.42 \mu\text{g}/\text{m}^3$ , respectively, and their composition in OC shows high variation in the sample. WISOC was calculated by subtraction of WSOC from OC and good correlation of WISOC with EC was observed. It means WISOC is originated from primary emission. While, WSOC concentrations were highly related with SOC (Secondary Organic Carbon) concentrations which were estimated by the EC tracer method. The results indicate the formation of secondary organic aerosol (SOA) is major factor for the determination of WSOC concentrations in this region. HULIS-C as known one of brown carbon was major component of WSOC which accounts for 39 to 99% in WSOC. The average concentrations of HULIS-C was  $2.02 \pm 1.42 \mu\text{g}/\text{m}^3$  and the highest concentration was observed in fall. About 100 individual organic compounds were also analyzed and seasonal characteristics of their distributions in the atmosphere were investigated to understand the relation carbonaceous aerosol with the compounds.

**8CA.29****Property of Black Carbon Particles Measured by a Laser-Induced Incandescence Technique in the Spring at Noto Peninsula, Japan.**

FUMIKAZU TAKETANI, Yugo Kanaya, Tomoki Nakayama, Sayako Ueda, Yutaka Matsumi, Yasuhiro Sadanaga, Yoko Iwamoto, Atsushi Matsuki, *JAMSTEC*

Ground-based measurement for black carbon (BC) using a laser-induced incandescence technique was performed at NOTO Ground-based Research Observatory (NOTOGRO) in Suzu City, Ishikawa, Japan (37.45N, 137.36E) from April 17 to May 14 in 2013. Mass concentration of BC ranged 1.5-823 ng/m<sup>3</sup> in 1-hour average. In the observed period, we captured East Asian outflow, the domestic and clean air masses by the analysis of backward trajectories. Temporal variations of BC number and mass distributions indicated that the size of BC particles in the East Asian outflow was the largest, followed by the domestic and clean air masses. The analysis of mixing state of BC indicated that the ratio of internally mixed BC particles in which diameter is 200 +/- 10 nm were 65%, 54%, and 23% in the East Asian outflow, domestic air mass, and clean air mass, respectively. This result qualitatively supported that the degree of enhancement in light absorption observed by a photoacoustic soot spectrometer.

**8CC.1**

**Sensitivity of Cloud-Albedo Aerosol Indirect Effect on Assumed Aerosol Size Distribution Shape.** JOHN KODROS, Jeffrey R. Pierce, *Colorado State University*

Aerosol-cloud interactions are among the most uncertain climate forcings partly due to the strong sensitivity of cloud droplet number concentration (CDNC) to size-resolved aerosol number; however, many climate and chemical-transport models do not include explicit treatment of the aerosol size distribution. In order to estimate CDNC and thus the cloud-albedo aerosol indirect effect (AIE), these bulk aerosol models scale particle mass into a size-resolved number distribution by assuming a fixed size-distribution shape (commonly a lognormal distribution). This method fails to capture nonlinear microphysical processes at the regional level. We use the global chemical-transport model, GEOS-Chem, to estimate the AIE due to anthropogenic emissions when using several fixed size-distribution shapes and compare this to estimates using particle number distributions calculated online with the Two Moment Aerosol Sectional (TOMAS) microphysics scheme. For a given supersaturation, the fixed size-distribution models overestimate CCN in clean conditions and underpredict CCN in polluted regions, leading to a net overprediction of CCN in the simulation with anthropogenic emissions turned off. We show that a fixed size distribution can underestimate the anthropogenic AIE in the global-mean by 0.1-0.3  $W m^{-2}$  and regionally by more than 2.0  $W m^{-2}$ . Much of this variability is caused by failure to capture changes in nucleation and condensational growth due to altering primary emission mass.

**8CC.3**

**Impact of Climate Change on Summertime Ozone and Fine Particulate Matter in China.** JIANLIN HU, Zhan Zhao, Qi Ying, Hongliang Zhang, *Nanjing University of Information Science & Technology*

China has severe summertime air pollution, characterized by high ozone (O<sub>3</sub>) and fine particulate matter (PM<sub>2.5</sub>) concentrations. Exposure to high concentrations of O<sub>3</sub> and PM<sub>2.5</sub> causes serious health consequences. Studies have revealed that meteorological conditions including wind field, boundary layer height, temperature, humidity, precipitation, clouds, influence the atmospheric chemistry and physical processes. Therefore climate change will not only alter the weather patterns in China, but also modify O<sub>3</sub> and PM<sub>2.5</sub> concentrations. It is necessary to quantitatively investigate the impact of climate change in China.

The current study investigates the impact of climate change on O<sub>3</sub> and PM<sub>2.5</sub> concentrations using a dynamic downscaling approach with bias correction technique. The regional climate is simulated by dynamically downscaling the Community Earth System Model (CESM) simulation results from the fifth phase of the Coupled Model Intercomparison Project (CMIP5) with RCP6.0 emission scenario ) using the Weather Research and Forecasting (WRF) model. The air quality is simulated using the Community Multi-scale Air Quality Model (CMAQ). The CESM-WRF-CMAQ model system is used to simulate the air quality in the entire China using a horizontal resolution of 36 km for summer episodes (June-July-August) in current years of 2006-2015 and future years of 2046-2055. The concentration changes of O<sub>3</sub> and PM<sub>2.5</sub> due to climate change will be analyzed. The areas where air quality is most sensitive to climate change and the meteorological parameters that are most responsible to the air quality change will be identified.

**8CC.4**

**Aerosol Formation and Growth Associated with Hurricane Intensification: Observations from Hurricanes Edouard and Cristobal in 2014.** LUKE ZIEMBA, Michael Shook, Andreas Beyersdorf, Richard Moore, Kenneth Thornhill, Edward Winstead, Bruce Anderson, NASA

Particles are integral to convective storm dynamics by serving as cloud condensation nuclei (CCN) and ice nuclei. Aerosol effects are especially uncertain for hurricane formation, intensification, and dissipation, where the role of aerosols is unclear and difficult to decouple from overlying meteorological factors. For example, the prevalence of dry air associated with the Saharan Air Layer (SAL) makes understanding the role of transported dust on Atlantic hurricanes difficult to untangle. While much attention has focused on interactions between SAL dust and hurricanes, storms with well-formed eyes may present conditions conducive to new particle formation, i.e., low surface area of pre-existing aerosols to promote nucleation and enough time isolated from wet scavenging for condensation or coagulation growth.

Aerosol number concentration (BMI mixing condensation particle counter, model 1720) and size distribution (DMT Ultra-High Sensitivity Aerosol Spectrometer) observations were made from a NOAA WP-3D hurricane hunter aircraft during the 2014 hurricane season. Two storms were sampled. Hurricane Cristobal was sampled over a three day period from August 24-26 during transitions from tropical depression to Category 1, never forming an organized eye before weakening off the Atlantic coast. Hurricane Edouard did not threaten the continental coast, but rapidly intensified East of Bermuda forming a well-defined eye and reaching Category 3 strength on September 16. Here, we contrast aerosol observations associated with these storms, where high particle concentrations (greater than  $5 \times 10^3 \text{ cm}^{-3}$ ) were observed only during penetrations of Edouard's eye. A large fraction of the size distribution was above 60 nm diameter, particles that were likely effective CCN. Concentrations inside the hurricane eye were always greater than at the storm periphery, suggesting local formation. The highest concentrations were observed during Edouard rapid intensification. Potential ramifications on storm dynamics of new particle formation inside the eyes of hurricanes are discussed.

**8CC.5**

**Black Carbon, Aerosol Water, Mixing States and CCN.** Diep Vu, Shaokai Gao, Tyler Berte, Desiree Smith, Mary Kacarab, AKUA ASA-AWUKU, *University of California, Riverside*

To characterize and modify mixing states, a new laminar flow tube apparatus was developed to control the extent of mixing of black carbon, organic and inorganic fractions under different relative humidity environmental conditions. Data sets yielding multiple activation curves have been recreated by mixing multiple inorganic and organic compounds in the flow tube. Results show that aerosol water is a significant factor; under dry conditions, the aerosols remained externally mixed while humid conditions facilitated internal mixing. For example, ammonium sulfate (inorganic) and succinic acid (organic) when dry, maintained an external mixture and multiple activation curves were observed to be constant. Under humid conditions, external mixing was initially observed; however, the aerosol water promoted internal mixing and the activation curves were observed to converge onto a single curve. The data agree well with Kohler Theory and single parameter ( $\kappa$ ) theory thermodynamic predictions of droplet activation. The method of analysis and the effect of mixing states of multiple components on the supersaturated hygroscopic properties of aerosols are presented.

**8CC.6**

**Probing the Source of Ice Nucleating Particles in Sea Spray Aerosol.** PAUL DEMOTT, Christina S. McCluskey, Thomas Hill, Francesca Malfatti, Kimberly Prather, Alain Protat, Sonia Kreidenweis, Ruby Leung, *Colorado State University*

The oceans provide a distinct source of ice nucleating particles (INPs) to the atmosphere in comparison to land sources (DeMott et al., 2015), one with INP active site density ( $\text{cm}^{-2}$ ) values, based on the sea spray aerosol (SSA) surface area distribution, that are more than 2 orders of magnitude below values documented for mineral and soil dusts from land. We present more recent data collected over Northern Hemisphere oceans which confirm these results. We will also present new measurements underway from collections in the Southern Ocean region, some of the first in nearly 40 years, and we will discuss implications for description in numerical modeling.

Discerning the composition of INPs from sea spray is challenging, which limits parameterization efforts. At sufficiently low temperatures, a real-time INP measurement such as a continuous flow diffusion chamber can be used to collect individual activated INPs. Such measurements indicate a variety of components in INPs from SSA at temperatures around  $-30\text{C}$ , including components of diatoms, exudates, and even fatty acids and lipids. Bulk INP collection and processing methods that are needed to quantify the low numbers active at modest cloud supercooling do not permit inspection of individual INPs, but indirect methods using application of heat, enzymes and other chemicals gives inferences to the nature of these particles or entities (e.g., they may be molecular in scale). Such investigations and an assessment of present understanding of the source of INPs in SSA will be presented.

**8CC.7**

**Bimodal CCN and Cloud Microphysics.** James Hudson, Stephen Noble, *Desert Research Institute*

Bimodal spectra observed by DRI CCN spectrometers in two aircraft field campaigns showed opposite relationships with droplets. Clouds associated with more bimodal CCN had higher droplet concentrations than clouds associated with more unimodal CCN in MASE stratus clouds whereas clouds associated with more bimodal CCN in ICE-T cumuli had lower droplet concentrations than clouds associated with more unimodal CCN. Furthermore, there was an order of magnitude less drizzle in clouds associated with bimodal CCN than clouds associated with unimodal CCN in MASE stratus and orders of magnitude greater drizzle in clouds associated with bimodal CCN than clouds associated with unimodal CCN in ICE-T cumuli. Therefore, chemical cloud processing that predominates in thinner stratus clouds with smaller droplets enhances first (albedo) and second (cloud lifetime) indirect aerosol effects (IAE) whereas predominant coalescence processing in thicker cumulus clouds with larger droplets reduces both IAE.

Surface aerosol bimodality at the Oklahoma ARM site correlated with greater cloud fractions, lower cloud base altitudes, greater liquid water paths, greater negative vertical wind and precipitation. These results provide further proof that clouds are the source of bimodal aerosol/CCN. Particle hygroscopicity ( $\kappa$ ) measurements obtained by matching differential simultaneous CCN and dry particle size spectra showed consistently greater  $\kappa$  for larger particles. These lower critical supersaturation particles that resulted from cloud processing indicate chemical processing. Because of around-the-clock year-round coverage surface measurements provide more data more economically than aircraft campaigns. Thus, surface aerosol and remote sensing measurements that have now been validated at ARM sites can be used to further advance understanding of cloud processing. Cloud processed CCN may be so good (low critical supersaturations and high  $\kappa$ s) that they may prevent anthropogenic CCN from making cloud droplets, thus precluding IAE except for the anthropogenic contributions to the trace gases that do the chemical processing.

**8CC.8****Volatility of Material Coating Black Carbon Particles at Duke Forest, an Anthropogenically-influenced Forest Site in Southeastern USA.** ANDREY KHLYSTOV, R.Subramanian, *Desert Research Institute*

Secondary organic aerosol (SOA) from biogenic sources has a significant contribution to ambient aerosol loadings in Southeastern USA and thus contributes to adverse health effects of air pollution and influences regional and global climate. SOA can contribute to aerosol climate forcing via scattering and absorption of solar light. The latter could occur either when organic compounds absorb light by themselves (the so-called brown carbon) or by enhancing light absorption efficiency of black carbon (BC) when they coat BC particles. As part of a larger study to assess the effect of biogenic SOA on aerosol optical properties, a set of instruments, including scanning mobility sizers (SMPS), single particle soot photometer (SP2), and a thermodenuder, was deployed during June 2015 at a site in Duke Forest near Chapel Hill, NC. The site is characterized by a significant contribution of both biogenic and urban (mostly traffic) sources. Measurements of changes in aerosol volume and optical size upon heating in the thermodenuder at different temperatures are used to derive volatility properties of the ambient aerosol. A set of experiments using the tandem differential mobility analysis (TDMA) approach was carried out to investigate whether BC is internally or externally mixed with other aerosol constituents. We will discuss volatility properties of the bulk aerosol and the material that coats BC particles, as well as implications of external vs. internal mixing for derivation of bulk volatility properties of ambient aerosol.

**8CC.9****The Partial Scattering Cross Section and Efficiency.**JUSTIN MAUGHAN, Chris Sorensen, Amit Chakrabarti, *Kansas State University*

The partial scattering cross-section and efficiency are introduced. We define the partial scattering cross-section as integral of the differential scattering cross-section over theta from 0 to  $\theta_p$  and from 0 to  $2\pi$  over phi, where theta is the standard polar scattering angle and phi is the azimuthal angle. The partial efficiency is defined as the partial scattering cross-section normalized by the geometric cross-section of the particle as viewed from the direction of the incident light. Investigation of the partial scattering cross-section of a sphere shows that nearly half of all the scattered light is reached by  $\theta_p = \lambda/3R$  where lambda is the wavelength of light and R is the radius of the sphere. Q-space analysis is applied to the partial scattering cross-section, which involves plotting vs. the scattering wave vector  $q = 2kR\sin(\theta/2)$  here  $k = 2\pi/\lambda$  on a log-log plot. When Q-space analysis is applied to the partial scattering cross-section, it is found that half of the scattered light comes from 2d diffraction while the other half comes from 3d diffraction. The internal coupling parameter  $\rho = 2kR|(m^2-1)/(m^2+2)|$  provides a universal description of the partial quantities. When Q-space analysis is applied to the partial efficiency, it is found that strong absorption removes approximately one geometric cross-section from the scattered light. The removed geometric cross-section comes almost entirely from the 3d diffraction while leaving the 2d diffraction relatively unaffected.

**8CC.11**

**Design and Testing of the NASA Axial Cyclone Cloud-water Collector (AC3).** EWAN CROSBIE, Luke Ziemba, Andreas Beyersdorf, Chelsea Corr, Richard Moore, Michael Shook, Kenneth Thornhill, Edward Winstead, Jeffrey Collett, Bruce Anderson, *NASA*

A new design for airborne cloud-water collection was implemented for testing onboard the NASA C-130 aircraft as part of the North Atlantic Aerosols and Marine Ecosystems Study (NAAMES). The technique involves the separation of droplets from the airstream using a swirl chamber induced via a stator - a set of eight turning vanes - followed by capture and collection of the water for subsequent offline analysis. The operating principle was based on a previous design reported in Straub and Collett (2004), and has been flown previously on the NCAR C-130. We aim to replicate the successes, and improve upon the reported shortfalls, of their design. Here we present details of the design process, laboratory testing, and preliminary results from NAAMES.

Straub, D. J., & Collett Jr, J. L. (2004). An axial-flow cyclone for aircraft-based cloud water sampling. *Journal of Atmospheric and Oceanic Technology*, 21(12), 1825-1839.

**8CC.12**

**Universal Description of Light Scattering by Irregularly Shaped Particles.** YULI HEINSON, Justin Maughan, William Heinson, Amit Chakrabarti, Chris Sorensen, *Kansas State University*

We report a universal and coherent description of light scattering by non-spherical, non-fractal, irregularly shaped particles. We built our experimental apparatus to detect scattering light at 31 angles simultaneously, starting from a small angle of  $0.32^\circ$  to  $157^\circ$ . We applied Q-space analysis to the phase function for the data from both our group and others. Q-space analysis uncovers patterns common to all particles: a q-independent forward scattering regime is followed by a Guinier regime, a power law regime with quantifiable exponents, and sometimes an enhanced back scattering regime. Moreover, the power law exponents have a universal functionality with the internal coupling parameter  $\rho'$  where  $\rho' = 2kR|(m^2 - 1)(m^2 + 2)|$ . The absolute value of the exponents start from 4 when  $\rho'$  is small. As  $\rho'$  increases, the exponents decrease until the trend levels off at  $\rho' \gtrsim 10$  where the exponents reach a constant  $1.75 \pm 0.25$ . All the non-spherical, non-fractal, irregularly shaped particles fall on the same trend regardless of the detail of their structure.

**8CC.13****A General Description of the Angular Distribution of Light Scattered by Particles of Arbitrary Shape.** CHRISSORENSEN, Yuli Heinson, Justin Maughan, William Heinson, Amit Chakrabarti, *Kansas State University*

We present a general description of the angular distribution of light scattered (the phase function) by particles of arbitrary shape. This description includes particles found in the atmosphere such as mineral dusts, ice crystals, soot and spherical drops. Our method analyzes the scattered light as a function of the scattering wave vector  $q=2k\sin(\theta/2)$  where  $k=2\pi/\lambda$  on a log-log plot, as opposed to plotting versus linear scattering angle  $\theta$ . This Q-space analysis uncovers patterns common to all particles: a q-independent forward scattering lobe is followed by a Guinier regime, a power law regime with quantifiable exponents, and sometimes an enhanced back scattering regime. We show that the internal coupling parameter  $\rho'=2kR|(m^2-1)(m^2+2)|$  unifies the description. We also show that approximately half of the scattered light occurs in the forward scattering lobe for which  $\theta \leq \lambda/D$ , where D is the particle size. Finally, the effects of the imaginary part of the refractive index are included in this universal description.

**8CC.14****Use of Machine Learning and Particle-resolved Simulations to Predict Global Distributions of Aerosol Mixing State Metrics.** MICHAEL HUGHES, Jack Kodros, Jeffrey R. Pierce,Matthew West, Nicole Riemer, *University of Illinois at Urbana-Champaign*

Atmospheric aerosol particles are complex mixtures of chemical species. The aerosol mixing state describes how the species are distributed among the particles in the population. A population in which each particle is composed of one chemical species is called externally mixed, one where all particles are the same mixture of species is internally mixed, and real populations lie in between. Due to computational cost, mixing state representation in global climate models (GCMs) is highly simplified. For example, modal models represent all aerosols within a given mode as internally mixed. If the real mixing state is closer to external mixture, errors in a variety of aerosol properties, including the concentration of cloud condensation nuclei (CCN), will result. In previous work, we introduced the mixing state parameter  $\chi$  to quantify the mixing state with respect to the particle species.

In this study, we use the particle-resolved model PartMC in conjunction with machine learning techniques to produce a global map of  $\chi$ . Such a map provides a valuable tool to predict where the assumption of internal mixture may lead to large errors. To this end, we created a library comprising about 1,000 PartMC scenarios. Input parameters of each scenario, including gas and aerosol emission rates and meteorological parameters, were selected by Latin hypercube sampling from parameter ranges determined by GCMs. Machine learning techniques including random forests, support vector machines, and gradient boosting were used to construct a lower-order model of  $\chi$  from the particle-resolved training data set. Importantly, this model uses only variables known to GCMs, enabling us to create the global map of  $\chi$  based on GCM data.

We used a testing data set to determine the accuracy of model predictions, and we will discuss regional differences and seasonal variation of the  $\chi$  distribution, and the implications for aerosol representation in GCMs.

**8CC.15**

**Investigating Visibility Loss Caused by Fog within an Environmentally Controlled Chamber.** ANDRES SANCHEZ, Gabriel Birch, Crystal Glen, Matthew Tezak, Steven Storch, Gabriel Lucero, *Sandia National Laboratories*

In order to better understand the effects of visibility loss caused by fog, Sandia National Laboratories (SNL) has developed an environmentally controlled fog chamber to characterize and qualify test equipment, such as thermal imagers, visible cameras, and Class 3B/4 laser systems at a variety of wavelengths. The chamber provides a unique, controlled environment in which naturally occurring fog is mimicked for the purposes of establishing a quantitative assessment of the visibility degradation experienced by sensing systems. Because natural occurring fog is difficult to measure, due to inconsistency in density, visibility, and formation, SNL is currently investigating ways to measure particle size and concentration while testing a variety of visible and IR cameras to determine propagation loss. Currently, Located in a tunnel system, the chamber has relatively stable environmental conditions such as temperature, humidity, air pressure, and airflow, making it ideal for laboratory testing. The goal of this research is to improve upon current techniques and instrumentation to overcome visibility loss by providing a realistic, yet controllable environment that could be later implemented into automotive or aircraft industries, for example.

**8CC.16**

**Determination of the 3nm Particle Formation Rates at Puijo (Finland) Site Using an Analytical Formula Linking “Real” and “Apparent” Formation Rates.** ELHAM BARANIZADEH, Tuomo Nieminen, Tuukka Petäjä, Markku Kulmala, Taina Yli-Juuti, Kari Lehtinen, *PhD candidate*

Atmospheric new particle formation (NPF) events, i.e. nucleation and the subsequent growth of the newly formed particles has received increasing attention due to its impact on climate and human health. Several features at the nucleation level including the actual mechanism, the vapors involved, and the actual rates are not well-understood. At several locations particle size distribution measurements do not extend to nucleation size range but instead start at larger sizes (e.g. 7 nm) which limits the use of the particle data in NPF studies and poses a challenge in understanding NPF globally. In this study, we use previously derived analytical formula between “real” formation rate and the “apparent” formation rate of particles at larger sizes for which measurements are available. Our aim is to determine the formation rates of particles of 3 nm ( $J_3$ ) in diameter at Puijo, Finland site where the size distribution of particles below 7 nm is not measured. We have evaluated the formula over Hyytiälä, Finland site where the aerosol size distribution of particles larger than 3 nm is measured. We calculated formation rates of 7 nm particles ( $J_7$ ) and used the analytical formula to scale down to 3 nm. These estimated  $J_3$  were compared to observed  $J_3$  calculated directly from the size distribution. We have analyzed 55 NPF event days for which the formation and growth rates could be quantified. The daily arithmetic mean of  $J_3$  for each NPF day was calculated. The preliminary results show that 64 % of estimated  $J_3$  are within the factor of two of the observed  $J_3$ ; with the tendency of the analytical formula to overestimate the  $J_3$ . NPF days where estimated  $J_3$  exceeded observed  $J_3$  by over the factor of two were characterized with more uncertainty in the analytical formula arising from the uncertainty in particle growth rate.

**8CC.17****Hygroscopicity of Sub 30nm SOA Particles during CLOUD**

10. ANGELA BUCHHOLZ, Pasi Miettinen, Aki Pajunoja, Olli Väisänen, Hao Wang, Arttu Ylisirniö, Annele Virtanen, *University of Eastern Finland*

The impact of aerosol particles on the atmosphere depends strongly on their ability to take up water vapor (hygroscopicity) and act as cloud condensation nuclei. The hygroscopicity is determined by the composition and the size of the particles.

Sulfuric acid ( $\text{H}_2\text{SO}_4$ ), ammonia and oxidized organic vapors play an important role in new particle formation of secondary organic aerosol (SOA) and growth of those particles. The CLOUD chamber at CERN was designed to study new particle formation and the early stages of particle growth. During the CLOUD10 campaign a range of different conditions (e.g. organic precursors, oxidation conditions) was studied aiming at mimicking atmospheric relevant processes as well as possible and at the same time deciphering the influence of the different factors on hygroscopicity.

The hygroscopic growth factor at 90% relative humidity was measured with a custom built Hygroscopicity Tandem Differential Mobility Analyzer (nanoHTDMA) for particles of sizes from 10 to 25nm, and the hygroscopicity parameter kappa was calculated based on Petters and Kreidenweis (2007). As the kappa values for pure  $\text{H}_2\text{SO}_4$  and alpha-pinene derived SOA are known, the volume fractions of organics and  $\text{H}_2\text{SO}_4$  in the particles can be calculated with the simple Zdanovskii–Stokes–Robinson mixing rule. Direct measurements of the chemical composition of sub 30 nm particles is quite challenging. Thus, size resolved hygroscopicity measurements may give valuable insights into the composition of these particles.

Higher gas phase  $\text{H}_2\text{SO}_4$  concentrations increased the hygroscopicity of the particles while higher organic precursor concentrations in the gas phase decreased it. Only a small effect of the particle size was observed between 15 and 25nm. The impact of  $\text{NO}_x$  in the system was also investigated.  $\text{NO}_x$  can influence the composition of the particles directly through the oxidation pathway of the organics and indirectly by changing the  $\text{H}_2\text{SO}_4$  concentration in the chamber.

**8CC.18****Changes in Precipitating Snow Chemistry with Location and Elevation in the California Sierra Nevada.**

JESSICA AXSON, Jessie Creamean, Amy Bondy, Rebecca Craig, Nathaniel May, Hongru Shen, Michael Weber, Kerri Pratt, Andrew Ault, *University of Michigan, Ann Arbor MI*

Orographic snowfall in the California Sierra Nevada Mountains is an important source of water for California and can vary significantly on an annual basis. The microphysical properties of orographic clouds and precipitation formation are impacted by aerosols of varying size, number, and chemistry, which are incorporated into clouds formed along the Sierra barrier. The physicochemical properties and sources of insoluble residues and soluble ions found in precipitation samples were explored for three sites of variable elevation in the Sierra Nevada during the 2012 – 2013 winter season. Residues were characterized using nanoparticle tracking analysis (NTA), Raman microspectroscopy, scanning electron microscopy (SEM-EDX), and ion chromatography (IC) to determine the size-resolved number concentrations and associated chemical composition. A transition in the aerosol sources that served as cloud seeds or were scavenged in- and below-cloud was observed as a function of location and elevation. The transition with increasing elevation to aerosols that serve as ice nucleating particles may impact the properties and extent of snowfall in remote mountain regions where snowpack provides a vital supply of water. The residues and soluble ions observed provide insight into how multiple aerosol sources can impact cloud and precipitation formation processes, even over relatively small spatial scales.

**8CC.19**

**How Uncertainty in Field Measurements of Ice Nucleating Particles Influences Modeled Cloud Forcing.** SARVESH GARIMELLA, Daniel Rothenberg, Chien Wang, Daniel Cziczo, *MIT*

This study investigates the systematic low bias in field measurements of ice nucleating particles using continuous flow diffusion chambers. Such instruments have been deployed in the field for decades to measure the formation of ice crystals using ambient aerosol populations. These measurements have, in turn, been used to construct parameterizations for use in global climate models by relating the formation of ice crystals to temperature and aerosol particle number. Non-ideal instrument behavior, which exposes particles to lower humidities than reported, has resulted in a systematic underestimation of the number of ice nucleating particles. Variability in this bias affects climate model response to these parameterizations. We show that a machine learning approach can be used to minimize this uncertainty. In addition, we find that the simulated long wave cloud forcing in a global climate model simulation can vary up to  $0.8 \text{ W/m}^2$  and can change sign from positive to negative depending on the treatment of this uncertainty. Based on these results, more careful treatment is required at both the experimental and modeling stages of parameterization development in order to account for such biases.

**8CC.20**

**Climate Implications of Coal Fly Ash Particles Due to Ice Cloud Formation.** SARVESH GARIMELLA, Daniel Rothenberg, Martin Wolf, Maria Zawadowicz, Costa Christopoulos, Karl D. Froyd, Yi-wen Huang, Daniel Murphy, Chien Wang, Daniel Cziczo, *MIT*

This study investigates the impact fly ash particles have on cloud formation and climate. It examines the physical and chemical properties of several types of fly ash particles and the efficiency with which they form cloud droplets and ice crystals in the laboratory. Fly ash particles are found to be moderately hygroscopic and are found to form ice in the deposition mode at temperatures colder than  $\sim -30^\circ\text{C}$  and in the immersion mode at temperatures colder than  $\sim -20^\circ\text{C}$ . The laboratory results are used to investigate the impacts of fly ash emissions on the properties of cirrus clouds and climate in a global climate model. Single particle mass spectrometry data from aircraft campaigns are used to estimate the abundance of fly ash in the atmosphere and constrain the sensitivity of the cloud forcing response to fly ash emissions. Overall, current levels of fly ash emissions are estimated to contribute  $\sim 0.1\text{-}0.6 \text{ W/m}^2$  of extra warming through their role in cirrus cloud formation.

**8CC.21**

**Physical and Optical Aerosol Properties of Aged Biomass Burning Events at the Mt. Bachelor Observatory.** JAMES LAING, Dan Jaffe, Jon Hee, *University of Washington, Bothell, WA, USA*

The Mt. Bachelor Observatory (MBO) is located in central Oregon at 2.8 km asl and has been operational since 2004. In the summer of 2015 we investigated particle size distributions, PM<sub>1</sub> mass concentration, and aerosol scattering ( $\sigma_{\text{scat}}$ ) and absorption ( $\sigma_{\text{abs}}$ ) coefficients and mass scattering efficiency at three wavelengths of 20 biomass burning (BB) plumes. During August, 51% of the month was influenced by biomass burning (defined as  $\sigma_{\text{scat}} > 20 \text{ Mm}^{-1}$  and  $\text{CO} > 150 \text{ ppbv}$ ). The events were predominantly caused by regional BB smoke from fires in Northern California and South-West Oregon, as well as several events influenced by Siberian BB from intense forest fires around Lake Baikal.

Significant differences between Siberian events and Regional BB events were observed. Siberian events had higher absorption enhancement relative to PM<sub>1</sub> (higher  $\Delta\sigma_{\text{abs}}/\Delta\text{PM}_1$ ), CO (higher  $\Delta\sigma_{\text{abs}}/\Delta\text{CO}$ ), and aerosol scattering (lower single scattering albedo ( $\omega$ )) compared to regional BB events. Transport from Siberia to the continental US via pyro-convection would typically be from intense, flaming combustion conditions which produce more black carbon (BC) compared to smoldering fires. The greater flaming combustion may account for the absorption enhancement. The Siberian events also had lower Absorption Ångström Exponent (AAE) values than the regional events, signifying either a lack of production of brown carbon (BrC) or the loss of BrC during transport to photo-bleaching, volatilization, and aerosol-phase reactions.

The geometric mean diameter (GMD) of the BB events size distributions ranged from 138 to 229 nm, and the geometric standard deviations ( $\sigma_g$ ) ranged from 1.53-1.89. No clear distinction was observed between Siberian influenced and Regional BB event size distributions. GMD was determined to be well correlated with mass scattering efficiency (MSE), as well as  $\sigma_{\text{scat}}$ , and PM. A model from Sakamoto et al. (2016) based on fire characteristics was used to predict the GMD with reasonable accuracy.

**8CM.1**

**HVAC Filter Loading Characterization by Ammonium Sulfate and Ammonium Nitrate Sub-micron Particles.** CHENXING PEI, Qisheng Ou, David Y. H. Pui, *University of Minnesota*

Sodium chloride and potassium chloride are typical salt aerosols used in laboratory for filter loading test, and they are also recommended in ASHRAE52.2 as challenging particles for HVAC filter test. While in the atmospheric aerosol, the most common ions are ammonium, sulfate and nitrate, hence the ammonium sulfate and ammonium nitrate particles may be better salt particles to challenge HVAC filter used in ambient environment, especially considering the hydration and dehydration processes are different among these hydrophilic salt. It is worthwhile to compare the loading performance of conventional sodium chloride and potassium chloride particles to that of ammonium sulfate and ammonium nitrate.

In this study, the loading characteristics of a HVAC filter media by three salt particles are investigated, including potassium chloride, ammonium sulfate, and ammonium nitrate. Salt particles with very similar size distribution but different concentrations are generated by a home-made Collision-type atomizer with proper solution concentration and dilution. A SMPS system is employed to monitor the size distribution of the upstream and downstream of the filter, while the relative humidity in the system is monitored and recorded. The loading performance is found independent with the salt aerosol concentration within the range from 5 to 21 mg/m<sup>3</sup>. The KCl and (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> particles have similar loading characteristics when the RH is below 15%, while the NH<sub>4</sub>NO<sub>3</sub> needs more loading mass to achieve the same pressure drop. Different dendrite structures are found in loaded filter samples by scanning electron microscopy, and their effect on loading characteristics will be discussed in the presentation.

**8CM.3**

**Filtration Area of a Pleated Filter Bag Determined by Filter Cleaning Characteristics.** MYONG-HWA LEE, Jeong-Uk Kim, Hyun-Jin Choi, Jungho Hwang, *KITECH*

Pleated filter bag has a major advantage which has higher filtration area than a cylindrical filter bag. Therefore, it can be used to increase both filter lifetime and dust holding capacity, because it is possible to decrease filtration velocity at the same exhaust gas amount. However, effective filtration area of a pleated filter bag is still uncertain, although it is an important design parameter in a pulse-jet bag house. The effective filtration area of a pleated filter bag was determined by assuming the effective filtration area (50%, 60%, 70% and 100% of theoretical filtration area) and comparing its filter cleaning characteristics with those of a cylindrical filter bag in this study. Filtration characteristics of a pleated filter bag with optimal geometry were investigated under the conditions of filtration velocity of 1.2 m/min and dust concentration of 10 g/m<sup>3</sup>. As a result, we found that a pleated filter bag had an effective filtration area of approximately 50-60% in contrast to theoretical filtration area due to a dead space by filter pleating.

**8CM.4**

**Effects of Various Mitigation Measures in Reducing Fine and Ultrafine Particle Concentrations inside Taxi Vehicles.** NU YU, Shi Shu, Yan Lin, Yifang Zhu, *University of California Los Angeles*

More than 4000 taxi drivers working in Los Angeles are likely exposed to high levels of traffic related air pollutants (TRAP) such as fine (PM<sub>2.5</sub>) and ultrafine particles (UFPs). However, their TRAP exposures were poorly understood and mitigation strategies were rarely explored. In this study, 22 Los Angeles taxi drivers were recruited and UFP and PM<sub>2.5</sub> concentrations were monitored concurrently inside and outside of their taxis for 6-hour a day and four consecutive days under four exposure mitigation strategies. The results showed under realistic working condition (no mitigation, NM), the average UFP and PM<sub>2.5</sub> levels inside taxis were 2.57x10<sup>4</sup> particles per cm<sup>3</sup> and 26.00 microgram/m<sup>3</sup>, respectively, and the average in-cabin to on-roadway (I/O) ratios for UFP and PM<sub>2.5</sub> were 0.60 and 0.75, respectively. When the taxi ventilation was set to outside air (OA) mode and windows were all kept closed (WC) with high efficiency cabin air (HECA) filter working, the average in-cabin UFP and PM<sub>2.5</sub> levels were observed to achieve the lowest among all four mitigation conditions, at 1.13x10<sup>4</sup> particles/cm<sup>3</sup> and 13.57 microgram/m<sup>3</sup> respectively, and the average I/O ratios for UFP and PM<sub>2.5</sub> were significantly reduced to 0.47 and 0.52 respectively. Taxi vehicles provided higher reduction on in-cabin UFP concentrations than on PM<sub>2.5</sub> concentrations under all four mitigation conditions. Setting the vehicle ventilation to OA mode consistently and closing taxi windows (WC) doubled the HECA filter reduction on both UFP and PM<sub>2.5</sub> I/O ratios.

**8CM.5**

**Advanced Emission Reduction Devices and Particle Number Emissions: Knowledge from a California On-road HD-truck Testing.** TIANYANG WANG, David Quiros, Arvind Thiruvengadam, Shaohua Hu, Tao Huai, Yifang Zhu, *University of California, Los Angeles*

Particle emissions from heavy-duty vehicles (HDVs) have significant environmental and public health impacts. Currently, the air quality standards for PM have all been set on a mass basis; however, numerous studies have suggested that PM-related health hazards are correlated with the particle number concentration, which primarily indicates the concentration of ultrafine particles (UFPs,  $d \leq 100$  nm). Previous research found that particle number emission from HDVs could be highly elevated by sulfur oxidation and the nucleation mode particle formation dependent on vehicle on-road status, engine technology and emission controls. In this study, we measured real-time particle emissions from six modern HDVs powered by diesel and compressed natural gas over six route types totaling over 6,800 miles of on-road operation in California to investigate the particle number emissions from HDVs. The distance-based particle number emission factors (PNEFs) of the five tested diesel HDVs equipped with diesel particulate filters (DPFs) were between  $2.94 \times 10^{11}$  and  $2.99 \times 10^{13}$  particles/mile, which were 50 to 5000 times lower than a 1998 HDV not originally equipped but retrofitted with a DPF. PNEFs significantly increased due to passive regeneration when the DPF outlet temperature reached a critical value, usually between 250 and 340 °C, which was commonly exceeded when HDVs were traveling at speeds over 45 mph. Compared with passive regeneration, active DPF regeneration events produced higher PNEFs in a 2013 model year diesel HDV. No directly relationship was found between distance-based PNEF and vehicle speed. However, linear changes in vehicle speed result in logarithm changes in an alternative parameter, particle number emission rate (particles/s), indicating that vehicle speed may be used as an indicator of particle number emissions from modern HDVs.

**8CM.6**

**Are Aftertreatment Systems on Diesel Engines an Atmospheric Source of Isocyanic Acid?** SHANTANU JATHAR, Christopher Heppding, Michael Link, Ali Akherati, Michael Kleeman, Delphine Farmer, *Colorado State University*

Diesel engines account for half of the nitrogen oxide (NO<sub>x</sub>) emissions from combustion sources in the United States. Strict emissions standards have mandated the use of aftertreatment devices such as the Selective Catalytic Reduction (SCR) system. In an SCR system, urea is injected into the hot exhaust to yield ammonia, which reduces NO<sub>x</sub> over a catalyst surface to form N<sub>2</sub>. However, SCR chemistry is known to produce isocyanic acid (HNCO) as an intermediate product and SCRs have been implicated as an atmospheric source of HNCO. HNCO is a highly toxic gas linked to adverse health outcomes. In this work, we measure HNCO emissions from a representative diesel engine and, by leveraging earlier data, use a three-dimensional air quality model to simulate the ambient concentrations of HNCO in a polluted urban environment. Experiments were performed on a diesel engine that was configured to meet three generations of EPA emissions standards over the past 10 years. Engine tests were conducted at three different engine loads, with two different fuels (diesel and biodiesel) and four urea injection rates. HNCO was measured using an acetate reagent-based chemical ionization mass spectrometer. The engine was found to emit primary HNCO, although the emission factors were an order of magnitude higher than those found earlier; we suspect that steady state engine loads produce more HNCO. In contrast to earlier findings, we do not find any evidence that the aftertreatment devices produce or enhance HNCO in the exhaust. The use of biodiesel was found to slightly reduce HNCO emissions. At present, work is underway to model the emissions, chemistry and deposition of HNCO in using a chemical transport model (CTM). The CTM will be used to predict ground-level concentrations of and comment on the possible human exposure to HNCO in southern California.

**8EC.1**

**The Impact of Device Settings and Vaping Patterns on the Size Distribution of Particles Generated from Electronic Cigarettes.** QINGYU MENG, Yeongkwon Son, Gediminas Mainelis, *Rutgers School of Public Health*

The use of E-cigarettes continues to increase, and adverse health effects associated with E-vapors exposure have already been reported. However, the pattern of personal exposure to E-vapor and resulting particle deposition patterns in human lungs are not well understood.

The goal of this work was to investigate and better recognize personal exposures to E-vapor. E-cigarette users were recruited from Rutgers campuses and their vaping patterns were measured and used to program an E-cigarettes smoking machine. The resulting particle concentration and particle size distributions from 10 nm to 5 micro-meter were measured using an optical particle counter and a portable aerosol mobility spectrometer under various combinations of E-cigarette coil heating power (6.48 watt, 14.7 watt, and 29.7 watt) and different E-juice (propylene glycol vs. vegetable glycerin).

The puff volume, puff duration, and puff peak flow across the 16 subjects were 70.6 +/- 46.2 mL, 3.2 +/- 1.2 s, and 30.6 +/- 15.7 mL/s, respectively. The count median diameter (CMD) ranged from 53 nm to 74 nm to 78 nm, when the device power increased from 6.4 watt to 14.7 watt and to 29.4 watt. Longer puff duration created larger particles. Propylene glycol generated smaller particles than vegetable glycerin, with an average of 10 nm differences in CMD. Total particle number concentration increased from  $1.2 \times 10^6$  to  $5.8 \times 10^7$  when coil heating power increased from 6.4 watt to 29.4 watt. Vegetable glycerin generated 5 – 10 times more particles than propylene glycol. The total particle number counts were highly corrected with puff duration ( $r = 0.62$ ).

This study demonstrated the impact of device power, vaping patterns, and E-juice on the size distribution of particles generated from E-cigarettes. Since the physical and chemical properties of vapors affect the deposition and toxicity of E-vapor, our study provides insights into product regulations for E-cigarettes.

**8EC.2**

**Developing High-Throughput Screening Approaches for E-liquids and Flavor Constituents.** M. FLORI SASSANO, Eric Davis, Sarah Sizer, Shernita Lewis, Robert Tarran, *University of North Carolina at Chapel Hill*

E-cigarettes deliver nicotine without combusting tobacco. Whilst tobacco smoking has declined since the 1950s, e-cigarette use has increased, attracting both former tobacco smokers and never smokers. E-cigarette liquids (e-liquids) are often a propylene glycol/vegetable glycerin (PG/VG) vehicle containing nicotine and flavorings. To date, neither e-cigarette devices, nor e-liquids, are regulated by the FDA. Since little is known about the potential toxicity of e-liquids, we designed a high-throughput assay to assess potential harm of the 7,000 different e-liquids that are commercially available.

To validate this assay, we plated HEK293T cells, which were previously used as a tobacco exposure model<sup>1</sup> in 384-well plates. Using an imaging-plate reader, we acquired bright-field images every 2h for 4h in the plate reader at 37°C/5% CO<sub>2</sub>. Cells were entering the log phase of growth at this time and were subsequently treated with e-liquid/vehicle and imaged for an additional 18h. After, cells were stained with calcein-AM and propidium iodide for live/dead measurements, respectively. Growth curves were created from bright-field images. Using this approach, ~150 e-liquids were screened as well as a dose response to PG/VG.

Of the 150 e-liquids tested, ~50% prevented growth or caused a reduction in cell numbers at a 1% dilution. Our future approach is to complete dose response curves on the most toxic e-liquids. Our data demonstrates that we can now test ~70 e-liquids per plate, suggesting that this approach is valid to screen all available e-liquids. We conclude that (i) PG/VG is itself potentially toxic at high concentrations and (ii) that many e-liquids have the potential to affect cell viability/proliferation. A full investigation into e-liquid toxicity will help inform the FDA as to how e-liquids should be regulated. However, further investigation is required to fully understand this phenomenon.

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1. Rasmussen et al. (2014). *JBC* 289(11), 7671–7681.

**8EC.3**

**Aldehyde Emissions from Electronic Cigarettes: Relation to Atomizer Age, Product Manufacturing Variability, and Intra-puff Particle Generation Intermittency.** Mohamad Baassiri, Rola Salman, Soha Talih, Nareg Karaoghlanian, ALAN SHIHADDEH, *American University of Beirut*

Electronic cigarettes (ECIGs) electrically heat and aerosolize a liquid containing propylene glycol (PG), vegetable glycerin (VG), flavorants, water, and nicotine. They typically employ an atomizer consisting of an electrical heating filament wrapped around a fibrous wick which serves to replenish liquid as it evaporates. Volatile aldehyde (VA) species, including the human carcinogen formaldehyde, are commonly found in ECIG aerosols, and have been implicated in respiratory diseases in cigarette smokers. VAs are known thermal degradation products of PG and VG. Literature reports of VA yields from electronic cigarettes indicate wide variability in emission rates even when measurement conditions and devices are nominally identical, sometimes confounding study findings. In this study we sought to identify potential sources of variability in VA yields within a given product. In particular, using three nominally identical devices, we investigated effects on VA emissions of atomizer age (zero to more than 1200 puffs) and device variability under various randomly ordered use conditions (4 or 11 W, 4 different PG/VG ratio solutions). In addition, instantaneous particle emission rates were measured during repeated sessions of 15-puffs using a fast particle mobility spectrometer (TSI EEPS). Simultaneously, instantaneous heating filament temperatures were measured. We found large differences in VA emissions across devices, and across power levels. ECIG age (cumulative number of puffs taken prior to measurement) and PG/VG ratio had no effect on VA yields. Greater variability in instantaneous intra-puff particle emission rates and atomizer temperatures were associated with greater aldehyde yields, suggesting that high-emitting ECIG units may be more prone to intermittent starvation of liquid in the heating element of the atomizer during a puff (e.g. due to poor contact between heating filament and wick). This finding would suggest that better quality control in the manufacturing of the wick-heater assembly may reduce human exposure to unwanted ECIG toxicants.

**8EC.4**

**Are Sweet Flavored Electronic Cigarettes a Source of Furans?** Sarah Soussy, Ahmad El Hellani, Rima Baalbaki, Rola Salman, Alan Shihadeh, NAJAT A. SALIBA, *American University of Beirut*

The wide availability of sweet flavors has been hypothesized as a factor in the popularity of electronic cigarette (ECIG), especially among youth. Saccharides, which are commonly used to impart a sweet flavor to ECIG liquids, thermally degrade to produce toxic compounds, like aldehydes and furans. This study investigates the formation of furanic compounds in aerosols produced when a propylene glycol/vegetable glycerol (PG/VG) solution of varying concentrations of sweeteners is vaped with different ECIG power and puff duration parameters. Liquids of varying concentrations are prepared and aerosols are generated using an ECIG operating at 4.3 and 10.8 W power and 4 and 8 s puff duration. Aerosols are trapped on filter pads which are extracted and quantified using a novel SPE technique and GC-MS method. This allows the assessment of 5-Hydroxymethyl Furfural (HMF) and Furfural (FA) without interference from PG, VG and other impurities. Well-resolved peaks of HMF and FA are detected. Both are quantified in the aerosols of sweet flavored e-liquids under all vaping conditions. A correlation of furan emission with electric power, sweetener concentration and puff duration is evaluated. It is also reported that under certain conditions, the per-puff yield of HMF and FA in ECIG emissions is comparable to values reported for combustible cigarettes.

**8EC.5**

**Metal Concentrations in Mainstream Aerosols from Electronic Cigarettes.** TONGKE ZHAO, Shane S Que Hee, Qiuju Guo, Yifang Zhu, *University of California, Los Angeles*

The electronic cigarette (EC) is an increasingly popular alternative to tobacco cigarette. ECs are usually composed of two parts: a rechargeable battery and a metal cartridge which generally contains a heating coil and some e-liquid (i.e. chemical mixture of propylene glycol or glycerol as the main composition with small amounts of flavor additives and selected amounts of nicotine). When ECs are puffed, the electric current provided by the battery can bring high temperature on the heating coil to evaporate the e-liquid into vapor. Metals in the cartridge shell and heating coil might be emitted due to the high temperature process. To study the metal concentrations in EC mainstream aerosols and further identify the sources of these metals, this study measured the metal concentrations in mainstream aerosols from different brands and types of electronic cigarettes by an Inductively Coupled Plasma Mass Spectrometry (ICP-MS). Furthermore, to identify the sources of metals in mainstream aerosols, the metals in the cartridge shell, e-liquid and heating coil were also quantified. These results showed that non-negligible levels of Chromium (Cr), Iron (Fe), Cobalt (Co), Nickel (Ni), Copper (Cu), and Lead (Pb) were presented in the mainstream aerosols, which were coming from both cartridge shell and heating coil. This study can be used for metal exposure assessment of electronic cigarettes.

**8EC.6**

**Banana Pudding Flavored E-liquid Alters Cell Proliferation and Ca<sup>2+</sup> Signaling in Lung Epithelia.** TEMPERANCE ROWELL, Robert Tarran, *University of North Carolina at Chapel Hill*

E-cigarettes are popular and available in over 7,000 flavors, yet little is known about their effects on pulmonary epithelia. We purchased flavored e-liquids from the Vapor Girl (<http://www.thevaporgirl.com/>) to characterize their biological effects on human bronchial epithelial cultures (HBECs) and CALU3 lung epithelial cells. We screened 13 e-liquid flavors for effects on cell proliferation/viability and ability to alter cell signaling (e.g. Ca<sup>2+</sup>). Ca<sup>2+</sup> signaling regulates cell division, mucus secretion, ciliary beat frequency, and Cl<sup>-</sup>/fluid secretion in airway epithelia. Altered Ca<sup>2+</sup> signaling could change cell homeostasis, thus we measured changes in cytosolic Ca<sup>2+</sup> and other pathway components (i.e. STIM1 puncta, kinase phosphorylation, IP<sub>3</sub> generation).

Cells were plated on glass coverslips or in multiwell plates and exposed to e-liquids diluted into media either acutely (10 min) or over 24h. Cell proliferation/viability was measured using the MTT assay. Cytosolic Ca<sup>2+</sup> changes were measured using Fura-2-AM. Relative kinase phosphorylation was measured using a Phospho-Kinase Array and IP<sub>3</sub> generation was measured using a competitive ELISA. All assays were done with HBECs and/or CALU3s except STIM1 puncta visualization, which used transiently transfected STIM1-mCherry HEK293 cells.

Several flavors inhibited cell proliferation in a dose-dependent manner, including Banana Pudding (Southern Style) (BPSS). BPSS also elicited an acute cytosolic Ca<sup>2+</sup> signal involving both the endoplasmic reticulum (ER) and store-operated Ca<sup>2+</sup> entry (SOCE), formed STIM1 puncta, and altered phosphorylation of ERK1/2, which regulates STIM1 phosphorylation.

Our data showed that BPSS-flavored e-liquid altered ER/SOCE Ca<sup>2+</sup>-signaling mechanisms in airway epithelia, which could have biological consequences to Ca<sup>2+</sup>-mediated HBEC innate defenses. This suggested that other flavors may alter cell signaling and other important lung epithelial functions. Investigations into the effects of flavored e-cigarette aerosol on Ca<sup>2+</sup>-dependent aspects of innate defense are ongoing.

This study was funded by UNC TCORS NIH (P50-HL-120100-01) and the Marsico Lung Institute Tissue Core provided HBECs.

**8EC.8****Chemical Characterization of Submicron Particulate Matter and Vapors Derived from E-Cigarette Usage.**

RACHEL LONG, Ilona Jaspers, Phillip Clapp, Barbara Turpin, Jason Surratt, *University of North Carolina at Chapel Hill*

Advanced electronic cigarettes (e-cigarettes), or advanced personal vaporizers (AVPs), are increasingly popular. AVPs' larger battery capacity and greater user control of output voltage and wattage allow wicking materials, metal heating coils, and e-liquids to be heated to extremely high temperatures, possibly yielding unintended, potentially toxic thermal-decomposition products in both the gas and aerosol phases. Though some metals and carbonyl species have been previously identified in e-cigarette aerosols, it is unknown how aerosols and gases from AVPs change as a function of e-liquid formulation, output voltage, and wattage. This study aims to characterize molecular-level gas- and aerosol-phase constituents in AVP smoke derived from varying e-liquid formulations, output voltages, and wattages in order to identify known and potentially unknown toxicants. To capture both the gas- and aerosol-phase components, modified PM<sub>2.5</sub> filter samplers containing polyurethane foams (PUFs) behind the aerosol filters will be used to collect AVP smoke generated in a 1 m<sup>3</sup> Teflon chamber. Advanced offline mass spectrometry techniques not previously employed in e-cigarette research will characterize collected species, including gas chromatography/electron ionization mass spectrometry and ultra performance liquid chromatography interfaced to high-resolution quadrupole time-of-flight mass spectrometry equipped with electrospray ionization. Online mass spectrometry techniques, including chemical ionization high-resolution time-of-flight mass spectrometry and an aerosol chemical speciation monitor will also characterize emissions in real time. This study will also use the dithiothreitol (DTT) assay to quantify DTT consumption of gas- and aerosol-phase constituents collected by the PM<sub>2.5</sub>/PUF samplers, allowing for an estimation of the oxidative stress potential of AVP emissions. Enhanced characterization of AVP smoke constituents and better understanding of their oxidative potential will inform future studies aimed at resolving mechanisms of toxicity of e-cigarette smoke.

**8IA.1****Experimental Investigation of the Transport of Surrogate Indoor Bioaerosols from Simulated Human Respiratory Activities and Control by HVAC Filtration in an Unoccupied Apartment Unit.**

STEPHANIE KUNKEL, Parham Azimi, Haoran Zhao, Brent Stephens, *Illinois Institute of Technology*

Breathing, sneezing, and coughing are important sources of many microbial pathogens, with microbes being aerosolized and dispersed in droplets and droplet nuclei. Knowledge of how this dispersion is affected by recirculation airflow, outdoor air ventilation, particle deposition, and central HVAC filtration is critical to understanding how airborne microbes are spread and potentially controlled. Here we use a custom nebulizer-based human respiratory activity simulator to aerosolize non-pathogenic organisms (mimicking the airborne transmission of pathogenic viruses and bacteria) in an unoccupied test apartment unit. Model organisms include (1) *Escherichia coli* K12, a gram-negative bacterium (size ~1 μm), as a model for *Bordetella* and *Neisseria*, and (2) bacteriophage T4, a double-stranded DNA coliphage (~60 nm), as a model for influenza virus. Size-resolved bioaerosol sampling was conducted using Sioutas cascade impactors located in four locations (0.5m, 3m, 5m and 7m from the source). Quantitative PCR was performed to quantify the concentrations of the model organisms found at the various test locations around the room. Test conditions included four different central recirculating HVAC filter conditions: no filter, MERV 8, MERV 11 and MERV 16. The concentration of collected biomass across all bins decreased rapidly with distance from the source. Both organisms were still detected in small amounts up to 7m away under all filtration conditions. There was over a 90% reduction in detection of both organisms in air 3m and 5m from the source with MERV 11 and MERV 16 filters. At the longest distances representing long-range airborne transport, more biomass was found in the larger size bins for the larger *E. coli* compared to the smaller T4 bacteriophage. Approximately 45% of the *E. coli* biomass was found in the >1 μm size range in the longest range samples, while only ~13% of the T4 biomass was found in the same size range.

**8IA.2**

**Using Virtual Impactor for Classification of Submicron-Sized Indoor Bioaerosols.** ALI MOHAMADI NASRABADI, Ji-Woon Park, Hyung Sun Kim, Jang-Seop Han, Junho Hyun, Dongeun Yong, Jung-ho Hwang, *Yonsei University, Department of Mechanical Engineering*

Airborne fungal and bacterial particles (i.e., bioaerosols) can penetrate deep into the lower respiratory tract and deposit in the bronchi, bronchioles, and alveoli, particularly when inhaled by infants. This study aimed to sample and classify indoor bioaerosols using a virtual impactor with a cutoff diameter of 1  $\mu\text{m}$ , which was designed and fabricated. To design the virtual impactor, a computational fluid dynamics simulation was conducted to determine its optimal design and predict its performance. Using polystyrene latex particles, laboratory tests were conducted to evaluate performance and validate simulation results. By changing the inlet flow rate and minor-to-total flow ratio, cutoff diameters of 635 nm and 1.5  $\mu\text{m}$  were obtained. Using an SKC Button Aerosol Sampler at the virtual impactor outlets, field test results demonstrated that 56% of fungal fragments and 63% of bacterial particles that were suspended in an office environment had aerodynamic sizes that were smaller than 1  $\mu\text{m}$ . Furthermore, Our results from MALDI-TOF analysis showed that nearly the same bacterial species were found in the major and minor outlet channels, with gram-positive bacteria being dominant in all samples.

**8IA.3**

**Effect of Relative Humidity on Resuspension of Indoor Allergen Particles.** PARICHEHR SALIMIFARD, Donghyun Rim, James Freihaut, *The Pennsylvania State University*

Humidity of indoor air is one of the important factors in resuspension of particles from indoor surfaces, yet the effect of humidity is not clearly understood. Existing literature shows conflicting results, indicating that particle resuspension may increase or decrease depending on indoor humidity level. The objective of this study is to investigate the effect of humidity on resuspension of typical allergen containing particles. Experiments were conducted using four surrogate samples: quartz as a non-biological reference particle, and dust mite, dog fur and cat fur particles as indoor biological particles. The resuspension behavior of these particles, having the same size distribution as NIST reference dust, was investigated over a range of relative humidity levels from 10% to 80%. A small-scale resuspension chamber system was used to precisely control the relative humidity level and also simulate the mechanical and aerodynamic reservoir disturbances caused by occupant walking. The results showed that the particles in this experimental study can be divided into two groups: hydrophilic and hydrophobic particles. Resuspension rates of hydrophilic particles (quartz and dust mite) notably decrease as the relative humidity increases, while relative humidity variation has marginal effects on hydrophobic particles (cat fur and dog fur). The results suggest that the indoor humidity level is a significant contributing factor to the resuspension of the hydrophilic indoor dust particles. This finding implies that increasing indoor relative humidity, particularly in winter season, could be used as a method for reducing the resuspension of hydrophilic dust mite particles.

**8IA.4**

**Building-Integrated Low-Cost Optical Particle Counters: Conceptual Framework and Field Measurements in an Occupied Office and Air Handling Unit.** BRANDON E. BOOR, Donghyun Rim, *Purdue University*

The evolving domain of low-cost (<\$1,000) sensor technologies for the measurement of airborne particles and gases presents vast opportunities for real-time monitoring and control of pollutants in buildings. Research is needed to provide guidance to indoor air quality researchers and practitioners, along with the HVAC industry, on how to integrate low-cost sensors with building systems to reduce population exposures to airborne pollutants of indoor and outdoor origin. The objectives of this study are to (1) establish a conceptual framework for the integration of low-cost optical particle counters (OPCs) with building systems and (2) conduct field measurements with a commercially available OPC (OPC-N2 Particle Monitor, AlphaSense Ltd.).

The framework for building-integrated OPCs is based upon a material-balance modeling approach, whereby all processes that generate or remove particles from a spatial domain are accounted for, e.g. emissions, ventilation, filtration, deposition. The material-balance model can inform the number and location of OPC sensor nodes that are necessary to mechanistically evaluate indoor particle dynamics in each zone (room) of a building. Such an approach will ensure sufficient spatiotemporal input data are collected to identify (in real-time) appropriate control strategies to maintain particle concentrations below specified levels. We explore the application of our framework for building-integrated OPCs in an occupied office and air handling unit (AHU) in the new Living Laboratories at Purdue Herrick Laboratories. Five calibrated OPC-N2 sensors were installed to monitor particle number size ( $D_p$ , optical diameter) distributions ( $dN/d\log D_p$ ,  $\text{cm}^{-3}$ ) across sixteen size fractions from 0.38 to 17  $\mu\text{m}$  at various nodes, including: (1) bulk room air, (2) AHU intake of outdoor air, (3) upstream and (4) downstream of in-duct filters, and (5) AHU recirculation. We studied the impact of modulating AHU settings, including fan speed and damper positions, via the NiagaraAX building automation system; manual-replacement of in-duct filters of varying MERV-rating; natural ventilation via a double-skin façade; and office occupancy on  $dN/d\log D_p$  at each node. The  $dN/d\log D_p$  data for each condition is then used in a material-balance model to estimate size-resolved indoor emission rates, in-situ filtration efficiencies, deposition loss rate coefficients, and indoor/outdoor ratios.

**8IA.5**

**Performance of Four Consumer-Grade Air Pollution Measurement Devices.** SYDONIA MANIBUSAN, Gediminas Mainelis, *Rutgers, The State University of New Jersey*

There is a developing trend in consumer electronics to design inexpensive (<\$300) devices that could be used indoors for monitoring airborne contaminants of human health concern. Most of these devices monitor the mass concentration of PM<sub>2.5</sub> and PM<sub>10</sub> particles, temperature, and relative humidity while some also advertise monitoring of volatile organic Compounds (VOCs) or other chemical pollutants. This study focused on four recently released devices, the Air Quality Egg 2, Blueair Aware, Foobot, and Speck, which utilize optical sensors to measure the concentration of airborne particulate matter. The devices were collocated and operated simultaneously in several home environments over 7 days for each household against established optical sensing devices including the PersonalDataRAM (pDR-1000, Thermo Fisher), DustTrak DRX (TSI Inc.), and gravimetric mass measurements using two collocated Personal Modular Impactors (PMI<sub>2.5</sub>, SKC, Inc.). Results have shown that some consumer grade devices were in reasonable agreement with some of the used reference instruments. For example, the BlueAir Aware and Air Quality Egg 2 registered 24-hour averages of PM<sub>2.5</sub> as 23.5  $\mu\text{g}/\text{m}^3$  and 13.8  $\mu\text{g}/\text{m}^3$ , respectively, for one of the households. The gravimetric mass measurement yielded an average PM<sub>2.5</sub> concentration of 14.6  $\mu\text{g}/\text{m}^3$ . On the other hand, the 24-hour PM average for the same household was 6.4  $\mu\text{g}/\text{m}^3$  as registered by the DustTrakDRX and 4.7  $\mu\text{g}/\text{m}^3$  as registered by the pDR. Similar trends were observed for other households. The data show the utility of the consumer-grade devices, especially due to low cost allowing their wide-scale deployment; however, testing in various environments and with different particles and at different concentrations is needed to ascertain consumer-grade instrument accuracy for application in field studies.

**8IA.6**

**Rapid Oxidation of Skin Oil by Ozone.** SHOUMING ZHOU, Matthew Forbes, Yasmine Katrib, Jonathan Abbott, *University of Toronto, Toronto, Canada*

One of the major recent findings in the field of indoor air chemistry is that human occupancy has significant impacts on indoor air pollution, mainly due to reactions of ozone with human surfaces such as skin oils. However, to date, there are no mass spectrometric studies of the chemical changes that occur in the condensed phase when skin oil is exposed to ozone.

In this work we investigated the reaction of human skin oil with ozone mixing ratios similar to those in the ambient environment. Using Direct Analysis in Real Time-Mass Spectrometry (DART-MS) skin oil gives rise to prominent mass spectral signals resulting from highly unsaturated alkenes (squalene), sterols, triglycerides, long chain fatty acids, pyroglutamic acid, and probably waxy esters. A rapid loss of squalene, fatty acids, and triglycerides was observed upon oxidation with 50 ppb ozone for 90 minutes, with the formation of highly oxygenated carboxylic acids, such as succinic acid, levulinic acid, adipic and suberic acids. One species, pyroglutamic acid, however, is found to be unreactive toward ozone. Therefore, this chemical may be used as a tracer of human contamination indoors.

This work demonstrates experimental evidence for rapid chemistry between skin oil and ozone, implying that the highly oxygenated reaction products are always present on human skin. Given earlier studies that have indicated the irritancy and redox-activity of squalene oxidation products, it will be important to further determine the toxicity of the condensed phase products from the multiphase reaction of ozone with skin oils.

**8IA.7**

**Effect of Diurnal Sunlight and Shading Patterns on Indoor Air Flow and on Human Exposure to Fine Particulates.** Yan Zheng, KAI-CHUNG CHENG, Wayne Ott, Lynn M. Hildemann, *Stanford University*

With the construction of tighter, energy-efficient buildings, human exposure to indoor emissions of particulates is a growing concern. Chaotic and turbulent airflow has made inhalation rates to these aerosols to be highly unpredictable, and thus a well-mixed assumption is often applied in exposure models. Sunlight patterns, however, produce a reliable heating cycle which directly affects indoor airflow patterns. As sunlight heats the top of a building, it creates an indoor temperature difference, inducing buoyancy driven flows. Strong temperature stratification impedes vertical mixing and reduces the effective mixing volume, allowing for spikes in particle concentrations near the effective height of the source. To capture this phenomenon, a series of 29 experiments were conducted in a residence in northern California. Cigarette smoke was passed through a smoke actuator and the cooled to create a non-buoyant fine particulate source to be released in the room center. PM<sub>2.5</sub> monitors were placed every 0.25m height up to 2m and were repeated 4 times in each cardinal direction so as to account for directionality. There were a total of 16 sampling monitors and 48 sampling points for each experiment. Temperature sensors were placed every 10cm vertically for a total of 36 sampling points to obtain an accurate reading of temperature stratification. Stratification strength ranged from 0 to 15°C/m. Vertical mixing strength was quantified via Fick's Law, yielding vertical turbulent diffusion coefficients ( $K_v$ ) ranging from  $3 \times 10^{-4}$  to  $4.3 \times 10^{-4}$  m<sup>2</sup>/s. The horizontal turbulent diffusion coefficients were roughly an order of magnitude higher than the vertical coefficients.  $K_v$  was found to have a strong correlation with temperature stratification which in turn made significant impact on particle dispersion. The vertical concentration profiles showed that the maximum particle levels at the effective height of the source emissions spiked 15x higher than the vertically-averaged concentration, when comparing stratified to unstratified indoor spaces.

**8IA.8**

**Kinetic Studies of the Heterogeneous Surface Reactions of Indoor Organic Films with Hydroxyl Radical.** RAMINA ALWARDA, Shouming Zhou, Jonathan Abbatt, *University of Toronto, Toronto, Canada*

Most previous studies on indoor chemistry have focused on gas-phase and surface reactions that involve oxidation with ozone. However, a recent study reported gas-phase OH radical concentrations in an indoor environment can be as high as  $1.8 \times 10^6$  molecules/cm<sup>3</sup>. It is therefore important to characterize the reactions occurring on indoor surfaces with gas-phase OH radicals.

This work focuses on the heterogeneous surface chemistry that occurs when compounds ubiquitously found indoors, such as squalene (a major component of skin oil that accounts for ~10% skin lipids by mass) or di-n-octyl phthalate (DnOP, a plasticizer) adsorb onto indoor surfaces. In this study, squalene or DnOP were loaded onto the surface of glass capillaries and reacted with hydroxyl radicals in a quartz flow tube. Gas-phase hydroxyl radicals were generated by the photolysis of hydrogen peroxide. Samples on the capillaries were analyzed by direct analysis in real time-mass spectrometry (DART-MS). We will present the surface reaction kinetics and product formation from the OH oxidation of squalene and DnOP. In addition, using the same experimental setup, the oxidation of organic films developed in real indoor conditions with the OH radical will be investigated.

**8IA.9**

**Application of ISO 14644-1 to Evaluate the Impact of Materials and Devices on Clean Room Class Ratings or to Evaluate Respiratory Device Airstreams.** ELLIOTT HORNER, Scott Steady, Mark Reardon, Benjamin Britt, Scott Lawrence, *UL Environment*

Building material and office equipment manufacturers need to evaluate the impact of their products in a clean room environment if those products are used there. Separately, evaluation of respiratory therapy devices lacks a reference method to screen particulate matter (PM) release levels. Our use of ISO 14644 for these purposes provides a reference level for further improvements.

Building materials, hardcopy devices and respiratory therapy devices were evaluated for the emission of PM. The evaluations were conducted in environmental exposure chambers operated in accordance with ASTM D6670. Prior to evaluations, a chamber was monitored for 4-24 hours with either a MetOne 3445 Laser Particle Counter or a TSI Aerotrak 9500 particle counter. The ISO 14644 class at equilibrium was determined prior to loading the device or material to be tested.

When sampled directly from the airstream, the ISO 14644 class of the discharge of multiple respiratory therapy devices was one class cleaner (Class 4 to 3) based on average concentration than the chamber environment in which the device was operating, consistent with additional internal filtration. Two construction assemblies were within one class unit (Class 3 to 2 or 2.5 to 3) of the chamber rating prior to installation. Hardcopy devices are recognized to emit PM, but the models evaluated increase the average-concentration-based ISO class no more than one unit (Class 4 to 5 or 6 to 7) and typically for less than 15 minutes.

The proposed method ISO 14644-14 should become available in 2016 and specifically addresses devices to be used in clean room settings. This will offer a degree of standardization of these procedures, which will be particularly valuable since the concept has already proven useful for related purposes not in clean rooms settings.

**8IA.10**

**Mixing and Distribution of a Point Source Pollutant in a Chamber with Two Airflow Conditions.** MATTHEW VANNUCCI, *U.C. Berkeley, Civil and Environmental Engineering Dept*

The mixing rate of an air pollutant from an indoor source is a significant contributing factor to occupant exposure. In a residence with natural ventilation the mixing rate of pollutants from indoor sources is strongly influenced by the relative temperature of the walls and floors to the air. This ongoing study correlates the mixing time of an instantaneously released bolus of carbon dioxide (CO<sub>2</sub>) in a sealed 1.75 m<sup>2</sup> chamber with independently controlled surface temperatures of the walls. Opposing walls are symmetrically heated and chilled to create a natural convection with no net heat flow, while chilling the floor and heating the ceiling create a stable thermally stratified condition. Six real-time CO<sub>2</sub> sensors are used to measure the mixing time and are calibrated in situ with co-located syringe sampling points.

It is not yet known how the mixing time varies with wall temperature in natural convection systems, but for other sources of mixing, such as forced convection, mixing times correlate well with the cube root of mechanical power. For a natural convection system it is hypothesized that the mixing time will decrease with increased wall to average air temperature differences, while for a thermally stratified condition the opposite may hold true. We will also investigate a single sensor's ability to estimate human exposure under these conditions by measuring the spatial variability of CO<sub>2</sub> concentration on a horizontal plane. This estimate is done using an array of syringe sampling points located on a plane 2/3 of the height of the chamber, roughly equivalent to the breathing zone in a full-scale room, in conjunction with the real-time sensors. Understanding the spatial distribution of airborne pollutants can be utilized to develop improved source control strategies and enhanced distribution of ventilation air with the aim to mitigate occupants' exposure.

**8IA.11**

**Microbial Activity and Phthalate Degradation in Carpet.** KAREN C. DANNEMILLER, Charles Weschler, Jordan Peccia, *Ohio State University*

Floor dust is a major source of human exposure due to resuspension, especially from carpet. This dust contains a complex mixture of chemicals and a diverse microbial community. Chemicals may include phthalate esters, which can be present at elevated concentrations and are endocrine-disrupting compounds with public health significance. While aerobic microbial degradation of phthalate esters is well documented in aquatic systems and soils, biological transformation has not been demonstrated in house dust. The goal of this study was to quantify microbial degradation of phthalate esters. Worn carpet was sectioned into 10 cm x 10 cm coupons, embedded with dust from the same home, and incubated at constant elevated relative humidity. In the first experiment, carpets were incubated for 1-6 weeks at equilibrium relative humidity (ERH) between 50-100% and existing concentrations of nine phthalate esters were measured in the dust before and after. Di(2-ethylhexyl) phthalate (DEHP), benzyl butyl phthalate (BBzP), diisononyl phthalate (DiNP), and to a lesser extent di-n-octyl phthalate (DOP) demonstrated potential removal by chemical and/or microbial mechanisms. In the second experiment, 250 mg of dust was spiked with 10 µg deuterated di(2-ethylhexyl) phthalate (D-DEHP), embedded in carpet, and incubated at 100% ERH. As measured by sterilized controls, abiotic losses contributed 10.1% (±1.1%, standard error) of total D-DEHP after 1 week and 27.2% (±1.4%) of total D-DEHP after 3 weeks. Microbial degradation removed 8.5% (±1.7%) of the D-DEHP after one week, and at three weeks there was no additional loss with the total microbial loss at 8.2% (±2.7%). These losses were concomitant with fungal growth (above 80% ERH) and bacterial growth (at 100% ERH). Overall, this study supports the hypothesis that, in addition to abiotic chemical degradation and/or volatilization, microbes are also capable of degrading phthalates in house dust under elevated relative humidity conditions.

**8IA.12**

**Characterization of Fouling with Hygroscopic and Non-hygroscopic Aerosols in Composite Polymer Membranes for Water Vapor Transport Applications.** AMIN ENGARNEVIS, Ryan Huizing, Sheldon Green, Steven Rogak, *University of British Columbia*

Composite membranes using a thin vapor-permeable polymer layer over a structural substrate are used in gas dehydration, food-packaging, and humidity control of indoor spaces. The impact of exposure to air pollution on the water vapor permeability and selectivity is investigated to develop an understating of potential air-side particulate fouling mechanisms and resulted performance degradation during membrane lifetime in the field. Samples of commercial membrane media were loaded with hygroscopic NaCl, and non-hygroscopic spark-generated graphite (SGG) aerosol particles. The effects of particle charge distribution and number concentration, air flowrate, temperature-gradient across membrane (Thermophoresis), and membrane surface on the rate of particle deposition were investigated using a Scanning Mobility Particle Sizer (SMPS). It was found that particle charge distribution and air flowrate had the largest impact on the rate of particle deposition. The results of permeability measurements showed that deposition of SGG and NaCl particles under a dry loading condition (RH<20%) had minimal influence on the membrane. However, when membranes loaded with hygroscopic particles in dry condition were exposed to an elevated humidity (RH>70%) leading to surface condensation, the membrane permeability reduced by up to 30%. This is hypothesized to be caused by increased resistance of microporous membrane substrate due to a pore-narrowing process. Scanning electron microscopy (SEM) combined with EDX analysis was used to examine the morphology and chemical composition of the fouled membrane surface. Analysis of SEM images showed a significant reduction in the average pore diameter of degraded samples, proportional to the fouling degree. It was also found that cleaning of fouled samples can reverse their permeability back to nearly the initial value. The reversibility of the loaded membrane permeability along with the EDX analyses imply that re-crystallization of salt ions, entrained into the pores of membrane substrate in aqueous form, is a potential explanation for the changes observed.

**8IA.13**

**Using a Portable Air Cleaner to Improve Residential Indoor Air Quality in Chongqing, China.** QINGYU MENG, Han Wang, Jing Zhang, Runming Yao, Zhihua Fan, Baizhan Li, Howard Kipen, *Rutgers School of Public Health*

Ambient air quality in China has experienced significant deterioration in the past 20 years. One promising approach to reduce air pollution exposure is to use portable air cleaners in indoor environments. The effectiveness of portable air cleaners to reduce indoor air pollution has not been tested in high air pollution areas (e.g., urban areas in China), in lower latitude cities where home ventilation patterns are different from higher latitude areas, and for application to mixtures of air pollutants (e.g. primary pollutants and pollutants formed through indoor air chemistry).

We conducted an intervention study in 20 residential homes in Chongqing, China, to test the effectiveness of a portable air cleaner for indoor air quality improvement. Each home was followed for four consecutive days, during which the air cleaner was operated with a high efficiency particle air (HEPA) filter (with a charcoal layer) installed for two days and without the filter installed for the other two days. On each day, simultaneous indoor and outdoor measurements was conducted, including PM<sub>2.5</sub>, black carbon, NO<sub>2</sub>, O<sub>3</sub>, formaldehyde, OC and EC, 6-MHO, temperature and humidity, and CO<sub>2</sub>.

The air pollution level in Chongqing was high during our study, with outdoor PM<sub>2.5</sub> concentrations ranging from 63.3 µg/m<sup>3</sup> to 127.5 µg/m<sup>3</sup>. Indoor pollutants of outdoor origin accounted for more than 50% of the measured indoor air pollutants. Operating a portable air cleaner with HEPA filter indoors significantly reduced the infiltration factors of PM<sub>2.5</sub>, black carbon, and O<sub>3</sub> by 22.9%, 7.5%, and 14.5%, respectively. The air cleaner also reduced outdoor originated PM<sub>2.5</sub>, black carbon, and O<sub>3</sub> by 19.4%, 34.9%, and 40.8%, respectively. Using the portable air cleaner reduced the population attributable risk for PM<sub>2.5</sub> from 18% to 13% for COPD and from 24% to 17% for lung cancer.

**8IA.16**

**Aerosol Emissions of 3d Printers in a Chamber Study and Real Indoor Environments.** MARINA VANCE, Valerie Pegues, Schuyler Van Montfrans, Andrea Tiwari, Linsey Marr, *University of Colorado Boulder*

Additive manufacturing (3D printing) is a growing field with vast applications ranging from high-precision industrial manufacturing to hobbyist projects. As the popularity of 3D printing grows, printers become more affordable and are expected to become a ubiquitous office equipment. Fused-deposition modeling (FDM) is the most common 3D printing method, especially in low-end printers. The heating and extrusion of polymeric feedstocks may generate ultrafine, or nanoscale aerosols due to chemical vapor deposition. Little in-depth research has been conducted on 3D printers' airborne nanoparticle emissions and associated risks. The objective of this work is to measure the size distribution and concentration of ultrafine aerosols emitted as an incidental byproduct of the operation of FDM 3D printers using different feedstock materials (acrylonitrile butadiene styrene, ABS and polylactic acid, PLA) in a chamber study and also under real-use conditions in different indoor environments. Preliminary results have shown a significant increase in the concentration of airborne particles ranging from 10 to 300 nm in aerodynamic diameter above background levels in 6 different indoor environments.

**8NS.1**

**Molecular Characterization of Alkyl nitrates in Atmospheric Aerosol by Ion Mobility Mass Spectrometry.** XUAN ZHANG, Wen Xu, Andrew Lambe, Michael Cubison, Michael Groessl, Stephan Graf, John Jayne, Douglas Worsnop, Manjula Canagaratna, *Aerodyne Research Inc.*

We demonstrate the capability of Ion Mobility Mass Spectrometry (IMS-MS) to characterize alkyl nitrates in atmospheric aerosols at molecular level. We show the significant production of ion adducts from selected alkyl nitrate standards by clustering with inorganic anions including chloride and nitrate during negative electrospray ionization, a special chemical ionization mechanism in the condensed phase. This approach enables straightforward detection of ANs that have low tendency to form molecular ions on its own. Molecular identity of each AN adduct is well constrained by the developed collision cross section - mass correlation, which provides a two-dimensional separation of the -ONO<sub>2</sub> containing compounds on the basis of their molecular size and geometry. Structural information of alkyl nitrates is further probed by the identification of the characteristic fragments produced from collision induced dissociation of the parent AN adducts. We apply the IMS-MS technique to characterize alkyl nitrates in the secondary organic aerosols produced from photochemistry of biogenic emissions in the presence of NO as an illustration.

**8NS.2**

**How does a 10 fold Pulse Increase of Aircraft-Related NO<sub>x</sub> Impact Global Concentrations of O<sub>3</sub> and Secondary Organic Aerosol (SOA)?** NIMA AFSHAR-MOHAJER, Barron Henderson, *University of Florida*

Aircraft-related industries are fast growing due to their advantages over the other transportation routes and to fulfill the global needs in developing the complicated network of the international relationships. The global fleet of aircrafts emits a variety of air pollutants all over the world. NO<sub>x</sub> emissions are one of the most important air pollutants emitting from the aircrafts, as they are contributing in formation ozone as well as partitioning of the organic gases into secondary organic aerosol (SOA). Ten times pulse increase in the total NO<sub>x</sub> emitted from global aircraft fleet in a certain month relative to the baseline was investigated in this study for the entire year of 2007. Presented by Bey et al. (2001), GEOS-Chem model was modified to introduce pulse additions for two different seasonal cases of winter and summer. Pulses of NO<sub>x</sub> are immediately evident, and the peak ozone burden increase, as expected, lags by a month. For SOA, the relationship is more complex. Initially, the pulse of aircraft NO<sub>x</sub> increases secondary organic gases due to the extra reactions between NO and RO<sub>2</sub> (the product of the aromatic hydrocarbon reactions with OH). Due to the volatility of the produced secondary organic gases (SOG) and higher consumption rate of HO<sub>2</sub>, however, the burden of SOA decreases by 4.3 times in the Northern America and Europe. Following the pulse for both summer and winter perturbations, concentrations of SOG and SOA generally decreased by 0.016 ppt and returned to normal after almost 6 months. In areas close to industrial units in the northern Far East, SOG and SOA concentrations actually increased for up to 2-3 months following the pulse. The reason for observing positive  $\Delta$ SOG and  $\Delta$ SOA values close to the earth surface over the northern hemisphere was having a greater reactions between aromatic hydrocarbons and HO<sub>2</sub> compared to the baseline. Understanding the magnitude and duration of perturbations helps use to understand the natural modes of atmospheric chemistry and the inter-relationship of aircraft emissions and biogenic volatile organic compounds.

**8NS.3**

**Fragmentation Patterns of Organosulfur Compounds in HR-ToF-AMS.** YUNLE CHEN, Lu Xu, Elizabeth Stone, Timothy Humphry, Nga Lee Ng, *Georgia Institute of Technology*

Organosulfur compounds are ubiquitous components of secondary organic aerosols (SOA), and have been observed in both ambient measurements and laboratory chamber experiments. Due to their surface-active nature, organosulfur compounds can play a potentially important role in altering aerosol chemical and physical properties. High-resolution time-of-flight aerosol mass spectrometer (HR-ToF-AMS) has been extensively used in aerosol study. However, the HR-ToF-AMS's response to organosulfur compounds is not well-understood, making the quantification of organosulfur compounds highly uncertain. Organosulfur compounds can fragment into both organic and sulfate fragments in the HR-ToF-AMS. However, typically all the sulfate fragments in the instrument are interpreted as inorganic sulfate fragments, despite that they can originate from an organic molecule. This leads to uncertainties in the quantification of organosulfur species and inorganic sulfate species, where the contribution of organosulfur compounds to total organic mass is underestimated. Here, we systematically investigated the fragmentation patterns of organosulfur compounds in HR-ToF-AMS, and contrasted them with that of inorganic sulfate compounds. Further, we studied how fragmentation patterns are related to organosulfur types, organic group structures, aerosol acidities, and organic coatings. These results will also be discussed in the context of ambient measurements and chamber experiments.

## 8NS.4

**Observations of Particle-phase NO<sub>y</sub> and SO<sub>x</sub> Species during Nanoparticle Growth Events at CLOUD10.**

DANIELLE C. DRAPER, Michael J. Lawler, James N. Smith, *National Center for Atmospheric Research*

Chamber experiments were performed in the CLOUD chamber at CERN in Geneva, Switzerland during the CLOUD10 campaign using atmospherically relevant concentrations of a variety of trace gases, including  $\alpha$ -pinene, D-3-carene, O<sub>3</sub>, NO, and SO<sub>2</sub>. We present observations of nanoparticle composition from the Thermal Desorption Chemical Ionization Mass Spectrometer (TDCIMS) from experiments exhibiting new particle formation and growth from different chemical precursors, including monoterpene photooxidation and monoterpene photooxidation in the presence of NO and SO<sub>2</sub>. In the latter set of experiments, NO<sub>y</sub> and SO<sub>x</sub> species are both observed in the particle phase, indicating that these precursors react to directly contribute to nanoparticle growth.

## 8NS.5

**Effects of Aerosol-Phase and Bulk Aqueous-Phase Browning in Aldehyde Reactions with SO<sub>2</sub>.** BENJAMIN JOYCE, David De Haan, *University of San Diego*

Climate can be affected by the aqueous-phase formation of aerosol brown carbon from aldehyde reactions with SO<sub>2</sub>, due to the resulting increase in sunlight absorbed by aerosol particles. Previous studies have found that brown carbon formation occurs in the dark due to quinone formation, but this study focuses on the effect of UV exposure on brown carbon formation in bulk aqueous solution and aerosol phases. Aqueous aldehyde + SO<sub>2</sub> bulk reaction mixtures studied at pH ~ 5.5 and concentrations of 0.25 M were analyzed via ultraviolet-visible spectroscopy (UV-Vis) to characterize the production of brown carbon products (indicated by increased absorbance in the range ~ 350-450 nm). These same aqueous solutions were either placed in vials and exposed in varying UV environments for 10 h to allow production of brown carbon or used to generate aerosol. These aerosol particles were dried in silica gel diffusion driers, and collected on Teflon membrane filters for 2 - 4 h. The filters were ultrasonically extracted in Milli-Q water, and the extract was also analyzed via UV-Vis to quantify the formation of brown carbon products. The UV environments consisted of exposing samples to direct sunlight, direct UV light (366 nm), and dark control environments. The spectroscopy data was compared on a per mass basis using mass absorption coefficients. Bulk aqueous glyoxal + SO<sub>2</sub> solutions browned under all conditions, with the most browning in dark control conditions and the least in direct sunlight. Glyoxal + SO<sub>2</sub> aerosol browned almost twice as fast as the corresponding bulk aqueous solution. Aqueous and aerosol methylglyoxal + SO<sub>2</sub> solutions did not reliably form brown products in any UV environment.

## 8NS.6

**Observation of Biogenic Secondary Organic Aerosols in the Atmosphere of a Mountain Site in Central China: Temperature and Relative Humidity Effects.** JIANJUN LI, Gehui Wang, *Institute of Earth Environment, Chinese Academy of Sciences*

Secondary organic aerosols (SOA) derived from isoprene, pinene and caryophyllene were determined for PM<sub>10</sub> and size-segregated (9-stages) aerosols collected at the summit (2060 m, a.s.l.) of Mt. Hua, central China during the summer of 2009. Estimated concentrations of isoprene,  $\alpha$ -/ $\beta$ -pinene and  $\beta$ -caryophyllene derived secondary organic carbon (SOC) are  $81\pm 53$ ,  $29\pm 14$  and  $98\pm 53$  ng m<sup>-3</sup>, accounting for  $2.7\pm 1.0\%$ ,  $0.8\pm 0.2\%$  and  $2.1\pm 1.0\%$  of OC, respectively. Concentrations of biogenic (BSOA, the isoprene/pinene/caryophyllene oxidation products) and anthropogenic (ASOA, mainly aromatic acids) SOA positively correlated with temperature ( $R=0.57-0.90$ ). No significant relationship was found between sulfate and BSOA tracers in the current study. However, a decreasing trend of BSOA concentration with an increase in relative humidity (RH) was observed during the sampling period, although a clear trend between ASOA and RH was not found. Based on the AIM Model calculation, we found that during the sampling period an increase in RH resulted in a decrease in the aerosol acidity, and thus may reduce the effect of acid-catalysis on BSOA formation. Size distribution measurements showed that most of the determined BSOA are formed in the aerosol phase and enriched in the fine mode ( $<2.1\mu\text{m}$ ) except for cis-pinonic acid, which is formed in the gas phase and subsequently partitioned into aerosol phase and thus presents a bimodal pattern with a small peak in the fine mode and a large peak in the coarse mode ( $>2.1\mu\text{m}$ ).

## 8NS.7

**Modeling Biogenic Secondary Organic Aerosol (BSOA) with CMAQ: A Case Study of the SOAS Campaign.** Momei Qin, PETROS VASILAKOS, Christopher Boyd, Nga Lee Ng, Armistead G. Russell, Athanasios Nenes, *Georgia Institute of Technology*

Biogenic secondary organic aerosol (BSOA) has important impacts on climate and air quality, particularly in locations with high biogenic volatile organic carbon (BVOC) emissions. In this work, summertime BSOA formation was simulated using the Community Multi-scale Air Quality (CMAQ) model, with a focus on the Southeast United States during the Southern Oxidant Aerosol Study (SOAS) campaign. We utilize an extended version of CMAQ, that includes the mechanism for the formation of IEPOX-derived SOA (Pye et al. 2013), further constrained with the 2013 SOAS observations by adjusting the highly uncertain reaction rate constants, partitioning coefficients and deposition coefficients of the relevant species (Vasilakos et al. 2016).

In the revised model update, we incorporate SOA yields of monoterpenes+NO<sub>3</sub> reactions based on recent experimental results (Boyd et al., 2015), with a modified representation of BSOA production from individual monoterpenes. As a result, monoterpene-derived BSOA is enhanced by ~60% during the nighttime, exhibiting a strong correlation with less-oxidized oxygenated OA (LO-OOA), although the model concentration was still biased low. After implementing the multigenerational oxidation scheme, the simulated OA was similar to the observations, suggesting that important sources are missing in the current model. Sensitivity tests were also conducted to predict the response of BSOA to reduction in NO<sub>x</sub> and SO<sub>x</sub> emissions in the future.

The simulations validated the fact that isoprene-derived SOA is mediated by the abundance of sulfate, while LO-OOA is controlled by monoterpenes reacting with the nitrate radical (NO<sub>3</sub>) during the nighttime, consistent with the main findings of the SOAS campaign.

**8NS.8**

**The Role of Hydrocarbons in the Oxidation of SO<sub>2</sub> in Oil Sand Regions.** NEDA AMIRI, Ann-Lise Norman, *University of Calgary*

Secondary sulfate aerosols are formed within the atmosphere through the oxidation of SO<sub>2</sub>. Homogeneous oxidation of SO<sub>2</sub> occurs mostly by hydroxyl radicals and to a minor extent by CH<sub>3</sub>O<sub>2</sub> and HO<sub>2</sub>. The role of hydrocarbons in the oxidation of SO<sub>2</sub> has been investigated extensively, and the importance of stabilized Criegee intermediates (sCI) which are formed from the ozonolysis of alkenes, on SO<sub>2</sub> oxidation has been identified. Despite this extensive research, however, the importance of hydrocarbons in SO<sub>2</sub> oxidation is not fully understood. The present study investigates the role of hydrocarbons in SO<sub>2</sub> oxidation in the oil sand regions of northern Alberta, Canada.

Size-segregated sulfate aerosols were collected on glass fiber filters using a high volume sampler fitted with a cascade impactor from 13 Aug to 5 Sep 2013 on Wood Buffalo Air Monitoring Station 13 (AMS13) site just south of Fort MacKay. Sulfate concentrations were determined for soluble extracts from the filters using Ion Chromatography. Co-located hydrocarbon measurements analyzed using GCMS were made by Daniel Wang and Jeff Brook from Environment Canada.

Daily aerosol sulfate <490nm was compared to total hydrocarbon concentration and to individual hydrocarbons. The correlation for this mainly secondary sulfate fraction and various hydrocarbons were examined. The highest correlations were observed between sulfate and octane ( $r=0.88$ ,  $p<0.01$ ) and 1,3-Dimethyl cyclohexane ( $r=0.87$ ,  $p<0.01$ ). More than 30 hydrocarbons are well correlated with secondary aerosol sulfate <490 nm diameter having  $r>0.7$  ( $p<0.0004$ ). The very strong correlation demonstrates the significance of hydrocarbons on secondary sulfate in this size fraction.

Hydrocarbons may be important to consider in the oxidation of SO<sub>2</sub> and the formation of secondary sulfate aerosols. Alkanes, cycloalkanes, and aromatic hydrocarbons show the highest correlation with secondary sulfate. A few alkenes also show high correlation but less significant than alkanes and cycloalkanes. This observation is novel and warrants further investigation to identify unidentified oxidation pathways for SO<sub>2</sub> and their relative importance.

**8NS.9**

**Semi-Continuous VOC Measurements in the SEARCH Network.** KARSTEN BAUMANN, Eric Edgerton, Stephanie Shaw, John Jansen, *Atmospheric Research & Analysis*

In the fall of 2015, new auto-GC systems were implemented in four SouthEastern Aerosol Research and Characterization (SEARCH) network sites. The auto-GC consists of a thermal desorption air sampler (collection onto a sorbent at -30C, desorption at 100C/s holding at 280C for 3 minutes) coupled to a dual-column gas chromatograph (GC), allowing automated hourly collection of ambient air samples with subsequent GC analysis. Peaks were identified and quantitated using a multi-component calibration gas mix. In addition to the 54 target compounds from the Photochemical Assessment Monitoring Stations (PAMS) established by the US Environmental Protection Agency, iso-butene and 1,3-butadiene were measured routinely since January 2016 at two rural and two urban SEARCH sites. Compound specific lower detection limits (LDL) were assessed by periodic (once every 3-4 days) analysis of very small ambient sample volumes (20 ml), yielding LDL below 100 pptv for all VOCs except ethane and propane with ~200 pptv and ~150 pptv, respectively. Stability was tested at the same frequency by analysis of 200 ml volumes of the calibration gas, undergoing the same absorption/desorption process. Most compound recoveries were between 95% and 100% over a period of six months. Calibration via standard addition to the glass inlet under carefully controlled dilution, revealed a systematic reduction in recovery of some aromatics and alkenes but most significantly of isoprene. Removing ambient ozone from the sample drawn onto the cold trap by use of a quartz filter impregnated with 2 %v thiosulfate, helped improve the recoveries of these compounds, suggesting their removal from the cold adsorbent during sample collection is largely driven by reaction with ambient ozone. Diurnal behaviors of isoprene and other reactive VOC in urban and rural environments are compared for winter, spring and summer seasons, and discussed in light of their potential to forming secondary organic aerosol.

**8NS.10****Impacts of Oxidation Processes on Complex Refractive Index of SOA Generated from Isoprene.** TOMOKINAKAYAMA, Kei Sato, Takashi Imamura, Yutaka Matsumi, *ISEE, Nagoya University*

Isoprene is the most abundant volatile organic compound emitted from the biosphere and is known as one of the important precursors of secondary organic aerosol (SOA) in the atmosphere. The formation yield of the isoprene-SOA is considered to be enhanced in the presence of acidic seed particles, such as sulfuric acid. Recently, we have reported the wavelength-dependent complex refractive index (RI) values for the SOA generated during photooxidation of isoprene in the presence of NO<sub>x</sub> and SO<sub>2</sub> [Nakayama et al. (2015)]. However, the impacts of oxidation processes on the RI values of isoprene-SOA are still unclear. In this work, the wavelength-dependent complex RI values of the SOA generated in the oxidation of isoprene with OH, NO<sub>3</sub>, and O<sub>3</sub> in the presence or absence of SO<sub>2</sub> have been examined, based on smog chamber experiments with photoacoustic and cavity ring-down spectrometers. As results, significant imaginary part (*k*) values of RI at <532 nm are obtained for the SOA generated in the OH oxidation in the presence of SO<sub>2</sub>, while the *k* values are smaller for the SOA generated in the ozonolysis (in the presence of OH scavenger) and are negligible for the SOA generated in the NO<sub>3</sub> oxidation, even in the presence of SO<sub>2</sub>. In the presentation, relationship with chemical properties will also be discussed.

Reference: Nakayama et al., "Complex refractive index of secondary organic aerosol generated from isoprene/NO<sub>x</sub> photooxidation in the presence and absence of SO<sub>2</sub>", *J. Geophys. Res. Atmos.*, 120, 7777-7787 (2015).

**8RR.1****Chemical Characteristics of PM in Coastal and Urban****Environments.** KWANGYUL LEE, Jiyeon Park, Min-Suk Bae, Kihong Park, *Gwangju Institute of Science and Technology, Korea*

The chemical characteristics of non-refractory submicrometer particles less than 1 micro-meter using AMS and less than 2.5 micro-meter using cyclone together with filter pack were investigated in coastal (Boseong, Korea) and urban (Gwangju, Korea) atmospheres. In addition, the black carbon (BC) concentration was measured at both sites. For further investigations, air mass backward trajectory analysis was also conducted to examine the effects of air mass types on the chemical characteristics of aerosols in coastal and urban environments. Diurnal patterns of chemical components (nitrate, BC, and organics) were more distinct at the urban site than at the coastal site. The enhanced sulfate and oxidized organics observed during the afternoon at both sites were likely caused by photochemical activity. Aerosol characteristics also varied with different air masses. The PM concentration increased when the air mass passed over heavy industrial areas before arriving at the site (polluted air mass), and these air masses moved slowly compared to other air masses. Additionally, sulfate-dominant and organic-dominant PM events were observed at both sites. These events were LTP events in which organics were highly aged during transport. More thorough analysis will be conducted, and their results will be presented

**8RR.2**

**Evaluation of Gas and Particle Concentrations of Water Soluble Inorganic Compounds by a Semi-continuous Monitor for Aerosols and Gases in Ambient Air (MARGA).**  
XI CHEN, John Walker, *US Environmental Protection Agency*

Evaluation and characterization of an Ion Chromatography technique based semi-continuous Monitor for Aerosols and Gases in Ambient Air (MARGA) was conducted to identify inherent issues with automated chromatography analysis systems. The performance and accuracy assessment revealed various errors and uncertainties resulting from mis-identification and mis-integration of chromatogram peaks by MARGA automated software. To aid data reprocessing efficiency and flexibility, an alternative chromatography data processing software was adopted to further evaluate MARGA generated data for method detection limits as well as accuracy and precision. Such reprocessing and calibration significantly improved the quality of measurement data by MARGA by lowering method detection limits (by a factor of 1.5) and variability between parallel sampler boxes. Further instrument performance evaluation, diurnal patterns of observed gaseous and particulate water soluble species (NH<sub>3</sub>, SO<sub>2</sub>, HNO<sub>3</sub>, NH<sub>4</sub><sup>+</sup>, SO<sub>4</sub><sup>2-</sup> and NO<sub>3</sub><sup>-</sup>) as well fine particle neutralization state were addressed during an intensive field campaign. The evaluation of MARGA tool performance revealed various potential issues encountered during monitoring especially when ambient concentrations are expected to be low. Under such circumstances a bias as high as 30% could be associated with un-examined and un-screened MARGA datasets in addition to invalid data due to peak mis-identification and mis-integration. Also calibration and verification of accuracy by external standards was deemed instrumental to data accuracy given the current reliance on an internal standard to achieve such goals. Analysis of field measurements across different synoptic meteorological patterns, including a nitrate rich arctic air mass, demonstrate that the MARGA is capable of resolving rapid composition change of PM<sub>2.5</sub> particles.

**8RR.3**

**Size-Segregated of Trace Elements Contents in Sub-urban Aerosols of Central Balkan Region.** Jelena Đuričić-Milanković, Ivan Anđelković, Ana Pantelić, Srđan Petrović, Andrea Gambaro, DRAGANA ĐORĐEVIĆ, *ICTM - University of Belgrade*

Forty-eight hour size segregated particulate matter samples from atmospheric aerosols in urban site of continental part of Balkans were collected during two years (in 2012nd and 2013in). Low-Pressure Cascade Impactors by Dr. Berners was used. Size segregated particulate matter in the size ranges:  $0.27 \leq D_p \leq 0.53$  micro-meters,  $0.53 \leq D_p \leq 1.06$  micro-meters,  $1.06 \leq D_p \leq 2.09$  micro-meters,  $2.09 \leq D_p \leq 4.11$  micro-meters,  $4.11 \leq D_p \leq 8.11$  micro-meters and  $8.11 \leq D_p \leq 16$  micro-meters was measured. ICP-MS was used to quantify next elements: Ag, Al, As, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Hg, Na, Ni, Mg, Mn, Mo, Pb, Se, Sb, Ti, Tl, V and Zn. Among these elements Al, Ca, Fe and Mg are dominating in coarse mode indicating natural emission sources as responsible origin, but some anthropogenic elements are noticed as As, Pb and V with their domination in fine mode indicating an anthropogenic influence.

**8RR.4**

**Observed Ambient Gas-particle Partitioning of Tracers for Biogenic Oxidation.** GABRIEL ISAACMAN-VANWERTZ, Lindsay Yee, Nathan Kreisberg, Rebecca Wernis, Joshua Moss, Susanne Hering, Suzane de Sá, Scot Martin, Lizabeth Alexander, Brett Palm, Weiwei Hu, Pedro Campuzano-Jost, Douglas Day, Jose-Luis Jimenez, Matthieu Riva, Jason Surratt, Juarez Viegas, Antonio O. Manzi, Eric Edgerton, Karsten Baumann, Rodrigo A. F. Souza, Paulo Artaxo, Allen H. Goldstein, *University of California at Berkeley, Berkeley, CA, USA*

Exchange of atmospheric organic compounds between gas and particle phases is an important process in particle formation, but is poorly understood due to a lack of simultaneous measurements in both phases of individual compounds. Measurements of particle- and gas-phase organic compounds are presented here for the southeastern U.S. and central Amazonia. Known isoprene oxidation products contribute 8% and 15% on average to particle-phase organic mass at these sites, but are also observed to have substantial gas-phase concentrations contrary to many models that treat these compounds as non-volatile. Observed gas-particle partitioning of approximately 100 known and newly observed oxidation products is not well explained by environmental factors (e.g. temperature). Instead, compounds with high vapor pressures have a higher particle fraction than expected. This demonstrates that gas-particle partitioning of biogenic oxidation products is driven by chemical processes such as the formation of low-volatility mass (e.g. accretion products, inorganic-organic adducts) that may in some cases be measured as individual compounds. Uncertainty in the characterization of this mass challenges the use of equilibrium to model partitioning of individual species, but average particle fractions for a given compound are observed to be consistent within ~25% across measurement sites.

**8RR.5**

**Mobile Monitoring of PM<sub>2.5</sub> and Black Carbon in Rural Washington During Winter 2015.** KELSEY GIBBS, Megan Baker, Jill Schulte, Anne Johansen, *Central Washington University*

Steadily declining air quality in rural Kittitas Valley in Central Washington has recently drawn federal attention, seeding efforts to increase understanding of particulate matter (PM) sources in this region. Toward that goal, a pilot mobile monitoring study was performed to establish temporal and geographical patterns of fine particulate matter (PM<sub>2.5</sub>) and black carbon (BC) during cold winter days with stagnant air conditions. Five sampling trips, encompassing 25 hours of mobile monitoring in the Ellensburg area (approximately 20,000 inhabitants) were completed between January and June, 2015. Results indicate that (i) the most prevalent source of PM<sub>2.5</sub> stems from wood burning for home heating during cool afternoons/evenings, and (ii) vehicular emissions represent a smaller but significant portion of PM especially during rush-hour traffic and when temperatures were not as cold and home heating absent. The one stationary PM<sub>2.5</sub> Federal Equivalent Method (FEM) monitor on the roof of the Community Center generally under-predicts concentrations obtained during mobile monitoring. As part of this study, Ellensburg High School students designed additional sampling projects with the personal BC monitor. Surveys revealed that these personal monitors significantly affect a person's behavior with regard to reducing their own exposure to air pollutants. With this new data, the community is better positioned to formulate strategies on how to best mitigate against winter air pollution.

**8RR.6****Assessment of Two Field-Deployed Portable Air Quality Monitoring Enclosures in Rochester, NY.** JOSEPH P.

MARTO, Jie Zhang, James Schwab, Margaret J. Schwab,  
*University at Albany, SUNY*

It can be difficult to assess localized air quality concerns with high quality sensors due to issues including protection of instruments, prohibitive cost, and space concerns. To alleviate these problems we have built eight weatherproof portable air quality monitoring enclosures that are adaptable and can be outfitted to address a variety of situations, including particulate matter (PM) pollution from wood smoke or near road sources, or the presence of toxic trace gases. Two of these units have been deployed since March 2016 at NYSDEC field sites in Rochester, NY to measure PM pollution, black carbon, carbon monoxide, and weather conditions. One system contains a Thermo Personal DataRAM (pDR-1500 for  $PM_{2.5}$ ), a Brechtel Tricolor Absorption Photometer (TAP for black carbon), a Magee AE33 aethalometer (for black carbon), and a LUFFT Smart Weather Sensor; the other contains a TSI Environmental DustTrak DRX (Model 8543 for size segregated PM), a Thermo Personal DataRAM (pDR-1500 for  $PM_{2.5}$ ), an Alphasense CO sensor, and a LUFFT Smart Weather Sensor. Preliminary results demonstrate the effects of local weather parameters, traffic emissions, and urban emissions on measured parameters. In addition, the comparison of TAP with AE33, and two pDR-1500s with the DustTrak will be presented, as well as the possible reasons for their differences.

**8RR.7****Particle Size Distributions in and Exhausted from a Poultry House.** PHILIP SILVA, Nanh Lovanh, *USDA-ARS*

Here we describe a study looking at the size range of particles in a poultry house. Agricultural particulates are typically thought of as coarse mode dust. But recent emphasis of  $PM_{2.5}$  regulations on pre-cursors such as ammonia and volatile organic compounds increasingly makes it necessary to look at the full particle size range. This study was performed at a poultry house using wood chips as the bedding material. Particle size distributions were obtained using a scanning mobility particle sizer for the small size range (0.01 – 0.5 micro-meters) and an aerodynamic particle sizer for the larger size range (0.3 – 20 micro-meters). In addition, optical particle counters were placed inside and outside the house at an exhaust fan to assess the concentrations and changes in particle size distribution in the house compared to emitted particles. Data was obtained for the duration of a flock of birds (six weeks) followed by clean out of the house. Results indicate that particle size distributions and number concentrations both changed significantly over the time period. Particle size distributions and mass concentration had a tendency to increase as the study continued. Large spikes in coarse particle concentrations were observed at times correlated to bird activity and dust generation. We expected that the constant presence of background particles in addition to high concentrations of ammonia and other gases would mean that secondary production of aerosol would be limited to accumulation on pre-existing particles, however some evidence for new particle formation was observed during the study.

**8RR.8**

**On the Applicability of Aerosol Optical Depth Retrievals as a Proxy for Surface Particulate Matter in India.** Karen Xia, DANIEL WESTERVELT, *Columbia University*

India is home to some of the world's poorest air quality, with ambient concentrations of fine-mode particulate matter (PM<sub>2.5</sub>) often exceeding World Health Organization daily health guidelines by as much as an order of magnitude. However, the spatio-temporal variability of air pollution in India is not well known. While PM<sub>2.5</sub> monitoring stations exist in some major cities and at U.S. Embassies in India, the amount of available data across the Indian subcontinent is somewhat sparse, especially in comparison to networks in the U.S. or Europe. The use of satellite observations has been proposed as a potential source of air quality data where ground-based measurements are lacking, since satellites can provide more complete spatial coverage than possible with ground-based monitoring. We aim to evaluate the relationship between available ground-based PM<sub>2.5</sub> measurements and satellite aerosol optical depth (AOD). In particular, we compare the spatial and temporal variability in high resolution MODIS AOD over India to that detected by ground-based PM<sub>2.5</sub> and PM<sub>10</sub> measurements across India. We correlate daily and monthly PM<sub>2.5</sub> and PM<sub>10</sub> with high-resolution MODIS aerosol optical depth retrievals and for individual cities and larger regions in India. We also evaluate the spatial and temporal coherence of the two datasets (PM and AOD) using an empirical orthogonal function (EOF) approach. Initial results for New Delhi indicate that daily PM-AOD temporal correlations for a full year are as high as 0.8 in non-monsoon months but as low as 0.3 during monsoon season, when clouds prevent accurate AOD retrievals. We also find large spatial heterogeneity in both AOD and PM<sub>2.5</sub> concentrations, whereas temporal variability is more consistent and is controlled by the monsoon. Our results will contribute to better understanding of the spatial and temporal variability of air pollution in India and will improve the accuracy of future retrievals of satellite-derived PM<sub>2.5</sub> products.

**8RR.10**

**Catching the Freshwater Wave: Lake Spray Aerosol Production, Size, and Chemical Composition in the Lab and Field.** ANDREW AULT, Nathaniel May, Jessica Axson, Isabel Colon-Bernal, Alexa Watson, Kerri Pratt, *University of Michigan*

Aerosol production from wave breaking on freshwater lakes, such as the Laurentian Great Lakes, is poorly understood in comparison to sea spray aerosol (SSA). Herein, lake spray aerosol (LSA) is defined as aerosol generated from freshwater through bubble bursting, analogous to SSA from seawater. LSA have the potential to impact regional climate and health, but their composition has not been reported. LSA number concentration, size, and chemical composition were measured on the southeastern corner of Lake Michigan during an event with wave heights up to 3.1 m (July 6 – 8th, 2015). Single particle microscopy and mass spectrometry analysis of field and lab-generated samples show that LSA particles are primarily calcium (carbonate), with lower concentrations of other inorganic ions and organic material. These measurements were coupled with results from an LSA generator (LSAG) used to isolate the properties of LSA from background particles. These studies of LSA are needed as models, at present, utilize SSA parametrizations for freshwater systems. As LSA can be generated and act as CCN, IN or eject toxic materials from harmful algal blooms, an improved understanding of LSA physicochemical properties is needed to determine the impacts on climate and health in the Great Lakes region.

**8RR.11**

**Light Scattering and Absorption of the Individual PM1 Chemical Components in the Central Amazonian Basin at ATTO Tower.** SAMARA CARBONE, Luciana Rizzo, Joel Brito, Nga Lee Ng, Lu Xu, Jorge Saturno, Christopher Pöhlker, Bruna Holanda, Meinrat O Andreae, Henrique Barbosa, Paulo Artaxo, *University of Sao Paulo*

Measurements of PM1 chemical composition and optical properties were performed at the ATTO (Amazonian Tall Tower Observatory) station, in the Amazon forest, during the dry season of 2014 (August-December) and wet season of 2015 (February-May). The particle size distribution was measured with the Scanning Mobility Particle Sizer (SMPS, TSI, mobility diameter=10-370 nm) and chemical composition with the Aerosol Chemical Speciation Monitor (ACSM, Aerodyne Inc.). Determination of organics, sulfate, nitrate, ammonium and chloride jointly with optical properties (absorption and scattering) were accomplished. The Mie scattering code was used to estimate the mass scattering efficiency (MSE) and scattering coefficient values of each PM1 component, during the dry season. The following refractive index values were assumed  $1.52+0i$ ,  $1.55+0i$ ,  $1.52+0i$ ,  $1.54+0i$  and  $1.55+0.37i$ , for sulfate, nitrate, ammonium, chloride and eBC, respectively. In addition, the organics refractive index was calculated based on the effective refractive index retrieved iteratively, and varied from  $1.55$  to  $1.65+0i$ . The MSE values obtained were 5.4, 4.6, 4.6, 5.0, and  $4.8 \text{ m}^2 \text{ g}^{-1}$  for organics, sulfate, ammonium, nitrate and chloride, respectively. These results indicate that all PM1 components scatter the visible radiation ( $\lambda=525 \text{ nm}$ ) very efficiently. However, because the organics represented, on average, 76% of the PM1 mass concentration, this component was responsible for 83% of the scattering coefficient in the dry season, followed by sulfate (8%). It was observed a good agreement between the scattering coefficient obtained by the Mie scattering code and Nephelometer measurements (slope=0.80,  $R^2=0.84$ ). This is the first time the MSE is calculated for each individual PM1 component in the atmosphere of the Amazon forest.

**8RR.12**

**Decrease in Acid Rain Over 25-Year Study at Paradise, Mt. Rainier National Park.** ASHLEEN REDDY, Jeff Barnes, Naomi Beebe, Rebecca Lofgren, Barbara Samora, Anne Johansen, *Central Washington University*

Weekly wet precipitation samples from Paradise in Mt. Rainier National Park, WA, were analyzed for major anions and cations, conductivity and pH. Volume weighted 3-month averages were tested for significant trends throughout the 25-year monitoring period starting in 1989 and compared with analogous data collected at established National Atmospheric Deposition Program (NADP) sites throughout the state. At Paradise, proton concentrations decreased by a significant amount of 59% resulting in a pH increase of wet precipitation from 5.1 to 5.5 ( $P=0.001$ ). Similar trends were observed for the acidic sulfate and nitrate species. Results compare well with observations made at WA NADP sites. Results indicate that air pollution standards contribute significantly to the decrease in acid rain deposition to this pristine and vulnerable high elevation location, and that trans-Pacific transport of pollution is not detected in the form of acid rain and associated anions.

**8RR.13**

**Long Term Profile of PM<sub>2.5</sub> at Egbert Ontario Monitored by the Canadian Air and Precipitation Monitoring Network (CAPMoN).** KULBIR BANWAIT, Nancy Lance, *Environment and Climate Change Canada*

Canadian Air and Precipitation Monitoring Network (CAPMoN) is a rural and remote air-quality monitoring network consisting of thirty-three sampling stations (one in U.S.) producing data in support of the Canada-U.S. Agreement on Air Quality and its December 2000 Ozone Annex, Canada-Wide Standards for Particulate Matter, Canada-Wide Acid Rain Strategy and Ground-level Ozone. Data from 2003 to 2013 was examined from one rural - Egbert - site located 60 km north of Toronto, Ontario for particulate matter with aerodynamic diameter of 2.5 micro-meter (PM<sub>2.5</sub>) dichotomous and speciation sampler gravimetric mass-concentration ([mass]) comparison, reconstructed chemical [mass] closure to the gravimetric [mass], and seasonal and annual trends in PM<sub>2.5</sub> chemical composition. Speciation sampler PM<sub>2.5</sub> gravimetric [mass] accounted for 92 percent of dichotomous sampler PM<sub>2.5</sub> gravimetric [mass] with 96 percent of the correlation variability explained. Ninety-five percent of the dichotomous sampler gravimetric [mass] was explained by the reconstructed chemical [mass] with 85 percent of the correlation variability explained. PM<sub>2.5</sub> gravimetric [mass] annual average loading was observed to be declining by 0.42 micro-gram/m<sup>3</sup>/yr for the reported period and averaged highest, at 11.10 micro-gram/m<sup>3</sup>, in 2005 and 5.76 micro-gram/m<sup>3</sup>, in 2013. Inorganic species sulfate, nitrate and ammonium (48.3%), and organic matter (26.2%) made up major portion of the PM<sub>2.5</sub> [mass] and, both, contributed significantly to the stated decrease in annual [mass] loading. Particulate trace elements (9.0%), crustal matter (7.1%), unidentified matter (5.2%), elemental carbon (2.8%), trace inorganic ions (0.9%), and sodium chloride (0.5%) contributed to the rest of the total gravimetric PM<sub>2.5</sub> [mass] loading, and stayed relatively constant at Egbert throughout the reported period.

**8RR.14**

**Power Generation Projections in Support of PM<sub>2.5</sub> State-Implementation-Planning.** ALEXANDER COHAN, Mark Janssen, *Lake Michigan Air Directors Consortium*

Demonstrating attainment of the PM<sub>2.5</sub> National Ambient Air Quality Standard (NAAQS) requires accounting for local and long-range transport of PM<sub>2.5</sub> and its precursors. This study presents the modeling used to support a PM<sub>2.5</sub> State-Implementation-Plan (SIP). The regional photochemical model CAMx is used with emissions from EPA's 2011 National Emissions Inventory (NEI) and local refinements. Alternate control implementation pathways for the Mercury and Air Toxics Standard (MATS) and various generation growth scenarios are examined with two different electrical generation projection models considering the impact to ambient PM<sub>2.5</sub>. The regulatory requirements and challenges will be discussed.

**8SA.1****ZeFir: A New Igor Tool for Wind and Trajectory Analyses.**

JEAN-EUDES PETIT, Olivier Favez, Alexandre Albinet, Francesco Canonaco, *Air Lorraine*

Ambient air pollution is nowadays of great concern, notably due to demonstrated health effects and impacts on climate. In order to settle adapted mitigation policies, great advances in statistical analysis have allowed a source apportionment that is more and more comprehensive. However, if answering “what are the sources?” is crucial, answering “where do they come from?” is just as much important. In this context, various methodologies have been developed in the last decades to investigate the geographical origins of atmospheric pollution, based either on wind data or on backtrajectory analyses. To date, only few software exist to easily perform one or the other approach, but do not offer user-friendly solutions to perform both.

We present here ZeFir, a new Igor-based package to achieve a comprehensive geographical origin analysis using a single tool. Non-parametric Wind Regression, Potential Source Contribution Function, Concentration-Weighted Trajectory and Concentration Field are easily run from user-friendly panels.

Innovative features are implemented and allow a deeper but eased understanding of the above methodologies. Indeed, for instance, trajectory analyses in ZeFir are doped with:

- dataset enlargement, to take more trajectories into account (especially useful for daily measurements)
- trajectory cut-off options using precipitation or altitude
- interactive parameterization of the weighing function
- multi-site merging.

Finally, ZeFir takes advantage of SourceFinder, an Igor-based tool for source apportionment, where freshly apportioned sources can have their geographical origins quickly examined.

**8SA.2****Impacts of Power Generation on Air Quality in China.**

JIANLIN HU, Lin Huang, Mindong Chen, Gang He, Hongliang Zhang, *Louisiana State University*

Power generation is an important source of air pollution in China. In 2012, it contributed 30% of CO<sub>2</sub>, 33% of NO<sub>x</sub>, 23% of SO<sub>2</sub>, and 8% of PM emissions. Five future power development scenarios were considered in this study to see the effects of different plans on air quality in 2030. REF is the business as usual case. CAP represents the trajectory to achieve 80% reduction by 2050 as proposed by IPCC, LOW reflects use of low-cost renewable wind and solar energy, PEAK allows China to peak its carbon emission by 2030, while WEST assumes power plants will be built more in west. The impacts of different scenarios were simulated with CMAQ model in January and August with unchanged emissions from other sectors and same meteorology in 2013. Air quality gets worse in REF in both months compared to 2013. CAP and WEST generally have larger impacts on pollutant concentrations than LOW and PEAK. The four scenarios improve PM<sub>2.5</sub> total mass and SO<sub>4</sub><sup>2-</sup> in North China, with maximum decreases of over 100 µg m<sup>-3</sup> in January and over 10 µg m<sup>-3</sup> in August in the Hohhot area. However, PM<sub>2.5</sub> total mass and SO<sub>4</sub><sup>2-</sup> pollution are worsened in Shandong for CAP and WEST scenarios and in Chongqing for LOW and PEAK scenarios. NO<sub>3</sub><sup>-</sup> and O<sub>3</sub> get worsened in the four scenarios in large areas of the North China Plain (NCP), East and South China due to more NH<sub>3</sub> available for NO<sub>3</sub><sup>-</sup> formation associated with reduction in SO<sub>4</sub><sup>2-</sup> and aerosol radiative effects on UV radiation for O<sub>3</sub> formation. Power development plans greatly affect air quality in Beijing, with decrease in PM<sub>2.5</sub> and PM<sub>10</sub>, but increase in O<sub>3</sub>. Reducing NO<sub>x</sub> and SO<sub>2</sub> combined with NH<sub>3</sub> should be considered to reduce contribution of power generation to future air pollution in China.

**8SA.3**

**Source Apportionment of PM<sub>2.5</sub> in Baton Rouge, Louisiana.** FENGLIN HAN, Hongliang Zhang, *Louisiana State University*

Fine particulate matter (PM<sub>2.5</sub>) composition data collected at a monitoring site in central Baton Rouge, Louisiana were analyzed using positive matrix factorization (PMF) version 5. These 24-h averaged mass concentrations and compositions were obtained from samples taken every third or sixth day from 2009 to 2014. Uncertainties were calculated based on reference and missing values were replaced with geometric mean and determined with method detection limit (MDL). Major contributors to PM<sub>2.5</sub> including secondary sulfate, secondary nitrate, diesel vehicle, sea salt, road dust and soil were identified. The seasonal variations and annual trends of contribution of each source were also analyzed. Being located in the urban area and adjacent to highways and Mississippi River, the PM<sub>2.5</sub> level at this site was a result of both local urban activities and regional transport. This study provides important information for PM<sub>2.5</sub> control in Baton Rouge and the results can be used for assessing health risks of exposure to PM<sub>2.5</sub>.

**8SA.4**

**Apportionment of Urban Aerosol Sources in Chongqing (China) using Synergistic On-line Techniques.** YANG CHEN, *Chinese Academy of Sciences*

The sources of ambient fine particulate matter (PM<sub>2.5</sub>) during wintertime at an urban background location in Chongqing (southwestern China) have been determined. Aerosol chemical composition was measured using multiple on-line techniques, such as a single particle aerosol mass spectrometer (SPAMS), on-line elemental carbon-organic carbon analyzer (on-line OC-EC), and In-situ Gas and Aerosol Compositions monitor (IGAC) for water-soluble ions in PM<sub>2.5</sub>. All the datasets from these techniques have been adjusted to a 1-h time resolution for receptor model input. Positive matrix factorization (PMF) has been used for resolving aerosol sources. The synergistic on-line techniques were helpful for clearer identifying aerosol sources than when only employing the results from the individual methods. These results are useful for better understanding of aerosol sources and atmospheric processes in the urban area of southwestern China.

**8SA.6**

**Resolving Chemical Contributions to Atmospheric Brown Carbon with the Aerodyne Aerosol Chemical Speciation Monitor.** LELIA HAWKINS, Raunak Pednekar, Jason Casar, *Harvey Mudd College*

Light absorbing organic carbon (also known as brown carbon) has many sources in an urban environment, including nitration of aromatics, secondary aqueous formation in aerosol or cloud water, and primary emission during combustion of biomass and fossil fuels. This work aims to deconvolute those sources based on organic mass fragments measured by an Aerodyne Aerosol Chemical Speciation Monitor (ACSM). Spectra were recorded at 30-minute intervals for a one month period in summertime in an inland location within the Los Angeles basin. Collocated measurements of water soluble organic carbon and water soluble UV/visible light absorption recorded at 5-minute resolution provide a solution phase mass absorption coefficient, allowing us report the variability in aerosol absorptivity over hours, days, and weeks. Preliminary analysis indicates that aerosol absorptivity is highest in the morning hours coinciding with rush hour traffic in the region, while secondary aerosol formation appears to contribute little to additional browning.

**8SA.7**

**Source Apportionment of PM<sub>2.5</sub> Using the Receptor Models in Island Area and Metropolitan Area, Korea.** INJO HWANG, Seung-Muk Yi, *Daegu University*

In order to estimate the mass contribution and chemical composition of PM<sub>2.5</sub> sources using the receptor models, hourly PM<sub>2.5</sub> samples were collected at Baengnyeong Island and Seoul air pollution monitoring supersites from January 2013 to December 2013 were analyzed. A total of 8571 samples were collected and 30 species were analyzed by XRF (X-ray fluorescence spectroscopy), IC (ion chromatography), and TOT (thermal optical transmittance) methods. Positive matrix factorization (PMF) and UNMIX model were used to develop source profiles and to estimate their mass contributions. In the case of Baengnyeong Island site, the PMF modeling identified ten sources such as secondary sulfate, mobile + Br, secondary nitrate, industry, oil combustion, coal combustion, Cu related, sea salt, soil, and biomass burning source. On the other hand, the UNMIX modeling identified eight sources such as oil combustion, soil, coal combustion, sea salt, industry, secondary sulfate, secondary nitrate, and biomass burning, respectively. Detailed results of source apportionment for PM<sub>2.5</sub> at two sampling sites will be presented.

**8SA.8**

**Source Apportionment of PM<sub>2.5</sub> at Multiple Northwest U.S. Sites: Using Chemically Speciated PM<sub>2.5</sub> to Assess Regional Winter Wood Smoke Impacts from Residential Wood Combustion.** ROBERT KOTCHENRUTHER, *U.S. EPA*

Wood smoke from residential wood combustion is a significant source of elevated PM<sub>2.5</sub> in communities across the Northwest U.S. This work uses Positive Matrix Factorization (PMF) receptor modeling to assess winter residential wood combustion impacts at 19 monitoring sites in the Northwest U.S. Each site was modeled independently. Model solutions had from 4 to 8 PMF factors, depending on the site. 15 different sources or chemical compositions were identified as contributing to PM<sub>2.5</sub> across the 19 sites. The 6 most common were; aged wood smoke and secondary organic carbon, motor vehicles, primary wood smoke, ammonium nitrate, ammonium sulfate, and fugitive dust. Wood smoke was identified at every site, with both aged and primary wood smoke identified at most sites. Wood smoke contributions to PM<sub>2.5</sub> were averaged for the two winter months of December and January, the months when wood smoke in the Northwest U.S. is mainly from residential wood combustion. The total contribution of primary plus aged smoke from residential wood combustion ranged from 11.4% to 92.7% of average December and January PM<sub>2.5</sub>, depending on the site, with the highest percent contributions occurring in smaller towns that have fewer expected sources of winter PM<sub>2.5</sub>.

Receptor modeling at multiple sites provided significant advantages over modeling a single site. Results from multiple sites allowed common factor chemical compositions to be identified, making it easier to evaluate when a PMF factor at a particular site represents a mix of sources versus a single source. For commonly identified factors, average chemical profiles were established. Regionally-based average profiles such as these could be used as source profile inputs in Chemical Mass Balance receptor modeling, when the availability of local source profiles is limited. Multisite results could also be used to evaluate source specific impacts in source-oriented models like CMAQ and CAMx.

**8SA.9**

**Source Apportionment of PM<sub>2.5</sub> in New York City: Chemical Speciated Mass Concentration vs. Particle Number Concentration.** MAURO MASIOL, Philip K. Hopke, H. Dirk Felton, Brian P. Frank, Oliver Rattigan, Marilyn Wurth, Gil H. LaDuke, *Clarkson University*

Epidemiologic studies have amply demonstrated that exposure to elevated mass concentrations of airborne particulate matter pollution is associated with many adverse health effects. In U.S., air quality standards are regulated under the National Ambient Air Quality Standards (NAAQS), which set the limit values to be fulfilled across the U.S. for mass concentrations of both PM<sub>10</sub> and PM<sub>2.5</sub>. However, recent population-based studies have reported that even exposure to low mass concentrations may increase acute and chronic effects and mortality. It is estimated that current (2009-2011) levels of PM<sub>2.5</sub> still cause annually more than 2,000 deaths, 4,800 emergency department visits for asthma, and 1,500 hospitalizations for respiratory and cardiovascular disease in NYC.

This study investigates the main sources of PM<sub>2.5</sub> in NYC through the application of receptor models for two particulate metrics: mass concentration and particle number concentration (PNC). The most probable sources of PM<sub>2.5</sub> mass concentration were identified and apportioned using the positive matrix factorization (PMF) model on chemically speciated samples analyzed for major inorganic ions, organic (OC) and elemental (EC) carbon and elements. The sources of PNC were investigated by applying PMF to hourly measurements of multiple variables including number concentrations resolved over six bins (20-30 nm, 30-50 nm, 50-70 nm, 70-100 nm, 100-200 nm, 200 nm to 2.5 μm), gaseous air pollutants and mass concentrations of PM<sub>2.5</sub> and particulate sulfate, OC, and EC. Subsequently, post-processing methods were applied to help interpret the results including: (i) the comparison of sources identified with composition and particle number concentrations; (ii) relationships with weather parameters; (iii) the use of wind data through the polar analysis to detect the location of the most probable local sources, and (iv) the use of meteorology-based hybrid methods for extracting further information on the strength of potential external sources.

**8SA.10****Source Apportionment of PAHs in the Vicinity of Industrial Activities: PMF-based Approach from Long-term Filter**

**Data.** EMMANUEL JANTZEM, Jean-Eudes Petit, Alexandre Ockler, Jean-Pierre Schmitt, *Air Lorraine*

The impacts of air pollution on human health is directly linked to its chemical composition. In particular, Polycyclic Aromatic Hydrocarbons (PAHs), and especially benzo(a)pyrene (BaP), are known carcinogenic and concentrations are regulated by European directives.

Within BaP evaluation program over the 2011-2015 period, Air Lorraine, the regional association for air quality monitoring in Lorraine (East of France), has conducted a source apportionment study of PAHs at a rural site in the vicinity of industrial activities (cement factory). Daily filter sampling has been carried out, evenly distributed year-long in order to take into account seasonal variations of meteorological conditions and sources. Concentrations of 9 major PAHs, monosaccharides (among which levoglucosan), sugar alcohols and 5 major metallic compounds were retrieved. Source apportionment has been performed by Positive Matrix Factorization (EPA PMF).

The 3-factor solution are respectively related to wood-burning, biogenic aerosols and mixed factor of traffic and industrial emissions. Similarly to what is found in the literature, wood burning explains most of PAHs variabilities (80%), emphasizing the need of stakeholder initiatives on this source in rural areas, even in the vicinity of industrial activities.

Surprisingly, the use of metallic compounds in the PMF did not allow to resolve primary traffic and the cement plant. However, wind analysis, performed by Non-parametric Wind Regression, applied on selected species clearly highlighted specific industrial emissions. Indeed, while Al, Ti and Mn show a clear hotspot towards the cement plant, Cu and Fe highlighted different patterns. This industrial activity can thus still influence air quality sporadically in the village, although its precise quantification remains laborious. This finally underlines the synergy between source apportionment and geographical origin works.

**8SA.11****Identifying PM<sub>2.5</sub> and PM<sub>0.1</sub> Sources and Estimating Their Health Impacts in the San Francisco Bay Area.** XIN YU, Melissa Venecek, Michael Kleeman, *University of California, Davis*

Numerous epidemiological studies have identified strong health associations with particles that have aerodynamic diameter < 2.5  $\mu\text{m}$  (PM<sub>2.5</sub>). Multiple toxicity studies suggest that particles with aerodynamic diameter < 0.1  $\mu\text{m}$  (PM<sub>0.1</sub>) may be even more dangerous to human health but confirmation of these results in epidemiology studies has been elusive. Accurate exposure estimates to PM<sub>0.1</sub> are difficult to generate partly because concentrations change over short distances which makes it impractical to use central site monitors to predict exposure for large populations. Furthermore, land use regression (LUR) models do not have enough input data to estimate exposure to PM<sub>0.1</sub>. Recent studies have employed regional chemical transport models to provide the first realistic population exposure estimates for PM<sub>0.1</sub> over large populations suitable for epidemiology studies.

In this work, the University of California, Davis/California Institute of Technology (UCD/CIT) chemical transport model with 4km resolution was applied to predict PM<sub>2.5</sub> and PM<sub>0.1</sub> concentrations over the San Francisco Bay Area (SFBA) in California. Model predictions were compared to measurements of PM<sub>2.5</sub> mass and chemical composition to evaluate the accuracy of simulations. Predicted source contributions to primary PM<sub>2.5</sub> mass, PM<sub>0.1</sub> mass, PM<sub>0.1</sub> EC, and PM<sub>0.1</sub> OC were compared to the analysis results from receptor-based Chemical Mass Balance (CMB) model. The contributions from most significant sources of PM<sub>2.5</sub> and PM<sub>0.1</sub> were assessed over the entire region with 4km resolution. The results from UCD/CIT model provided detailed spatial and temporal variations and enhanced source apportionment information for epidemiological studies to examine the relationship between health effects and concentrations of PM<sub>2.5</sub> and PM<sub>0.1</sub> in the SFBA.

**8SA.12**

**Semivolatile and Nonvolatile Particulate Matter Emissions from a Light-Duty Diesel Engine and the Effects of Biodiesel.** YUAN CHENG, Shao-Meng Li, John Liggio, Katherine Hayden, Yuemei Han, Tak Chan, Marie-Josée Poitras, *Environment and Climate Change Canada*

Semivolatile organic compounds (SVOCs) represents a dominant category of secondary organic aerosol (SOA) precursors that are missing in most air quality models. In the present study, an experimental system was developed and applied to a light-duty diesel engine to determine the emission factors of SVOCs and nonvolatile particulate matter (PM) components using ultra-low-sulfur diesel (ULSD) and three biodiesels, at dilution ratios representative of ambient conditions. For ULSD, the contribution of SVOCs to total OM mass in the engine exhaust could be as high as 85%. Evaporation of SVOCs from diesel particles during dilution led to decreases in the hydrogen to carbon ratio of organic matter (OM) and the number emission factor of the particles. Substituting biodiesels for ULSD could increase SVOCs emissions but brought large reductions in black carbon (BC) emissions. Among the biodiesels tested, tallow/used cooking oil (UCO) biodiesel showed reductions over soybean and canola biodiesels in terms of both SVOCs and nonvolatile PM emissions. It is noteworthy that PM properties, such as particle size and BC mass fraction, could differ substantially between emissions from conventional diesel and biodiesels.

**8SP.1**

**The Role of Aerosols in Degrading Solar Panels: Exploring the Dependency of Size and Absorptivity.** PATRICIO PIEDRA, Hans Moosmuller, *Desert Research Institute*

Sustainable energy from renewable resources such as wind, hydroelectric, geothermal, and solar energy may have reliability issues due to the limited predictability of nature. However, energy production needs to match energy demand during peak and non-peak consumption to avoid costly power outages. Smart solar grids may reduce such problems by using models that forecast solar energy production. One factor that needs to be included in such models is the degradation of solar panel performance by aerosol deposition, for example during dust storms or due to soot deposition in polluted areas. Aerosols degrade the performance of solar panels by absorbing or back-scattering part of the incoming solar power, with field experiments reporting up to 85% degradation depending on the type of aerosol particles deposited and the particle mass per unit area.

We have conducted a theoretical study using both Mie theory and surface interacting discrete dipole approximation to analyze the role of particle size and imaginary part of the index of refraction on optical transmission and consequently solar panel performance. Our calculations indicate that optical transmission is commonly less than 50% for absorbing aerosols, but remains at above 90% for non-absorbing aerosols. This study presents an innovative treatment of optical surface-particle interaction that can be used for predictive modeling of solar panel degradation as part of solar forecasting.

**8SP.2**

**An Algorithm to Derive Particle Size Changes from Full size Distribution Measurements.** CHIRANJIVI BHATTARAI, Andrey Khlystov, *Desert Research Institute*

One of the major uncertainties in understanding the Earth's climate system is the interaction between solar radiation and aerosols in the atmosphere. Aerosols exposed to high humidity and temperature will change their chemical, physical, and optical properties. Volatility and hygroscopic growth factors of aerosols are usually studied using the tandem differential mobility analyzer (TDMA) method. The TDMA method takes a relatively long time to complete a measurement at several sizes. Quicker methods to make such measurements are needed. We have used measurements of full size distributions before and after an aerosol underwent a physical change to determine how the change affected particles of different sizes. This was done using an inversion algorithm that is based on preservation of particle number. Using cumulative distributions, we find particle sizes in both distributions corresponding to a certain number concentration. This provides sizes of particles before and after transformation (evaporation or growth). This approach has been proposed and used in late 1970's and early 1980's [1, 2]. However, to our knowledge, there has been no experimental verification reported until now. In this study, we performed a detailed theoretical and numerical analysis of uncertainties associated with this algorithm. We also have carried out a set of experiments using adipic acid aerosol evaporation as an example. The inversion algorithm applied to full size distribution measurements provided results that are within 10 % of TDMA measurements.

## References:

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**8SP.3**

**Investigating the Evolution of Coatings on Black Carbon at Rapid Time Scales.** TREVOR KRASOWSKY, Scott Fruin, Constantinos Sioutas, George Ban-Weiss, *University of Southern California*

As black carbon (BC) particles are transported into the atmosphere, they acquire soluble coatings. However, there is still vast uncertainty associated with "how" and "when" coatings accumulate on BC particles, including at rapid time-scales (<1 hour). This study uses real-world measurements to investigate spatiotemporal changes in coatings on black carbon at rapid time scales after being emitted. The hypothesis is that as BC is emitted, coatings develop when supersaturated semi-volatile organics condense massively on freshly emitted BC near the roadway, and through subsequent atmospheric dilution following immediately, these semi-volatile coatings preferentially partition back into the gas phase down wind of the emissions source where exposed black carbon particles begin acquiring coatings thought to develop on longer time-scales (>1 hour).

Individual BC particle measurements were made using a Single-Particle Soot Photometer (SP2) at varying distances downwind of the 405 freeway at the Los Angeles National Cemetery. The location is ideal for measuring freshly emitted BC heavily dominated by roadway traffic with little influence from surrounding sources. Coating thickness was analyzed using two common methods, the "Lag-Time" and "Leading Edge Only" methods, to provide a comparison of the techniques and characterize the BC coatings at different aging times. Continuous measurements of BC mass concentration, CO<sub>2</sub> mixing ratio, and particle number concentration were also made at the roadway using a MicroAeth, Licor-840A CO<sub>2</sub> analyzer, and DiSCmini, respectively, to correct for background variation in source emissions during the measurement periods.

**8SP.4****Characterization of Aerosols by Forward Light Scattering.**

PAUL LANE, Matthew B. Hart, Brian Saar, Jay D. Eversole,  
*Naval Research Laboratory*

Environmental, health and security concerns are driving our interest in techniques to characterize airborne particles in real time. The primary cause of attenuation of incident radiation in aerosols is scattering, which is a function of the complex refractive index and the size and shape of particles. Light scattering varies significantly over wavelengths near absorption maxima, because the complex refractive index varies over this interval. This feature can be exploited to determine the absorption peak(s) of particles, and hence, their composition. Using silica particles as a test case, we differentiate bare particles from those thinly coated by an organic dye (rubrene) with an absorption maxima bracketed by three incident lasers. Experimental results on spherical and non-spherical particles will be compared and contrasted.

**8SP.5****Single Particle Characterization of Carbonaceous Aerosol using Soot-Particle Aerosol Mass Spectrometer (SP-AMS).**

ALEX K. Y. LEE, Megan Willis, Jonathan Abbatt, *University of Toronto*

Black carbon (BC) aerosol can play a critical role influencing regional air quality, human health, and global climate. Fossil fuel combustion and biomass burning such as forest fires are the primary sources of ambient BC. Most BC particles are internally mixed with co-emitted organics and/or secondary organic materials produced via atmospheric processing, modifying the physical and chemical properties of the particles and their fate and environmental impacts. A real-time analytical technique with a single particle detection capability is an ideal approach to quantify the mixing state of ambient BC particles. However, quantification of a tiny amount of single particle material at the femtogram level is a considerable analytical challenge. The primary objective of this presentation is to demonstrate the single particle characterization capability of the Aerodyne Soot-Particle Aerosol Mass Spectrometer (SP-AMS) based on our recent observations in the field. The instrument was deployed in an urban environment to determine the mixing state of BC-containing particles from traffic-dominated emissions and the results were used to drive a particle-resolved aerosol box model to assess the effect of accurately representing BC mixing states on aerosol optical properties. Furthermore, we observed non-uniform mixing of particles within a biomass-burning plume in terms of molecular weight. Our results illustrate that high molecular weight organics can be a key contributor to low-volatility brown carbon observed in biomass-burning organic aerosol (BBOA). Lastly, preliminary results of aircraft measurements in the High Arctic will be discussed.

**8SP.6****Ultrafine Particles Size Distribution, Single Aerosol Particle Morphology and Chemical Composition in Urban Air.**

CECILIA LEONI, Jan Hovorka, Miroslav Klán, Jan Bendl, Sona Marvanova, *Charles University in Prague*

Atmospheric ultrafine aerosol particles (UFP) were collected in Kladno, Czech Republic, in February 2016, using copper grids for transmission electron microscopy (TEM) placed on the back-up filter of a 3DRUM impactor. Concurrently, five-minute integration time data of particle number size distributions, concentration (PNC), gaseous pollutants and meteorological parameters were also registered. The vertical profile of temperature and humidity up to 300 m was measured with a tethered balloon.

The measurements of the mixing layer height revealed frequent formation of temperature inversion layer up to 50 m. With inversion conditions and calm air (wind speed  $<1\text{m}\cdot\text{s}^{-1}$ ) PNC rose to  $2\cdot 10^4 \text{ #cm}^{-3}$ , with a maximum of  $4\cdot 10^4 \text{ #cm}^{-3}$ , with a peak in the ultrafine size range, at 100 nm. UFP peaks occurred simultaneously with peaks of CO and SO<sub>2</sub> and PM<sub>10</sub> indicating wood and coal burning for home heating. New particles formation events with peaks at 15 nm were observed in two clear days (06 and 14.02), in the early afternoon, but not remarkable particle growth was recognized.

Several types of individual particles were observed using TEM: soot-like agglomerates and aggregates with complex morphology, composed by nanospheres with diameter between 5 and 50 nm; fly ash particles; presumably individual tar-ball particles with perfect spherical shape and diameter around 100-500 nm; and ammonium sulphate particles.

No significant shape difference was observed between the aggregates sampled during nucleation events and during air pollution events.

The next steps are: the chemical analysis of the single particles with electron probe microanalyzer with field emission gun (FEG-EPMA); PAHs analysis in the UFP.

The project is supported by the Czech Grant Agency (P503/12/G147).

**8SP.8****A Molecular Dynamics Simulation based Analysis of Atmospheric Droplets Containing Chromium.** MEHDI AMOUEI TORKMAHALLEH, Bekbol Aldamzharov, Assel Bukayeva, Dhawal Shah, *Nazarbayev University*

Two most stable chromium's oxidation states in the environment are trivalent and hexavalent states. Hexavalent chromium, Cr (VI), is human carcinogen, while trivalent chromium, Cr (III) is essential micronutrient. Possible reductants for conversion of Cr(VI) to Cr(III) in atmospheric droplets are ionic forms of As, V and Fe while Mn was found to be an oxidant for the conversion of Cr(III) to Cr(VI). In addition to the ionic reductants and oxidants, chromium may react with dissolved gaseous compounds such as volatile organic compounds (VOCs) and ozone. The availability of the Cr for the reactions may change whether Cr presents on the surface of the atmospheric droplets or at the interior parts of the particles. If Cr presents inside the particles, then diffusion of the dissolved gases within the atmospheric droplets towards the Cr ions could be important. Nonetheless, no study is found in the literature investigating the physical properties of Cr containing atmospheric particles, in particular in the presence of dissolved gases. Experimental measurements of such properties could be hard or even impossible. However, molecular dynamics simulation is a suitable tool to investigate physical interactions of molecules in such complex systems. The aim of this study was to estimate some physical properties of soluble Cr<sup>+3</sup> in a single droplet in the presence of dissolved gases such as ozone and VOCs using molecular dynamics simulation. The preliminary results showed that the presence of ozone, increased diffusion coefficient of chromium in water from  $0.5092\times 10^{-5}$  to  $0.6147\times 10^{-5} \text{ cm}^2/\text{s}$ . Dissolved methane increased the diffusion of chromium, while benzene slightly decreased. It is concluded that the presence of the Cr(III) in atmospheric droplets changes the solubility level of the gases compounds such as VOCs and ozone and this change then affects the availability of the atmospheric reductants oxidants to reacts with chromium species.

**8SP.9**

**Classification of Airborne Particulates Using Multispectral Light Scattering Imaging.** STEPHEN HOLLER, Stephen Fuerstenau, Charles Skelsey, *Fordham University*

Light scattering patterns from non-spherical particles and aggregates exhibit complex structure that is only revealed by observing the scattering pattern over a large solid angle. Because of morphological differences in these aerosols, whether from structure or composition, the rich structure in the two-dimensional angular optical scattering (TAOS) patterns vary from particle to particle, even when they belong to the same class. We have investigated such TAOS patterns using a single color CCD camera to simultaneously capture spectrally distinct patterns from individual aerosols. Since the optical size of the scattering particle is inversely proportional to the illuminating wavelength, the spectrally resolved scattering information provides characteristic information about the airborne particles simultaneously in two different scaling regimes. The simultaneous acquisition of data from airborne particulate matter at two different wavelengths allows for additional degrees of freedom in the analysis and characterization of the aerosols. We examine two-dimensional light scattering patterns obtained at multiple wavelengths using a single CCD camera with minimal cross talk between channels. The integration of the approach with a single CCD camera assures that data is acquired within the same solid angle and orientation. We have attempted to deconstruct the recorded TAOS patterns in order to identify characteristic descriptors that can describe the morphology and be implemented in multivariate algorithms for classification. The results of these classifications indicate that the descriptors we developed are meaningful for testing classes against a known database. The classifications were tested against several metrics, and we have achieved classification on par with previous analyses, but with morphological descriptors that reflect physical characteristics of the aerosols.

**8SP.10**

**Condensational Growth Kinetics of Spheres and N-mers.** Amruthesh Thirumalaiswamy, WILLIAM HEINSON, Rajan Chakrabarty, *Washington University in St. Louis*

Condensation is one of the key processes involved in the growth of aerosols. This study focuses on computationally probing the kinetics of diffusion-limited condensation of vapor molecules onto seed aerosol nuclei of two morphologies: sphere and cluster of aggregated spheres. A simulation setup consisting of vapor and gas molecules undergoing Brownian diffusive motion around an aerosol is used to obtain the condensation rates. The simulation parameters were set such as to best represent real-world condensational growth scenarios. Relevant parameters necessary to comprehensively define the deposition kinetics are investigated. Major findings include the differences in temporal evolution of the condensation rates and concentration profiles for n-mers and their equivalent-size coalescing spheres, and 3-dimensional mapping of condensation “hotspots” on particle surfaces. Our results highlight the need to better parameterize and incorporate the temporal evolution of condensational rate coefficients in existing aerosol growth models.

**8SP.11****Fluorescence Calibration Method for Single-particle****Aerosol Fluorescence Instruments.** ELLIS SHIPLEY

ROBINSON, Ru-Shan Gao, Joshua P. Schwarz, David Fahey,  
Anne Perring, *CU-CIRES - NOAA ESRL*

Real-time, single particle fluorescence instruments used to detect atmospheric bioaerosol particles are increasingly common, yet no standard fluorescence calibration method exists for this technique. This limits the utility of these instruments as quantitative tools and complicates comparisons between different measurement campaigns. To address this need we have developed a method to produce size-selected particles with a known mass of fluorophore, which we use to calibrate the fluorescence detection of a Wide-band Integrated Bioaerosol Sensor (WIBS-4A). We use mixed tryptophan-ammonium sulfate particles to calibrate one detector (FL1; excitation = 280nm; emission = 310-400nm), and pure quinine particles to calibrate the other (FL2; excitation = 280nm; emission = 420-650 nm). This procedure allows users to set the detector gains to achieve a known absolute response, calculate the limits of detection for a given instrument, improve repeatability of instrumental set-up, and facilitate intercomparisons between different instruments. We recommend calibration of single-particle fluorescence instruments using these methods.

**9BA.1**

**Design and Development of a Self-Contained Personal Electrostatic Bioaerosol Sampler (PEBS).** TAEWON HAN, Gediminas Mainelis, *Rutgers, The State University of New Jersey*

The goal of this project is to develop a personal electrostatic bioaerosol sampler (PEBS). PEBS is a two-stage electrostatic precipitator consisting of a novel wire-to-wire charger and a dual half-cylinder collection chamber. The newly designed wire-to-wire charger produces very low ozone concentrations (only ~ 10ppb) compared to more traditional charger designs, such as wire-to-cylinder or wire-to-plate. This new charging concept allows maintaining desirable physiological characteristics of collected bioaerosols during a long-term sampling process, leading to a more accurate sample analysis. When PEBS is operated, aerosols (and bioaerosols) are drawn into an open channel collector, electrically charged by the wire-to-wire charger and deposited onto a removable stainless steel plate. A one-inch long tungsten wire (0.003 inches in diameter) is positioned in the center of the charging chamber (i.e., 1-inch cylinder) and connected to the high voltage; and a ring of stainless steel wire (0.015 inches in diameter) is surrounding the "hot" electrode at its midpoint and is grounded.

At this stage of development, the sampler was tested in the laboratory at different charging and sampling voltages when challenged with polystyrene (PSL) particles ranging from 0.025 nm to 3 µm in diameter and at flow rates of 10 L/min and 30 L/min. Investigated sampling times ranged from 10 min to 4 hours. The sampler's collection efficiency was determined by measuring the amount of particles deposited on the collection plate relative to the particle concentration upstream of the sampler. For the investigated particles, including the nano-sized ones, the collection efficiency was 70-90% at charging voltages of (+)5.5 kV, while collection voltage was set to (-)7 kV. Overall, PEBS showed very consistent collection efficiency (~70%) even after 4 hours of continuous operation. The use of the unique wire-to-wire charger resulted in ozone production below 10 ppb. Experiments with bioaerosol also show high collection efficiency.

**9BA.2**

**Size Amplification and Viability Preservation of Aerosolized Virus by Batch Adiabatic-expansion for Size Intensification by Condensation (BASIC).** HAORAN YU, Chang-Yu Wu, Nima Afshar-Mohajer, John Lednicky, Hugh Fan, Alexandros Theodore, Liming Dong, *University of Florida*

Pathogenic viruses transmitted in airborne routes exert serious impacts on human health, agriculture, and are of major concern for homeland security. Sampling is a critical step for risk assessment of exposure to airborne viruses. However, conventional bioaerosol sampling devices operate based on inertia of sampled aerosol and are inefficient in collecting virus aerosols because of their low inertia. In this study, a novel Batch Adiabatic Size Intensification by Condensation (BASIC) device was developed as an assisting tool for efficient sampling of aerosolized virus particles. The BASIC device enlarges virus aerosols by condensing water vapor on them; condensation occurs on the virus nuclei as the result of a rapid, adiabatic expansion in a humid environment. The physical and viable virus collection effectiveness of BASIC was optimized through sensitivity analyses of key parameters. The results of physical efficiency tests showed that compression pressure, number of compression/expansion (C/E) cycles and water temperature affected the sampling performance of both polystyrene latex (PSL) and MS2 bacteriophage aerosols, and size amplification of ~100 nm growth to > 1 micro-m was attainable under optimal conditions. Virus viability tests indicated that increased compression pressure was beneficial for the collection of viable MS2, whereas multiple C/E cycles were not. A water temperature of 40 degree C promoted viable MS2 collection, but at 60 degree C, virus inactivation occurred. In addition, viable MS2 collected by BASIC-assisted BioSampler was much higher than that collected by Biosampler alone. In conclusion, this device is efficient for the collection of viable virus from aerosols.

**9BA.3**

**Gentle Sampler of Submicron Airborne Viruses via Electrostatic Forces.** SEONGKYEOL HONG, Chang-Ho Han, Jaesung Jang, *Ulsan National Institute of Science and Technology, Korea*

Since the aerosol transmission is an important mode for spread of the airborne viral diseases, it is critical to know the accurate concentration and pathogenicity of the virus via correct sampling. Sampling of submicron virus particles is especially necessary due to their high probability of the airborne stay and deposition on the lower respiratory tract. In this work, we developed a personal electrostatic particle concentrator (EPC) for the aim of gentle sampling of submicron airborne virus particles. Owing to the enhanced electric field intensity, collection efficiencies for 0.05-2  $\mu\text{m}$  particles were as high as 98.5-99.7% at the flow rate of 1.2 lpm. Fluorescence intensity for the collected submicron T3 and MS2 viral particles were 6.05 and 6.87 times higher in the EPC than in the SKC BioSampler, even though the sampling flow rate was more than 10 times lower in the EPC. Moreover, the concentration of viable T3 virus was 2498 times higher in the EPC than in the BioSampler, which is due to the gentle sampling in the EPC. This EPC in conjunction with a biosensor has potential for on-site accurate detection of airborne viruses.

**9BA.4**

**Advanced Exhaled Breath Aerosol (EBA) Collection Using Cryogenic Impaction.** SOMAYEH YOUSSEFI, Gregory Lewis, Susanne Hering, Sheryl Ehrman, Donald Milton, *University of Maryland School of Public Health*

Exhaled breath condensate (EBC) is a popular, non-invasive method to study biomarkers present in exhaled breath. Conventional EBC collects large amounts of water vapor resulting in sample dilution without efficient impaction of fine and submicron particles that are the dominant modes in EBA. In this study we developed a novel bioaerosol collector that can collect EBA effectively and in a significantly small volume.

Because exhaled breath is saturated with water at body temperature ( $\sim 37^\circ\text{C}$ ), it contains enough moisture to grow EBAs without input of additional water vapor. Therefore, decreasing exhaled breath temperature in a laminar flow regime establishes an environment with adequate super saturation. A major innovation here is impaction on a layer of ice maintained at  $\sim -12^\circ\text{C}$ . With a starting volume of 0.25 ml of water, the final sample volume is approximately 0.4 ml after 30 min of breath collection.

Collecting EBAs on ice has 3 key advantages: 1) Impacting particles on a solid surface is more efficient compared with liquid impingement; 2) Impacting on ice eliminates sample extraction and associated losses that result when particles are impacted on solid dry surfaces – recovery from ice merely requires melting the ice; 3) Collecting EBA on ice preserves labile biomarkers, especially proteins and free nucleic acids susceptible to enzymatic degradation when collected in aqueous media at room temperature.

We collected individual EBA samples from 18 volunteers to study their respiratory proteome. While wearing a nose clip, participants inhaled particle-free air and exhaled into the system. On average 23  $\mu\text{g}$  total protein was recovered from 30-min samples, 350x higher yield than previously reported for solid state impaction. It is also 4x higher total protein and 28x more concentrated than for the highest reported protein recovery from exhaled breath concentrate.

**9BA.5**

**Combined Processes of Aerosol-to-Hydrosol Sampling and ATP Bioluminescence Assay for Real-time Bioaerosol Monitoring.** JI-WOON PARK, Hyeong Rae Kim, Jungho Hwang, *Yonsei University, Korea*

We present a methodology of continuous and real-time bioaerosol monitoring by integrating an aerosol-to-hydrosol sampler and a bioluminescence detector. For performance test, air flow containing lab-generated test bacteria (*Staphylococcus epidermidis*) was supplied through the inlet of the sampler. A high voltage was applied between the discharge electrode and the ground electrode of the sampler to generate air ions by corona discharge. The bacteria aerosols were charged by air ions and sampled on the flowing liquid which contained cell-lysis buffer solution and ATP bioluminescence reagents. While the liquid was delivered to the bioluminescence detector, sampled bacteria were dissolved by the cell-lysis buffer solution and ATPs were extracted from the bacteria. Subsequently, the ATPs were reacted with the ATP bioluminescence reagents and then light was emitted. When experiments were carried out in a mode of changing the concentration of bacteria aerosols, the ATP bioluminescence signal (expressed as relative light unit, RLU) well followed the concentration (expressed as particles per unit air volume,  $\#/cm^3$ ) variation of the aerosols which was measured by an aerosol particle sizer. The response time required altogether for aerosol sampling and ATP bioluminescence was under 30 seconds when the air sampling flow rate was 8 lpm and the liquid sampling flow rate was 800  $\mu$ lpm. Our methodology will be used to trigger an alarm for biological air contamination.

**9CA.1**

**Comprehensive Characterization of Fine Particulate Matter from Southeastern United States: Implications for Composition, Origins, and Atmospheric Processing of Organic Aerosol.** HAOFEI ZHANG, Lindsay Yee, David Worton, Gabriel Isaacman-VanWertz, Nathan Kreisberg, Steven Spielman, Susanne Hering, Allen H. Goldstein, *University of California, Berkeley*

Chemically characterizing atmospheric organic aerosol (OA) composition is crucial to elucidating their origins and formation pathways, but also very challenging due to the chemical complexity in atmospheric aerosol samples. In this work, 254 ambient aerosol samples were collected at 4-hour time resolution by a customized sequential air sampler at Centerville, Alabama, United States, during the Southern Oxidant and Aerosol Study (SOAS). The samples were analyzed using a Thermal Desorption Two-Dimensional Gas Chromatography High-resolution Time-Of-Flight Mass Spectrometer (TD-2DGC-HTOF-MS) with on-line trimethylsilylation derivatization to obtain clear chemical separation with extensive ranges of volatility and polarity. Timelines were created for approximately 700 organic tracers, 10-20% of which are known species, including primary OA (POA) and secondary OA (SOA) chemicals with known anthropogenic and biogenic origins. Positive matrix factorization (PMF) analysis was performed to identify major OA sources and transformation processes, including association of a much more complete range of identified and unidentified tracers with specific factors than has previously been possible. The time series of all compounds are compared with co-located on-line measurements, including on-line Thermal desorption Aerosol Gas chromatograph (TAG), Aerosol Mass Spectrometer (AMS), and the AMS-resolved PMF factors. The origins and identifications of some previously unknown compounds are reported from ambient observations for the first time. The atmospheric processing that leads to the formation and evolution of these OA are also suggested.

## 9CA.2

**Seasonal Characterization of SOA Formed through the Uptake of Water-Soluble Gases to Aerosol Liquid Water (aqSOA).** MARWA EL-SAYED, Christopher Hennigan, *University of Maryland, Baltimore County*

The formation of secondary organic aerosols through aqueous processes (aqSOA) has been identified as an important route in forming organic aerosols; however, many aspects of aqSOA formation are still uncertain. The aim of this ambient study was to characterize the reversible and irreversible formation of aqSOA across the four seasons to provide insight into the main factors which govern the uptake of organic gases into aerosol liquid water. The reversible and irreversible uptake of water-soluble organic gases in liquid water was measured in Baltimore, MD using a recently developed on-line method. Not only did the amount of aqSOA vary across the seasons, but also there were strong seasonal differences in the reversible and irreversible nature of the uptake of gases into liquid water. Irreversible aqSOA formation was observed in all four seasons, and was a strong function of relative humidity (RH). On the other hand, reversible aqSOA formation was only observed during the late spring and throughout the summer, where it accounted for 10-15% of the total SOA formed in these two seasons. During the periods where reversible aqSOA was observed, its concentrations were of the same order as irreversible aqSOA, indicating the importance of both processes in the eastern United States. Based on the seasonal differences observed in aqSOA formation, some of the factors underlying the differences in the concentrations of reversible and irreversible aqSOA are investigated, which include: temperature, RH, precursor VOC emissions, mixing and transport.

## 9CA.3

**Water Solubility of Primary and Secondary Organic Aerosols in an Urban Atmosphere in Hong Kong.** Bin Yu Kuang, Peng Lin, X. H. Hilda Huang, Yee Ka Wong, JIAN ZHEN YU, *Hong Kong University of Science and Technology*

Sources of organic aerosols in an urban atmosphere in Hong Kong were investigated by applying the Positive Matrix Factorization (PMF) analysis to PM<sub>2.5</sub> chemical composition data set covering two years. The data set includes PM<sub>2.5</sub> major inorganic constituents, elements, organic carbon (OC), elemental carbon (EC), organic tracers, as well as water-soluble organic carbon (WSOC) and humic-like substances. Seven factors were resolved by PMF, consisting of two secondary formation processes factors, three primary combustion emissions factors (vehicle, ship, and biomass burning), and two non-combustion primary emission factors (dust and sea salt). Separation of primary and secondary organic aerosols into water-soluble and water-insoluble fractions was obtained by reconstructing the concentration of WSOC and water-insoluble OC (WISOC) from the PMF-resolved source factors. The two major primary OC sources, vehicular exhaust ( $1.88 \pm 0.83$  micro-gram-C/m<sup>3</sup>) and ship emission ( $0.64 \pm 0.59$  micro-gram-C/m<sup>3</sup>), were mainly water-insoluble, with WISOC taking up more than 70% of OC. The other major primary OC source, biomass burning ( $0.91 \pm 1.10$  micro-gram-C/m<sup>3</sup>), had comparable amounts of WSOC and WISOC. The secondary sulfate formation process ( $2.93 \pm 3.05$  micro-gram-C/m<sup>3</sup>) was found to have a considerable fraction (42%) of OC apportioned as water-insoluble while the dominate fraction (92%) of OC in the secondary nitrate formation process factor ( $1.28 \pm 1.27$  micro-gram-C/m<sup>3</sup>) was water-insoluble. The apportionment implies that off-line chemical characterization of the full range of secondary OC needs to go beyond water extraction to solvent-extraction based methods. Secondary WISOC had a stronger correlation with the hydrophobic fractions of WSOC (i.e., HULIS) ( $r = 0.81$ ) than the hydrophilic fraction of WSOC ( $r = 0.57$ ), and moderate correlations with EC fractions evolved at or before 700°C during thermal analysis ( $r: 0.72-0.78$ ) while no correlation with the higher temperature step (EC<sub>4</sub>) at 775°C. These correlation data suggest that aging of the primary OC might be the dominate source of secondary WISOC.

## 9CA.4

**Sources and Characteristics of Carbonaceous Aerosol with High-time Resolution Measurement in Beijing, China.** MEI ZHENG, Caiqing Yan, Yue Liu, Xiaoying Li, Jinting Yu, Bob Cary, Anthony D.A. Hansen, *Peking University*

Carbonaceous aerosol plays significant role on air quality, human health and climate change. Carbonaceous aerosol in China could account for 30-50% of the total fine particulate matter mass, and is the dominant component in some high fine particulate matter (PM<sub>2.5</sub>) pollution episodes. However, compared to other regions in the world, PM<sub>2.5</sub> in Beijing shows significant higher temporal variation. For example, its concentration can be increased by several hundred micrograms per cubic meter within 10 hours during winter period. Thus, high-time resolution measurements are required in order to better characterize carbonaceous aerosol and understand its sources. In this study, carbonaceous aerosol (including organic carbon, OC, and elemental carbon, EC) was continuously measured by Sunset Semi-Continuous OC/EC analyzer at an urban site of Beijing during winter in 2015, which is located inside the campus of Peking University. Along with continuous OC/EC measurement, aerosol light-absorption was also measured with a 7-wavelength Aethalometer (AE-33). Seasonal and diurnal variations of carbonaceous aerosol were examined, and the light absorption by organic carbon (brown carbon) and black carbon were apportioned and quantified. Our results showed that (1) carbonaceous aerosol dominated PM<sub>2.5</sub> mass in clean days, with obvious diurnal variation, while its importance decreased in polluted days with no evident diurnal variation, (2) light-absorbing organic carbon can be clearly seen during the heating season, and it was higher than the level in non-heating season. Using the model suggested by Sandradewi et al. (2008), source apportionment of light absorbing carbonaceous aerosol is also conducted and discussed.

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## 9CA.5

**Coupled AMS and Radiocarbon Analysis of Organic Aerosols for a Yearly Cycle in Magadino.** ATHANASIA VLACHOU, Kaspar Rudolf Daellenbach, Carlo Bozzetti, Francesco Canonaco, Gary Salazar, Konstantinos Agrios, Soenke Szidat, Urs Baltensperger, Imad El Haddad, Andre Prévôt, *Paul Scherrer Institute*

Carbonaceous aerosols, which can be categorized as primary and secondary, are emitted or formed via fossil and non-fossil sources. The use of filter sample measurements with the Aerodyne aerosol mass spectrometer (offline-AMS) and the application of positive matrix factorization have significantly improved our capability to identify these sources and quantify their contributions. Such technique not only offers spatial and temporal broadening of organic aerosol (OA) measurements, but also allows for measurements of different aerodynamic sizes (PM<sub>1</sub>, PM<sub>2.5</sub> and PM<sub>10</sub>). It is ideal to identify primary sources such as biomass burning, cooking or traffic and secondary such as oxygenated OA. Meanwhile, radiocarbon (<sup>14</sup>C) analysis provides an unequivocal distinction between fossil and non-fossil sources. The coupling of the two analyses provides a more robust source apportionment and a deeper investigation of the secondary OA origins.

Magadino, located in an alpine valley in Switzerland is characterized as a rural background site and suffers from high carbonaceous aerosol concentrations during winter which mainly stem from residential wood burning. Although previous studies have mostly focused on winter events, little is known about the seasonality of the pollutants and the influence of different sources thereon. Here we present offline AMS measurements coupled with <sup>14</sup>C analysis for one yearly cycle in Magadino. The results show the quantified contributions of the dominant factors: biomass burning in winter and oxygenated OA during summer, as well as the seasonal patterns of fossil and non-fossil primary and secondary organic carbon. Traffic and cooking showed a rather constant annual behavior. The source apportionment on size segregated OA (PM<sub>10</sub> and PM<sub>2.5</sub>) was crucial for the identification of a primary biological factor during summer.

## 9CC.1

**Measured and Modelled Cloud Droplet Activation of Aerosol Particles at the High-Alpine Research Station Jungfraujoch.** MARTIN GYSEL, Christopher R. Hoyle, Clare S. Webster, Harald E. Rieder, Athanasios Nenes, Emanuel Hammer, Erik Herrmann, Nicolas Bukowiecki, Ernest Weingartner, Martin Steinbacher, Urs Baltensperger, *Paul Scherrer Institute*

The interaction of aerosol particles with warm clouds has been studied at the high-alpine research station Jungfraujoch in a series of Cloud and Aerosol Characterisation Experiments (CLACE). Here we assess the sensitivity of cloud droplet number concentration (CDNC) to variability of updraft velocity and potential cloud condensation nuclei (CCN) number concentration. The cloud droplet number concentration was inferred from the total (including cloud droplet residuals) and interstitial (only non-activated) particle number size distributions measured in-situ within liquid clouds by means of two specific inlets. No direct measurement of updraft velocity at cloud base is available, however, a comparison of detailed microphysical box-model simulations with the in-situ measurements showed that the updraft can be estimated in reasonable approximation from the surface wind measured at the observation site.

In a first approach we used a regression analysis of the 2399 data points from 4 field campaigns to develop a simple statistical model to predict the CDNC. The number concentration of potential CCN alone is sufficient to explain 79% of the variance of observed CDNC. The model performance can be slightly improved by including additional predictors related to aerosol emissions. Including an explicit dependence on updraft velocity does not improve the correlation, indicating that cloud formation mostly occurs in the CCN-limited regime.

The droplet formation regime was further assessed by applying a state of the art cloud droplet formation parametrization to the aerosol size distribution and updraft data set. Excellent agreement between simulated and measured CDNC with high correlation and almost equal mean values was achieved. Sensitivity analyses using this parametrization confirmed that cloud formation at the Jungfraujoch with considerable orographic forcing mostly occurs in the CCN limited regime, i.e. CDNC is approximately linearly dependent on available CCN, while variations of updraft only become limiting for small updraft  $< \sim 1$  m/s.

## 9CC.2

**How Do Secondary Organic Aerosols Influence Cloud Condensation Nuclei? Insights from a Global Model Employing Detailed Aerosol Microphysics.** Peter Adams, MARGUERITE COLASURDO MARKS, *Carnegie Mellon University*

Atmospheric aerosols influence global climate by serving as cloud condensation nuclei (CCN), and the complexities of aerosol-cloud interactions dominate the forcing uncertainty in current climate models. Organic aerosol (OA) species play an important role in the CCN budget, as they are ubiquitous in the atmosphere and help drive condensational growth of particles to climate-relevant sizes. Not only does condensation of organics onto a particle increase its mass (and thus its survival probability), though: OA can contribute solute to particles, increasing the likelihood of activation into CCN; and the presence of surface-active organic compounds may decrease particle surface tension enough to significantly increase cloud droplet formation. Understanding the relative magnitude of these effects is necessary to focus further studies on the most important aspects of OA.

The goal of this modeling study is to examine the sensitivity of CCN levels to organic-aerosol-mediated influences. We simulate 2009 using the global chemical transport model GEOS-Chem with TOMAS aerosol microphysics using kappa-Kohler theory. We evaluate CCN sensitivity to: OA budgets, organic hygroscopicity, and condensation and coagulation parameterizations. The influence of surface-active species and the "salting-out" effect are also discussed.

We find that for a range of plausible assumptions regarding emissions and mechanisms, ultrafine growth (rather than primary emissions) dominates CCN production. The largest influence on CCN is the overall secondary organic aerosol (SOA) budget. Results suggest that a moderate portion of the influence of SOA is simply due to condensing mass increasing particles' survival probability -- that is, CCN levels are sensitive to the amount, but not necessarily the type of SOA. We hope that, by identifying the model processes to which CCN are most sensitive, our results will help determine the most promising directions for future research in this area.

## 9CC.3

**Modeling the Relative Contributions of Secondary Ice Formation Processes to Ice Crystal Number Concentrations within Mixed-Phase Clouds.** Sylvia Sullivan, Corinna Hoose, ATHANASIOS NENES, *Georgia Institute of Technology*

In-cloud measurements of ice crystal number concentration can be three or four orders of magnitude higher than the in-cloud ice nuclei concentration. A number of secondary ice formation processes after initial nucleation have been proposed, but the relative importance and even the exact mechanisms of these processes are still unknown. In this work, a multiple-bin parcel model is constructed to estimate possible ice enhancement, both its bounds and its value for different cloud types, due to rime-splintering and break-up upon graupel-graupel collision. The model also includes ice aggregation and droplet coalescence, ice hydrometeor non-sphericity as in Jensen and Harrington, 2015, and a time delay formulation as in Yano and Phillips, 2011. The maximum contribution from break-up, the computational cost of non-sphericity, and the effect of varying time delays are discussed. Finally, the model behavior under various limits and simplifications is considered.

## 9CC.4

**The First Global Picture of Observation-Based Estimate on Continental Boundary Layer New Particle Formation.** TUOMO NIEMINEN, Veli-Matti Kerminen, Tuukka Petäjä, Markku Kulmala, *University of Eastern Finland*

Formation of secondary aerosol particles is a major source of atmospheric aerosols. Regional events of new particle formation (NPF) have been observed worldwide, but reports of the seasonality of the NPF related parameters are rather scarce.

We present a global picture on the relevance of NPF. We gathered observations of the annual cycle of NPF events from sites with at least one year of particle size distribution measurements available. The data of sub-micron aerosol number size distribution is analyzed to reveal the characteristic features (event frequencies, particle formation rates and growth rates) of the NPF events at different sites. A common size range of 10–25 nm was used for nucleation mode particles. Altogether we identified 35 measurement sites worldwide where aerosol size distributions have been measured for at least one year. These sites range from arctic and remote areas to heavily polluted megacities.

Regional NPF events were observed at all the sites throughout the year. Globally averaged NPF frequencies range from 12% of days during December-February to 31% of days in March-May. The smallest NPF frequencies occurred in polar areas (NPF occurring in less than 20% of days), and the highest in the African savannah area (over 60% of days).

The particle formation rates did not, on average, show large seasonal variation, but there exist large differences between different environments. The highest formation rates occur inside cities and other anthropogenically heavily influenced areas. In these areas the SO<sub>2</sub> concentrations are typically high leading to high concentrations of sulphuric acid, which is one of the key precursor species in atmospheric NPF. On the other hand, the highest particle growth rates do not occur in these same areas of high formation rates, pointing to the decoupling of the mechanisms leading to the initial particle formation and the later growth of the particles.

**9CC.5**

**Aerosol, Cloud, and Precipitation Responses to Northern Hemisphere Aerosol Emissions Reductions in Three Climate Models.** DANIEL WESTERVELT, Arlene Fiore, Gustavo Correa, Andrew Conley, Jean-François Lamarque, Drew Shindell, *Columbia University Lamont-Doherty Earth Observatory*

It is widely expected that global and regional emissions of atmospheric aerosols and their precursors will decrease strongly throughout the remainder of the 21st century, due to emission reduction policies enacted to protect human health. Reductions in emissions of black carbon aerosols (and other short-lived climate pollutants) have been discussed recently as a potential option for near-term climate mitigation. Although there is some evidence that regional climate effects of aerosols can be significant, we currently lack a full understanding of the magnitude, spatial and temporal pattern, and statistical significance of these influences, especially in clouds and precipitation. Further, we often lack robust understanding of the processes responsible for these influences of regional aerosols on local and remote climate. Here, we aim to quantify systematically the cloud and precipitation response to regional changes in aerosols through model simulations using three fully coupled chemistry-climate models: NOAA Geophysical Fluid Dynamics Laboratory Coupled Model 3 (GFDL CM3), NCAR Community Earth System Model (CESM), and NASA Goddard Institute for Space Studies ModelE2 (GISS-E2). The central approach we use is to contrast a long control experiment (400 years) with a collection of long individual perturbation experiments (~200 years). We perturb emissions of sulfur dioxide (precursor to sulfate aerosol) and carbonaceous aerosol (BC and OM) within several world regions and assess which responses are significant relative to internal variability and robust across the three models. Initial results show consistent decreases in cloud droplet number, cloud effective radius, and liquid water path across the three models due to decreases in aerosols. Aerosols impact tropical precipitation strongly in each of the models, although there is less commonality among the three modeled responses. Despite prior work indicating a robust northward ITCZ shift in response to reduced future aerosol forcing, we find that only one of the models simulates a clear northward shift in the ITCZ due to the warming induced by U.S, European, or Chinese aerosol reductions. Our approach enables us to develop a basis for understanding the regional and global climate changes to regional aerosols.

**9EC.1**

**Temporal and Spatial Variations of Ultrafine Particles and PM<sub>2.5</sub> of Secondhand Electronic Cigarette Aerosols.** Tongke Zhao, Che-Husan (Sherry) Lin, Qiuju Guo, YIFANG ZHU, *University of California Los Angeles*

Electronic cigarettes (ECs), as an increasingly popular alternative to tobacco cigarettes, are a new source of indoor airborne particles. Although there is no sidestream of EC, the exhaled EC aerosols are recognized as secondhand EC aerosols. However, there were limited studies that characterized these particles. To study the characteristics of secondhand EC aerosols, real-time measurements of particle size distribution, particle number concentration (PNC), PM<sub>2.5</sub>, CO<sub>2</sub>, CO, and formaldehyde concentrations were conducted before, during, and after EC-use among 29 volunteers in an 80-m<sup>3</sup> room. To assess the transport of particles, two sampling locations were set up at 0.8 and 1.5 m away from the volunteers, respectively. Results showed that the average PNC and PM<sub>2.5</sub> mass concentrations during puffing were 2.14e4 and 52.6 µg/m<sup>3</sup> at the 0.8 m location. Owing to fast evaporation, the measured concentration of secondhand EC particles negatively correlated with the distances to EC users. The average PNC and PM<sub>2.5</sub> mass concentrations were 9.55e3 /m<sup>3</sup> and 9.89 µg/m<sup>3</sup> at the 1.5 m location. Both PNC and PM<sub>2.5</sub> measured in this study were either comparable with or less than other indoor emission sources. Two modes of secondhand EC particles were observed at about 19 nm and 95 nm, respectively. Furthermore, experienced EC users produced higher level of secondhand EC particles than naïve users. This study can be used for secondhand EC particle exposure assessment in indoor environments.

**9EC.2**

**What Factors Influence Electronic Cigarette Nicotine Yield and Delivery?** THOMAS EISSENBERG, *Virginia Commonwealth University*

Electronic cigarettes (ECIGs) are a class of products that use a heating element to aerosolize for user inhalation a solution made of solvents like propylene glycol and/or vegetable glycerin, flavorants, and, usually, the stimulant drug nicotine. Nicotine yield is the amount (in milligrams) of nicotine contained in the aerosol that is emitted by the device. Nicotine delivery is the concentration (in nanograms/milliliter) of nicotine found in user blood plasma after ECIG use. Nicotine yield and delivery are influenced by a variety of factors including device power (battery voltage, heater resistance), liquid nicotine concentration, and user behavior. Data demonstrating the influence of these factors on ECIG nicotine yield and delivery will be presented. In addition, the presentation will include a discussion of the variability of nicotine delivery profiles of ECIG products on the US market, some of which deliver very little nicotine while others exceed the nicotine delivery profile of a tobacco cigarette under similar use conditions. These data are relevant to public health today, given the dramatic rise of ECIG use, particularly in populations where nicotine administration may have long-term adverse health outcomes (e.g., adolescents).

**9EC.3**

**Electronic Cigarette Aerosol Characteristics as a Function of User Preferences.** JONATHAN THORNBURG, Seung-Hyun Cho, *RTI International*

Use of electronic cigarettes is increasing globally. Despite their growing prevalence, little is known about the physical and chemical properties of e-cigarette emissions inhaled by the user. This research is investigating the role of device settings, e-liquid properties (nicotine content, flavorings) and user topography on a users' inhalation exposure. These variables differ as a function of user age, gender, and experience. Therefore, the generated aerosol properties and potential toxicity could differ across users.

We produced physiologically relevant e-cigarette aerosol using an e-cigarette smoking machine connected to a simplified, simulated lung. The smoking machine enables tight control over device settings and topography parameters determined from surveys of current users collected as part of this research. The simulated lung mimics the humid environment of the human respiratory system. The size distribution from 10 to 10,000 nanometers and chemical composition of mainstream aerosols are being measured.

The aerosol size distribution produced by two liquids under the control (dry) and test (humid) conditions studied to date are different. The elevated humidity and residence time inside the simulated lung activates the growth of condensation nuclei. The resulting aerosol size distribution inside the simulated lung has a smaller median diameter (184 nm versus 220 nm) but had a broader range (GSD of 3.4 versus 2.8). The aerosol chemical composition changes under humid conditions because the humectants promote absorption of nicotine, flavorings, and preservatives. Nicotine and propylene glycol are the only compounds found in both gas and aerosol phases. The influence of e-cigarette heating element voltage and temperature, puff duration, puff frequency and additional e-liquids on aerosol properties are currently being evaluated.

This research will identify how user demographics and preferences influence the aerosol properties produced by e-cigarettes. Any changes in the aerosol size distribution or chemical composition could influence the design of inhalation toxicology studies.

**9EC.4****Computational Analysis of Inhaled Aerosol Deposition from E-Cigarettes for the Assessment of Potential Health Effects.**

YU FENG, Kwai L. Wong, Clement Kleinstreuer, *Oklahoma State University*

Electronic Cigarettes (ECs) are tobacco-free nicotine-delivery devices which are gaining increasing popularity, especially among teenagers and young adults. ECs are manufactured in a large variety of designs with widely varying nicotine concentrations, added flavors and glycerol, as well as propylene glycol (PG) to imitate smoke. A typical EC-droplet contains 15% water, 49% glycerol, 33% PG, 2% nicotine and various flavors. The inhaled droplets have an initial-diameter range of 260nm to 3200nm. The addictive nicotine may pose adverse health effects, especially at elevated amounts, while PG is a lung irritant and some flavor-chemicals may be toxic. Worse, EC-devices with high-voltage batteries powering the heating element generate instantaneously not only very strong nicotine vapor but possibly also formaldehyde and other toxins.

Although flavors in EC-smoke are safe for ingestion, they are not guaranteed to be safe for inhalation. For example, aldehydes (e.g., benzaldehyde and vanillin) were found in a significant number of flavors which are primary irritants of mucosal tissue of the respiratory tract. Also, metallic nanoparticles have been detected in EC-smoke, e.g., aluminum, copper, magnesium, zinc, lead, and/or nickel.

Thus, it is important to numerically simulate the fate of inhaled vapor-droplet EC-aerosols, using whole lung models, to assist toxicologists as well as regulators to evaluate possible health-impacts of EC-aerosols. As a first step, we analyzed the transport, phase-change and deposition of inhaled multi-component droplet-vapor mixtures in an idealized human upper airway model (Feng et al., *JAS*; 96: 2016). The results indicate that liquid-vapor phase change induces hygroscopic growth of droplets, which in turn impacts significantly the deposition concentrations of aerosols as well as the vapor-specific absorption rates. Presently, extensive parametric sensitivity analyses are being performed at JICS (UT Knoxville, TN) to evaluate with a subject-specific airway model the influence of different inhalation conditions on EC-aerosol transport, interaction, and deposition.

**9EC.5****The Application of Real-Time Monitoring Techniques to Estimate the Inhaled Dose of Volatile and Semivolatile Organic Toxicants from Vaping e-Cigarettes.**

MARIELLE BRINKMAN, Sydney Gordon, Stephanie S. Buehler, Samera Hamad, Courtney A. Granville, *Battelle Public Health Center for Tobacco Research*

Although machine smoking using an established puffing regimen can provide information on the identity of toxic emissions, measuring human toxicant exposures from the use of electronic cigarettes requires the incorporation of actual human vaping behaviors. We are applying human puff topography and real-time and batch sample mass spectrometry-based techniques to characterize harmful and potentially harmful constituent (HPHC) exposures from vaping e-cigarettes. The real-time techniques used in our laboratory for the analysis of mainstream smoke and exhaled breath are proton transfer reaction-mass spectrometry (PTR-MS) for continuous puff-by-puff characterization of selected volatile HPHCs, and an electrical low pressure impactor for the characterization and collection of fine and ultrafine particles. The collected particulate allows us to use batch sample mass spectrometry techniques to characterize the semi-volatile HPHCs that deposit in the body as a function of particle size. Real-time techniques offer the advantage of immediate analysis of dynamically changing e-cigarette emissions in order to more closely approximate user's real-world HPHC exposures, and the ability to make measurements in exhaled breath over time to determine rates of volatile HPHC clearance from the body. Batch sample mass spectrometry-based techniques, including two-dimensional gas chromatography-time-of-flight mass spectrometry (GC×GC-TOFMS), allow us to discover new chemical emissions in addition to detect part-per-trillion levels of established HPHCs. Taken as a whole, these techniques can be used to generate some of the evidence needed to determine where a given tobacco product lies on the continuum of harm in the delivery of toxicants to the user. Such techniques can also be applied to determine the effect of variation in an e-cigarette product's operating parameters and e-liquid content on human exposures.

**9NS.1**

**Effects of Atmospheric Conditions on the Composition of Secondary Organic Aerosol Formed from the Oxidation of Isoprene and Monoterpenes.** MEGAN CLAFLIN, Paul Ziemann, *University of Colorado*

Motivated by the Southern Oxidant and Aerosol Study (SOAS) field campaign of 2013, a series of environmental chamber experiments have been conducted to study the effect of environmental conditions (VOC, oxidant, NO<sub>x</sub>, RH, particle acidity) on the composition of secondary organic aerosol (SOA) formed from the oxidation of the major volatile organic compounds (VOCs) present during the field campaign. Isoprene and selected monoterpenes were reacted with OH radicals, NO<sub>3</sub> radicals, and O<sub>3</sub> under conditions that mimic those observed during SOAS, and the composition of the SOA formed was characterized using derivatization-spectrophotometric methods and FTIR to quantify carbonyl, carboxyl, hydroxyl, ester, peroxide, and nitrate groups in the aerosol sample. In tandem with derivatization methods, further molecular analysis was conducted on select systems using real-time and off-line mass spectrometry along with liquid and gas chromatography. Through a collaboration with the Russell group at SIO-UCSD, our groups will compare the composition of the chamber aerosol with field samples collected during the SOAS campaign in an attempt to identify the VOCs and chemistry responsible for SOA formation in the southeast US.

**9NS.2**

**Determinants of Isoprene SOA Yields from Recent Comprehensive Chamber Studies.** KELVIN BATES, Rebecca Schwantes, Tran Nguyen, Richard Flagan, John Seinfeld, *California Institute of Technology*

In light of recent field studies showing the prevalence of isoprene-derived secondary organic aerosol (SOA) in the atmosphere, along with new laboratory research elucidating the specific mechanisms by which isoprene oxidation can lead to SOA formation, we have undertaken a series of isoprene oxidation experiments in the Caltech Environmental Chamber to determine the dependence of isoprene SOA yields on a number of atmospherically relevant factors. By systematically adjusting such experimental conditions as [NO], [NO<sub>2</sub>], temperature, seed particle surface area and salt composition, relative humidity, and particle acidity, we are able to distinguish the individual contributions of each of these variables to changes in isoprene SOA yields. We characterize both the gas and particle phases of our chamber experiments with a suite of instruments, including a differential mobility analyzer, an aerosol mass spectrometer, and a CF<sub>3</sub>O- chemical ionization mass spectrometer. Additionally, we compare our results both to previously reported isoprene SOA yields and to simulated isoprene SOA formation using a newly developed model that incorporates detailed recent updates to the gas-phase oxidation mechanism of isoprene.

## 9NS.3

**Measurements and Modeling of Isoprene Photooxidation Products: The Role of Oligomeric Material and Particle Phase Reactions.** EMMA D'AMBRO, Felipe Lopez-Hilfiker, Claudia Mohr, Cassandra Gaston, Ben Lee, Jiumeng Liu, John Shilling, Rahul Zaveri, Avram Gold, Zhenfa Zhang, Jason Surratt, Joel A. Thornton, *University of Washington*

Isoprene is the predominant non-methane volatile organic compound emitted globally with the potential to produce large quantities of secondary organic aerosol (SOA) affecting climate, air quality, and human health. However, the mechanisms controlling isoprene SOA formation remain uncertain. We present novel measurements and modeling of isoprene SOA formation observed in environmental simulation chambers using dry neutral seed particles, thereby suppressing IEPOX multiphase chemistry, at a variety of atmospherically relevant conditions. A high resolution time of flight chemical ionization mass spectrometer utilizing iodide adduct ionization coupled to the Filter Inlet for Gas and AEROSol (FIGAERO) allowed for the simultaneous online sampling of the gas and particle composition. Under high HO<sub>2</sub> and low NO conditions, SOA yields reached > 10% and dihydroxy dihydroperoxides and related products were major components (~50%). A similarly large fraction of SOA was also detected as smaller compounds that desorbed at unexpectedly high temperatures, indicative of thermal decomposition of lower volatility components, likely larger molecular weight oligomers. A detailed chemical box model based on the University of Leeds Master Chemical Mechanism, with several custom updates and an online Raoult's law gas-particle partitioning module accurately reproduces the time evolution and approximate quantity of SOA, as well as a dominant role for dihydroxy dihydroperoxides, in both our chamber experiments and those conducted in other chambers. However, the predicted SOA composition and evaporation kinetics do not adequately reflect the measurements. These findings, together with observed composition evolution over time, strongly suggest efficient particle phase organic chemistry, in the absence of aqueous-phase acidity, leads to oligomeric material which accounts for ~50% of the SOA mass formed after 3-5 hours. We use these insights and observations of the same SOA components made during the SOAS field campaign to assess the importance of isoprene photo-oxidation as a local SOA source.

## 9NS.4

**Effect of Atmospherically-Relevant Organic Coatings, Humidity, and Aerosol Acidity on Multiphase Chemistry of Isoprene Epoxydiols.** ALLA ZELENYUK, Matthieu Riva, David Bell, Anne Maria Hansen, Greg Drozd, Zhenfa Zhang, Avram Gold, Dan Imre, Jason Surratt, Marianne Glasius, *Pacific Northwest National Laboratory*

Multiphase chemistry of isomeric isoprene epoxydiols (IEPOX) has been shown to be the dominant source of isoprene-derived secondary organic aerosol (SOA). Recent studies have reported particles composed of ammonium bisulfate (ABS) mixed with model organics exhibit slower rates of IEPOX uptake compared to pure ABS particles. We will present the results of a study, in which we investigated, for the first time, the effect of atmospherically-relevant organic coatings of  $\alpha$ -pinene SOA on the reactive uptake of trans-beta-IEPOX onto ABS particles under different conditions and coating thicknesses. Single particle mass spectrometry was used to characterize in real-time particle size, shape, density, and quantitative composition before and after reaction with IEPOX. We demonstrate that IEPOX uptake by pure ABS and deliquesced ammonium sulfate particles is a volume-controlled process, which results in particles with uniform concentration of IEPOX-derived SOA across a wide range of sizes. Aerosol acidity was shown to enhance IEPOX-derived SOA formation, consistent with recent studies. We find that the weight fraction of IEPOX-derived SOA for ABS particles is 41% as compared to 31% for ammonium sulfate particles. The presence of water has a weaker impact on IEPOX-derived SOA yield for ABS particles, but significantly enhanced formation of 2-methyltetrols, consistent with offline filter analysis. In contrast, we show that presence of  $\alpha$ -pinene SOA coatings greatly impact IEPOX heterogeneous chemistry. IEPOX uptake by ABS particles coated with  $\alpha$ -pinene SOA is lower compared to that of pure ABS particles, and strongly dependent on particle composition, and therefore on particle size. For example, in the experiment with thinly (~18 nm) coated ABS particles, the weight fraction of IEPOX-derived SOA increases rapidly from 0 to 30% with respect to ABS seed, as the seed aerosol diameter increases from 60 to 100 nm, and then remains nearly constant at ~30% for diameters > 100 nm.

## 9NS.5

**Implications of Anthropogenic-Biogenic Interactions Related to NO<sub>x</sub> and Sulfate on SOA Formation.**

MANISHKUMAR SHRIVASTAVA, John Shilling, Jerome Fast, Joseph Ching, Rahul Zaveri, Richard Easter, Alla Zelenyuk, Chun Zhao, Ying Liu, Joel Brito, Larry Berg, Shantanu Jathar, V. Faye McNeill, Joel A. Thornton, Henrique Barbosa, Helber Gomes, Rita Ynoue, Paulo Artaxo, Suzane de Sá, Alex Guenther, Lindsay Yee, Scot Martin, Allen H. Goldstein, Gabriel Isaacman-VanWertz, et al., *Pacific Northwest National Laboratory*

Latest laboratory and field measurements have identified several pathways by which anthropogenic emissions influence the formation and evolution of secondary organic aerosols (SOA) in the atmosphere. In this study, we perform coupled chemistry-cloud-meteorology simulations using the Weather Research and Forecasting model (WRF-Chem). We explore new chemical pathways for SOA formation that are affected by the mixing of anthropogenic emissions such as sulfate and nitrogen oxides (NO<sub>x</sub>) with the regional background dominated by biogenic volatile organic compound (VOC) emissions. These new pathways are based on some of the latest measurements such as influence of a new low NO<sub>x</sub> particle-phase isoprene oxidation product on SOA formation, multiphase chemistry of isoprene epoxydiols (IEPOX) affected by sulfate and nitric oxide (NO), and the impacts of relative reaction rates of peroxy-peroxy and peroxy-NO radicals on SOA formation yields. We also investigate the implications of low SOA volatility due to particle-phase processes such as oligomerization on simulated SOA loadings. We evaluate model predictions using the ground- and aircraft-based measurements of gas and particle-phase chemical composition collected during 2 different field campaigns: GoAmazon2014/5 in Manaus, Brazil and CARES 2010 in Sacramento, CA. Preliminary simulations using WRF-Chem show the urban plume mixing with the regional background, and the simulated SOA is dominated by biogenic VOCs during both field campaigns. We find that oxidants (such as hydroxyl (OH) radicals and ozone (O<sub>3</sub>)) and SOA formation are both enhanced in areas where the urban plume mixes with the regional background. Sensitivity simulations that turn the urban emissions on/off are performed to quantify the impacts of anthropogenic-biogenic interactions on SOA formation. This study provides insights about what processes could be most important for simulating SOA in two different regions characterized by different NO<sub>x</sub> regimes: the low NO<sub>x</sub> regime in the Amazon and the high NO<sub>x</sub> regime in an urban city.

## 9SP.1

**Optical Levitation of a Nanodiamond and Its Applications in Sensing.** Thai Hoang, Jonghoon Ahn, Jaehoon Bang, TONGCANG LI, *Purdue University*

An optically levitated aerosol nanoparticle can be characterized with great details in-situ and provides a powerful tool for probing local environment. Meanwhile, electron spins of diamond nitrogen-vacancy (NV) centers are important quantum resources for nanoscale sensing and quantum information. Here we optically levitate a nanodiamond and demonstrate electron spin control of its built-in NV centers in different gases and in low vacuum. We demonstrate that NV spins in a levitated nanodiamond can be used to measure the local temperature and magnetic field. We also observe that oxygen and helium gases have different effects on both the photoluminescence and the contrast of the electron spin resonance of nanodiamond NV centers, indicating potential applications of nanodiamonds in oxygen gas sensing. Our results also pave the way towards a novel levitated spin-optomechanical system for studying macroscopic quantum mechanics.

## 9SP.2

**Light Pushing or Pulling of Absorbing Airborne Particles.**

CHUJI WANG, Zhiyong Gong, Yong-Le Pan, Gordon Videen, *Mississippi State University*

Optical manipulation of microscopic objects using light is an emerging tool used in diverse research fields such as physics, chemistry, biology, materials. Research related to optical manipulation using optical forces ranges from the early demonstration of particle levitation and trapping in different media such as solution or air to the recent breakthrough in controlled optical manipulation. Of those significant theoretical or experimental studies in controllable optical manipulation of small particles using light, the fundamental light-particle interaction phenomenon, light can push or pull a small particle, has been demonstrated using transparent spherical particles, transparent nonspherical particles, and absorbing spherical particles (all except absorbing nonspherical particles). Whether it is a general fundamental light-particle interaction phenomenon for arbitrary particles lies in a theoretical or experimental breakthrough in controlled optical manipulation for the last yet unexplored category—absorbing nonspherical particles. However, to the best of our knowledge, this challenge has been addressed neither theoretically nor experimentally.

Here we report our experimental observation that light can push or pull small absorbing non-spherical particles, too. A single absorbing particle formed by carbon nanotubes in the size range of 10-50  $\mu\text{m}$  is trapped in air by a laser trapping beam and concurrently illuminated by another laser manipulating beam. When the trapping beam is terminated, the motion of the particle is controlled by the manipulating beam. Both pushing and pulling motions are observed. Additionally, the movement direction has little relationship to the particle size and manipulating beam's parameters but is dominated by the particle's orientation and morphology. With this observation, the controllable optical manipulation is now able to be generalized to arbitrary particles regardless of being transparent spherical, transparent non-spherical, absorbing spherical, or absorbing non-spherical that is shown in this work. Our observation would motivate future theoretical work to be extended for arbitrary particles. By then our understanding of optical forces would be unified.

## 9SP.3

**Optical Pulling of Single Aerosol Particles over a Meter-Long Distance Using a Single Laser Beam.**

Adam Hart, Joshua Mangum, YONG-QING LI, *East Carolina University, Department of Physics*

Capture and transportation of small objects in air using lasers are attractive for the collection and analysis of single aerosol particles and biological aerosols. Optical pulling is the attraction of objects back to the light source by the use of optically induced “negative forces”. It is commonly expected that when illuminated by a light beam, an object will be accelerated along the light propagation direction by radiation pressure. The idea of using laser beams to attract objects back to the light source is counterintuitive and has long been attractive to scientists. Here, we demonstrate the first experiment that micron-sized absorbing aerosol particles can be optically pulled and manipulated over a meter-scale distance with a collimated laser beam based on negative photophoretic force. The laser-induced negative photophoretic force is generated by the momentum transfer between the heating particles and surrounding gas molecules and can be several orders of magnitude larger than the radiation force and gravitation force. This force can force the aerosol particles moving against the laser propagation direction. We found that micron-sized particles are pulled towards the light source at a constant speed of 1-10 cm/s in the optical pulling pipeline while undergoing transverse rotation at 0.2-10 kHz. The moving speed of individual particles can be controlled by changing the laser intensity. A variety of micro-sized particles including carbon nano-clusters, smut biological cells, iron filings and copper oxide powders can be pulled by this optical pipeline to the region where they are optically trapped and their chemical compositions are characterized with Raman spectroscopy. Optical pulling over large distances with lasers in combination with Raman spectroscopy opens up potential applications for the collection and analysis of single aerosol particles in low-pressure environments.

## 9SP.4

**Light Scattering Retrievals Using Agglomerated Debris Particles.** GORDEN VIDEEN, Evgenij Zubko, Yuriy Shkuratov, Alex Yuffa, *US Army Research Lab*

Model agglomerated debris particles are designed to mimic the morphology of highly irregular dust particles. They have a non-analytical description and their light-scattering properties can be calculated using the discrete dipole approximation. It has been demonstrated that the light-scattering properties of a polydispersion of real dust particles can be replicated by agglomerated debris particles having the same refractive index and size distribution, making it possible to perform accurate inversions of light-scattering data. We demonstrate the use of these particles in making retrievals.

## 9SP.5

**Light Scattering Studies of Single Particle Optically Induced Plasma Explosions.** CHRIS SORENSEN, Jeff Powell, *Kansas State University*

Understanding the ultrafast formation, excitation, and relaxation of dense plasmas generated from single nanoparticles (NPs) under intense light is of fundamental importance. We present initial studies of ultrafast plasma formation and density evolution during plasma expansion of 100 nm SiO<sub>2</sub> NPs. The experiments were performed at SLAC Linac Coherent Light Source (LCLS) in Stanford. The NPs were aerosolized from aqueous suspension, dried and focused with an aerodynamic lens into the target area. An intense, 800 nm, femtosecond pump laser ionized single NPs. The transient structure of the resulting plasma was determined by elastic scattering of a subsequent intense, ultrashort, 1.5 nm, X-ray probe pulse at delay times in the range of 0 to 200 femtoseconds. This allowed for tracing the spatiotemporal plasma density dynamics. Analysis of the scattered "light" involved using Mie scattering theory and Q-space analysis. The plasma structure showed prolate symmetries with fuzzy boundaries that evolved over femtosecond time scales.

**10BA.1****Collection of Airborne Influenza Virus in a Student Health Care Center through Water-Based Condensation Growth.**

MAOHUA PAN, Julia Loeb, Tania Bonny, Xiao Jiang, John Lednicky, Arantzazu Eiguren Fernandez, Susanne Hering, Hugh Fan, Chang-Yu Wu, *University of Florida*

Transmission of influenza virus between humans mainly occurs through three routes: direct or indirect contact, large droplet spray, and aerosol. The relative importance of the aerosol route remains contentious since there is limited direct evidence of infection mediated by virus-containing aerosols. One of the reasons for this lack of evidence is the challenge in collecting aerosols of infectious influenza viruses.

In this study, ambient virus aerosol particles were collected by a newly developed Viable Virus Aerosol Sampler (VIVAS) and by an SKC BioSampler at a student health center during the 2015-2016 flu season. The VIVAS works by particle size-amplification through water vapor condensation and gentle deposition of the enlarged particles onto liquid collection media. In contrast, the BioSampler is an impinger that deposits collected aerosols onto collection media in a more aggressive swirling motion. Our prior study with lab-generated influenza H1N1 virus showed much higher efficiency for viable collection with the VIVAS. In the student health center study reported here, both samplers were operated in parallel under the same parameters. Efforts were made to isolate viable human respiratory viruses by inoculation of the collected material onto a variety of indicator cells lines. Whereas viable viruses were collected by both air samplers, virus-induced cytopathic effects were observed first in cells inoculated with material collected using the VIVAS, suggesting a higher concentration of viable viruses therein compared to material collected using the BioSampler. Influenza A and B and other respiratory viruses were isolated. After genomic sequencing to confirm identities, quantitative PCR and RT-PCR tests were performed. The collection efficiency for all viruses was higher using the VIVAS than using the BioSampler. All these suggest that the VIVAS is a promising device for effective sampling of viable influenza virus in healthcare facilities.

**10BA.2****Aerosolization of Ebola Virus Surrogates in Wastewater Systems.**

KAISEN LIN, Mari Lee, Amy Pruden, Linsey Marr,

*Virginia Tech*

Patients with Ebola virus disease may produce copious amounts of diarrhea that contains large numbers of virions. As flush toilets and sanitary sewer systems are known to produce aerosols, it is possible that Ebola virus could be aerosolized during the routine use and maintenance of wastewater systems, creating a risk for inhalation exposure to hospital and sewer workers. We evaluated the potential for aerosolization of viruses in three wastewater systems: flush toilets, a lab-scale aeration basin, and a lab-scale sewer model of converging pipes with a manhole. The model wastewater, consisting of activated sludge or anaerobically-digested sludge, was spiked with bacteriophages MS2 and Phi6 as Ebola virus surrogates. We measured the aerosol size distribution using a scanning mobility particle sizer and an aerodynamic particle sizer, collected aerosols on filters, and quantified both viable and total airborne bacteriophage concentrations as well as their emission rates. While the toilet did not generate any airborne viable MS2, the lab-scale aeration basin produced airborne MS2 concentrations of 3,900-8,300 plaque forming units per liter. From these measurements, we determined emission rates that can be used to predict inhalation exposure in a variety of scenarios. The risk of inhalation exposure to Ebola virus is expected to be low, but because it is a "high-consequence" pathogen, practitioners should consider respiratory protection when working in wastewater environments where Ebola virus may be present.

**10BA.3**

**Laboratory Scale Pig Buildings: A Controlled Environment to Develop Reduction Strategies for Airborne Contaminants.** JONATHAN PILOTE, Valérie Létourneau, Ariane Lévesque, Matthieu Girard, Stéphane Godbout, Stéphane.P Lemay, Caroline Duchaine, *CRIUCPQ, Université Laval*

Pig buildings produce and emit a large amount of airborne contaminants in the environment. Odours, gas, dust, and airborne microbes have already been blamed for the emergence of infectious, toxic, and inflammatory-based diseases diagnosed among exposed humans and animals. Eight laboratory scale pig buildings are used to test the efficiency of three distinct technologies aiming to reduce airborne contaminants in these working environments. New technologies such as vegetal oil spraying, separation of the liquid from the solid phase in manure using a v-shaped gutter and scrapper as well as an air treatment unit (ATU) are explored. In this experimental setup, pigs are used as a natural and continuous source of aerosols, odours and gases. Four experimental replicates are realised in order to investigate all possible combinations of these technologies. Each replicate is spread through seven weeks during which methane (CH<sub>4</sub>), carbon dioxide (CO<sub>2</sub>), nitrous oxide (N<sub>2</sub>O), ammonia (NH<sub>3</sub>) and the environmental conditions are monitored. Three times during each 7-week experiment, airborne dust and endotoxins, and bioaerosols are isokinetically sampled from the exhaust air of each chamber and downstream each air treatment unit. The airborne particles PM<sub>2.5</sub> and PM<sub>10</sub> are also monitored in real-time during the sampling of biological contaminants. Although biological, gas, and odour analysis are still to be completed, preliminary results show that airborne particle concentrations are reduced by the air treatment units even if ATUs are by themselves a constant source of particles. Vegetal oil spraying is as well effective at reducing airborne particles. In fact, few particles are detected in the exhaust air of chambers if oil is applied. This study confirms the usefulness and validity of the laboratory scale pig buildings for the study of bioaerosol emission control.

**10BA.4**

**Separation and Purification of Bacteria from Similar Size Distribution of Polystyrene Latex Particle.** ALI MOHAMADI NASRABADI, Jang-Seop Han, Milad Massoudi Farid, Sang Gu Lee, Jungho Hwang, *Yonsei University, Department of Mechanical Engineering*

In this study, we introduced a methodology to separate bacterial and non-bacterial aerosols of similar size due to the difference in their electrical mobilities. In this sense, similar sized *Staphylococcus epidermidis* (*S. epidermidis*) and polystyrene latex (PSL) particles were chosen, respectively, as target and non-target particles. By passing these particles through a corona region, *S. epidermidis* and PSL particles gained different electrical charge values. Since the number of charges obtained by aerosol particles depends on their relative permittivity. The relative permittivity for different kinds of bacteria is around 80 while the relative permittivity for PSL particles and dust is around 2.5. For charging the particles, a pin-cylinder type corona charger was used. By putting charged bacteria and PSL at equal electric field, they can be separated in an electric field due to the difference in their electrical mobility. This method can give a fast, simple, and inexpensive solution for increasing the purity, detecting and counting of bacterial agents in air. Recoveries for PSL and *S. epidermidis* particles were 55.7% and 35% and Purities for PSL and *S. epidermidis* were 65.1% and 80.1%. The experimental results of separation revealed the possibility of the real-time separation of between charged bio and none bio particles with having different charge numbers.

**10BA.5**

**Vacuum Ultraviolet Photocatalysis for the Inactivation of Ozone and MS2 Bacteriophage Aerosols on Palladium Deposited TiO<sub>2</sub> Catalyst.** JEONGHYUN KIM, Jaesung Jang, *Ulsan National Institute of Science and Technology, Korea*

Increasing concerns about airborne pathogens such as Middle East respiratory syndrome coronavirus and swine influenza virus have attracted public attention to clean indoor environment and spurred the development of air purification techniques for the removal of gaseous and biological pollutants. Recently, 185 nm vacuum ultraviolet (VUV) photocatalysis has attracted much attention in the purification of gaseous pollutants because the high-energy photon, although residual ozone is generated by dissociation of oxygen. In this study, we have synthesized titanium dioxide (TiO<sub>2</sub>) and palladium deposited titanium dioxide (Pd/TiO<sub>2</sub>) with four kinds of catalyst shapes (i.e., 2 mm and 5 mm pleated type, screw and flat sheet type) and investigated their effects on simultaneous inactivation of airborne MS2 bacteriophages and ozone under VUV irradiation. In addition, to investigate the role of 185 nm VUV light on MS2 bacteriophage inactivation, the comparative experiment, i.e., O<sub>3</sub>+UV (254 nm) was also conducted. Palladium nanoparticles (Pd NPs) were deposited on TiO<sub>2</sub> sheet via a low-temperature electrostatic self-assembly method. A VUV lamp, i.e. ozone-producing low pressure mercury lamp with  $\lambda$  max at 254 nm and a minor emission (ca. 5%) at 185 nm, was perpendicularly placed in the center of the reactor. The aerosol particles produced by each photoreaction were collected using an SKC BioSampler and particle size distribution was determined using a scanning mobility particle sizer. 2 mm pleated Pd-TiO<sub>2</sub> catalyst exhibited the highest activity for both MS2 bacteriophage and ozone inactivation because of the large catalyst area and well dispersed Pd NPs. This may be because the deposited Pd NPs promotes a photocatalytic reaction by acting as mediators for the charge transfer between Pd NPs and TiO<sub>2</sub>, and improves the generation of reactive species such as hydroxyl radicals for inactivation of MS2 bacteriophage.

**10BA.6**

**Tracking the Movement of Microbial Aerosols from Aquatic Systems with High-speed Video.** RENEE PIETSCH, Craig Powers, David Schmale, Sunghwan Jung, Shane Ross, *Virginia Tech*

Aquatic environments contain a great diversity of microorganism, including bacteria. These bacteria are capable of crossing the air-water interface and entering the environments as aerosols. One natural method of aerosol production is wind moving across the surface of a body of water creating droplets that leave the water surface. The droplets are formed by two different mechanisms, either bubble bursting or fragmentation. A laboratory flume was designed to simulate wind moving across the surface of a lake. High speed video was used to capture droplets moving across the air-water interface at four wind speeds (3.5, 4.0, 4.5, and 5.0 m/s). The images were analyzed to determine the diameter as well as initial speed and angle of each droplet as it leaves the water surface. The rate of droplet production increased quadratically with wind speed, while the droplet mass flux decreased slightly before increasing with wind speed. The diameter and speed of the droplets fit gamma distributions. Droplet angle had a narrower distribution at higher wind speeds. The two mechanisms of droplet production (bubble busting and fragmentation) yielded different distributions for diameter, speed, and angle. The capacity for bacterial flux into the atmosphere was calculated based on the droplet production and bacterial concentrations in freshwater systems. The results show significant amounts of bacteria are crossing the air water interface with the potential to be aerosolized. Aerosolized bacteria have the potential to impact the Earth's radiation budget, precipitation processes, and pathogen transport.

**10CA.1**

**Real-time Measurements of PM<sub>2.5</sub>, Black Carbon and Brown Carbon In Residential Woodsmoke Plumes.** BO YANG, Aleshka Carrion-Matta, Geng Chen, Jiajun Gu, George Allen, James Schwab, H. Dirk Felton, K. Max Zhang, *Cornell University*

Due to relatively low stack height and low exhaust temperature, emissions from residential wood burning for heating may cause significant near-source air quality impacts. To enhance our understanding of the impacts, we conducted field measurements of residential woodsmoke plumes in an urban setting using portable real-time instruments and mobile monitoring techniques during the 2015-2016 winter season. The instruments we deployed include a 7-wavelength Aethalometer for black carbon and brown carbon, multiple nephelometers for PM<sub>2.5</sub>, and two CO<sub>2</sub> sensors. The time resolution of each instrument was set to 1 second to capture the dynamical plume behaviors, and raw data were then processed for further analysis. Results from AE33 showed drastically different responses of woodsmoke plumes to different wavelengths, with 370 nm being the most sensitive. Real-time PM<sub>2.5</sub> signals were well synchronized with Aethalometer Delta-C (BC<sub>370</sub> nm - BC<sub>880</sub> nm) values, indicating that most of the PM mass falls into the detection range of the nephelometers, and confirming that Delta-C is a good indicator of woodsmoke particles. The real-time data revealed a wide range of Delta-C/PM<sub>2.5</sub> ratios, but Delta-C and PM<sub>2.5</sub> values exhibited strong correlations when the combustion conditions appeared to be consistent over a period of time. Our results suggest that Delta-C can be potentially used to provide quantitative estimate of levoglucosan, a commonly-used woodsmoke marker. However, further investigations are needed to derive a robust relationship.

**10CA.2**

**Online Analysis of Secondary Organic Aerosol Emissions from a Flexi-Fuel Gasoline Engine Operated with Gasoline-Ethanol Blends.** JORMA JOKINIEMI, Mika Ihalainen, Petri Tiitta, Miika Kortelainen, Martin Sklorz, Benjamin Stengel, Laarnie Müller, Stefan Stanglmaier, Vesta Kohlmeier, Gert Jakobi, Pasi Yli-Pirilä, Anni Hartikainen, Thorsten Streibel, Ralf Zimmermann, Olli Sippula, *University of Eastern Finland, Kuopio, Finland*

Automotive engines generate substantial fine particle emissions to ambient air, which are known to induce globally significant adverse health and climate effects. It has been recently shown that while gasoline engines generate relatively low primary particle emissions, they generate substantial secondary organic aerosol emissions (Tkacik et al., 2014), an emission component which is not currently considered in legislation.

In this work, a recently developed photochemical flow tube reactor (PEAR) was applied to study the photochemical aging of bioethanol and gasoline fueled car engine emissions. The reactor flow dynamics were optimized based on CFD modeling. It is constructed from stainless steel tube (Ø 34 cm) with 254 nm UV lamps assembled at the inner walls. Ozone and water vapor are added into the reactor to produce OH radicals via photolytical decomposition of O<sub>3</sub>. The OH exposure times were estimated by measuring D9-butanol gas decay with PTR-MS during the experiments. Ozone concentration and lamp intensities were varied to achieve different OH exposure times, ranging from 1 to 8 days of atmospheric age.

The engine applied for the experiments was EURO5 AUDI turbo charged flexi-fuel gasoline engine and two different gasoline-ethanol fuel mixes (E5 and E85) were used. Both the New European Driving Cycle (NEDC) and selected steady state conditions were used in the emission study. Particulate emissions were measured using HR-AMS, SMPS and Aethalometer.

Using of E85 bioethanol fuel had both lower primary particle and SOA concentrations than E5 gasoline. Increasing of OH exposures gradually increased aerosol oxidation states and SOA formation, reaching SOA/POA ratios of 4 and 5 at the highest OH exposure (8 days) for E5 and E85, respectively.

Tkacik, D.S., Lambe, A.T., Jathar, S., Li, X., Presto, A.A., Zhao, Y., Blake, D., Meinardi, S., Jayne, J.T., Croteau, P.L., Robinson, A.L. (2014) *Environmental Science & Technology*, 48, 11235-11242.

**10CA.3**

**The Role of Chemical Aging Reactions and the Production of Extremely Low Volatility Organic Compounds on Ultrafine Particle Concentrations over Europe.** David Patoulias, Christos Fountoukis, Jan Julin, Ilona Riipinen, SPYROS PANDIS, *Carnegie Mellon University*

In this work, we continue the development of a three-dimensional chemical transport model, PMCAMx-UF, focusing on the simulation of the ultrafine particle size distribution and composition. The Volatility Basis Set (VBS) approach is used for the simulation of organic aerosol. PMCAMx-UF is applied to Europe to quantify the contribution of organic vapors to total number concentrations and fresh particles' growth. PMCAMx-UF uses the new version of the Dynamic Model for Aerosol Nucleation and the Two-Moment Aerosol Sectional algorithm to track both aerosol number and mass concentration using a sectional approach. We evaluate the model predictions for the European domain against field observations collected in the PEGASOS campaigns during June of 2012 and May-June of 2013. The measurements include both ground stations across Europe and airborne measurements from a Zeppelin airship. Sensitivity tests highlight the importance of chemical aging reactions, the production of extremely low volatility organic compounds (ELVOCs) and the evaporation of primary organic emissions for the ultrafine particle number concentrations. PMCAMx-UF reproduces reasonably well the N10 (number concentration of particles larger than 10 nm) hourly observations both aloft (over the Po Valley in Italy) as well as at the ground level. The ground level concentrations of N100 are well predicted (fractional error of 55% and fractional bias equal to -20%) while there is tendency to overestimate N10 by approximately 40%. The chemical aging reactions and the production of ELVOCs result in increases of the N100 concentration mainly in central and northern Europe by 100-200% while increasing slightly by 10-30% the N10 concentration over central Europe.

**10CA.4**

**SOA Formation from OFR Oxidation of Rural and Urban Ambient Air Suggests Widespread Importance of S/IVOC Precursors.** BRETT PALM, Amber Ortega, Weiwei Hu, Douglas Day, Pedro Campuzano-Jost, William Brune, Lisa Kaser, Thomas Karl, Hansel Armin, James Hunter, Eben Cross, Jesse Kroll, Martin Graus, Carsten Warneke, Jessica Gilman, Joost de Gouw, Suzane de Sá, Lizabeth Alexander, Scot Martin, Roger Seco, Jeong-Hoo Park, Alex Guenther, Saewung Kim, Jose-Luis Jimenez, et al., *CIRES, University of Colorado*

Oxidation flow reactors (OFRs) are popular tools for studying secondary organic aerosol (SOA) formation from OH, O<sub>3</sub>, or NO<sub>3</sub> radical oxidation in both laboratory and field experiments. With a several-minute residence time and a portable design with no inlet, OFRs are particularly suited for oxidizing ambient air to investigate in situ SOA formation from real ambient precursors. In recent years, OFRs have been used to produce SOA from a wide variety of environments, including a rural pine forest, a regionally polluted deciduous/coniferous forest, the Amazon rain forest, air influenced by biomass burning, and urban outflow. With a focus on OH oxidation experiments, we present a comparison of the SOA production from these contrasting sources. In all settings, the amount of SOA formed was typically larger at night than during the day. In forests, the amount of potential SOA formation after oxidation of ambient air correlated with biogenic precursors (e.g., monoterpenes). In urban air, potential SOA formation correlated instead with reactive anthropogenic tracers (e.g., trimethylbenzene). Despite these correlations, the SOA predicted to be formed by the oxidation of speciated ambient VOC concentrations could only explain approximately 10-50% of the total SOA formed from the oxidation of ambient air, regardless of location. Evidence suggests that lower-volatility gases (semivolatile and intermediate-volatility organic compounds; S/IVOCs) are present in ambient air and are a likely source of the SOA formation that can't be explained by VOCs. These measurements show that S/IVOCs likely play an important intermediary role in ambient SOA formation in all of the sampled locations, from rural forests to urban air. Characteristics of the SOA formed from different air masses, e.g., H:C and O:C ratios of newly formed SOA as well as PMF factor analysis, will also be discussed.

**10CA.5**

**Simulating the Combined Effect of Volatility, Multigenerational Chemistry, Unspeciated Precursors and Vapor Wall-Losses on Ambient Organic Aerosol in 3-D Air Quality Model.** ALI AKHERATI, Christopher Cappa, Michael Kleeman, Shantanu Jathar, *Colorado State University*

Combustion-related primary organic aerosol (POA) is now known to be semi-volatile and reactive. Intermediate volatility organic compounds (IVOC), multigenerational chemistry and vapor wall losses during chamber experiments have all been shown to be important for the atmospheric production of secondary organic aerosol (SOA). While some of these processes have been accounted for in 3-D chemical transport models, it is unclear how these processes interact with each other at varying spatial and temporal scales and control the size, mass, composition and source contribution of ambient organic aerosol (OA) in urban and regional airsheds. To address this uncertainty, in this work, we simulated the air quality over Southern California and the eastern United States using a state-of-the-science 3-D chemical transport model (UCD/CIT) over a summer month. The chemistry and thermodynamics of the OA was modeled using the experimentally-constrained statistical oxidation model. A suite of simulations was performed over both geographical domains that systematically identified the relative importance of each source/process of interest to the ambient burden of OA. Preliminary results for Southern California indicate that a semi-volatile treatment of POA decreases while reactive POA, IVOCs and accounting for vapor wall-losses increases OA mass concentrations; multigenerational aging was found to have very small effect. Overall, the OA mass concentrations are only marginally enhanced when considering the influence of POA and IVOCs together but dramatically enhanced when accounting for vapor wall losses. Ongoing work is focussed on a systematic comparison of predictions with measurements not only of mass concentrations, but also of size and composition. Finally, we will investigate through the use of a source-resolved model, the contributions of gasoline and diesel mobile sources to the ambient OA burden.

**10CA.6**

**Drying-Induced Evaporation of Secondary Organic Aerosols during Summer.** Marwa El-Sayed, Dziejzorm Amenumey, CHRISTOPHER HENNIGAN, *University of Maryland, Baltimore County*

Aerosol liquid water can play a pivotal role in the formation of secondary organic aerosol (SOA) from biogenic VOCs. Anthropogenic emissions of sulfur and nitrogen oxides contribute to aerosol liquid water levels, and thus, to the aqueous formation of SOA from biogenic VOCs. However, many aspects of these interactions are unknown at present, including the relative contributions of reversible and irreversible uptake processes to SOA formed in aerosol water. Ambient measurements were conducted in Baltimore, MD to characterize the effects of particle drying on SOA concentrations during the summertime. On-line measurements of particulate water-soluble organic carbon (WSOC<sub>p</sub>), a surrogate for SOA, were alternated between an unperturbed ambient channel and a "dried" channel maintained at ~35% relative humidity. WSOC<sub>p</sub> concentrations measured through the dried channel were systematically lower than the ambient WSOC<sub>p</sub> concentrations: the average mass ratio between the two measurements was 0.85, showing that significant evaporation of the organic aerosol occurred due to drying. The average amount of evaporated water-soluble organic matter (WSOM = WSOC × 1.95) was 0.6 micro-grams per cubic meter; however, the maximum evaporated WSOM concentration exceeded 5 micro-grams per cubic meter, demonstrating the importance of this phenomenon. The systematic difference between ambient and dry channels indicates a significant and persistent source of aqueous SOA formed through reversible uptake processes. These results have important implications for our understanding of SOA formation from biogenic VOCs, including new insight into the measurement methods commonly used to characterize this process.

**10CC.1**

**Effects of Surfactants on the Hygroscopicity and CCN Activity of Aerosols.** Hemanta Timsina, Dabrina Dutcher, TIMOTHY RAYMOND, *Bucknell University*

Surface tension is a critical parameter affecting water interactions of aerosol particles. Surfactant compounds are those which alter the surface tension of solutions via interactions at the gas/liquid interface. In the atmosphere, compounds that may act as surfactants are produced from both biogenic and anthropogenic sources. When these compounds are combined with existing aerosol particles, they have the potential to alter the surface tension of liquid-phase interfaces which may change a particle's ability to take on water under sub-saturated or super-saturated conditions. In this work, we investigate the effects of various surfactants on both inorganic and organic aerosol particles on both hygroscopicity and CCN activity properties.

Dilute aqueous solutions were prepared using pure, single-component inorganic or organic compounds. These solutions were then mixed with various concentrations of different surfactants, atomized, and dried in diffusion dryers. The resulting aerosol stream was then measured for CCN activity using a DMT CCNC-100 instrument. In a second set of experiments, the same aerosols were passed through Nafion humidifier tubes exposing them to up to 97% relative humidity and their growth factors were measured using a TSI SMPS system. A final set of experiments exposed the aerosol streams first to the Nafion humidifier and then into the CCNC to determine if there was an effect of water vapor exposure time. Combined, these experiments investigated the effects of surfactant type, surfactant concentration, hygroscopicity changes, CCN changes, and kinetic limitations for water uptake by compounds that were already hygroscopic (such as ammonium sulfate) and organic compounds with much more limited water activity. The results of these experiments will be presented along with a comparison of experimental investigations available in the literature as well as some basic theory and modeling work on the subject.

**10CC.2**

**Chemistry, Morphology, and Cloud Activation: Chemical Composition Measurements of  $\alpha$ -pinene SOA at Low Temperature with a FIGAERO-CIMS.** CLAUDIA MOHR, Harald Saathoff, Aki Pajunoja, Annele Virtanen, Wei Huang, Xiaoli Shen, Robert Wagner, Yvette Gramlich, *Karlsruhe Institute of Technology*

During transport of newly formed secondary organic aerosol (SOA) from the lower troposphere to the upper troposphere where cloud formation becomes important, temperature and relative humidity (RH) conditions vary significantly. To simulate SOA uplifting and investigate the influence of atmospherically relevant temperature and RH conditions on phase state, morphology, chemical composition, and (ice) cloud activation in the atmosphere, we used 2 chambers at the Karlsruhe Institute of Technology (KIT).  $\alpha$ -pinene SOA was generated in a smaller stainless steel chamber at room temperature and then transported into the much larger AIDA chamber (84 m<sup>3</sup>, aluminum) kept at temperatures between 298 and 208 K. RH in the AIDA was then gradually increased from ~30% to ~95% to enable droplet or ice activation during an adiabatic expansion. The composition of the organic aerosol and its surrounding gas phase was measured with a Chemical Ionization Mass Spectrometer with a Filter Inlet for Gases and Aerosols (FIGAERO-CIMS) using I<sup>-</sup> as reagent ion. Viscosity of particles as a function of water uptake was investigated by the Aerosol Bounce Instrument.

We observed differences in chemical composition as well as water uptake behavior for organic particles under different temperature and humidity conditions. For semi-volatile compounds, thermograms from the FIGAERO show a shift towards larger maximum desorption temperatures with increasing AIDA RH at warm temperature, indicative of matrix effects or accretion reactions. Bounce measurements in the ABI indicate irreversible changes in the particles' physicochemical properties with increased exposure to humid conditions. Such effects were not observed at cold temperatures.

The results show the importance of meteorological conditions during SOA formation and processing in the atmosphere (and the laboratory) on their physicochemical properties and consequently their climate effects via cloud formation.

**10CC.3**

**Gas Phase Vapors Play a Critical Role in Cloud Condensation Nuclei Activation.** ASHLEY VIZENOR, Akua Asa-Awuku, *University of California, Riverside*

Particles that can uptake water and form cloud droplets are referred to as cloud condensation nuclei (CCN). The hygroscopicity, or ability of a particle to activate is traditionally quantified by a single parameter, kappa. Traditional CCN analysis is performed by dividing the number of particles activated by the total number of particles (condensation nuclei, CN). The point at which the ratio equals 0.5 is used to identify the critical supersaturation at which 50% of the particles activate for a given diameter. Alternatively, the critical diameter at which 50% of particles for a given supersaturation can be identified. This critical supersaturation and the corresponding dry diameter are then used to calculate kappa-hygroscopicity. However, this calculation assumes that the hygroscopicity of particles stays constant for a given precursor gas.

In the experiments presented, the CCN activity of secondary organic aerosol (SOA) from the photooxidation of two biogenic compounds, isoprene and longifolene were studied. Experiments were carried out in the UCR CE-CERT Environmental Chamber. A TSI SMPS ran in parallel with a Droplet Measurement Technologies Cloud Condensation Nuclei Counter (CCNC) was used to observe the hygroscopicity of resulting SOA, and an Agilent GC-FID quantified the gas-phase decay of the precursors. The gas phase decay of precursors was then related to the CCN/CN ratio rather than the size distribution to test if gas phase precursors play a direct role in CCN activation, and the extent to which the precursors influence CCN activation.

**10CC.4**

**Does Aerosol Chemistry Affect Droplet Kinetics?** EMMANUEL FOFIE, Ashley Vizenor, Akua Asa-Awuku, *University of California, Riverside*

Cloud droplet size influences particle scattering, the optical depth, and global cloud radiative forcing. In this study, we explore the droplet growth of simple inorganic salts (sodium chloride and ammonium sulfate) and organic acids such as succinic, malonic and oxalic acid. We also explore the droplet growth of activated complex aerosol from secondary organic aerosol (SOA) generated from seeded and un-seeded chamber experiments.

A DMT CCN counter with an enhanced resolution optical particle counter measures droplet sizes. The bin sizes are decreased two-fold and calibrated. The UC Riverside environmental chamber generated secondary organic aerosol from the ozonolysis of tricyclic sesquiterpenes and internally mixed, organic coated aerosols; dicarboxylic acids condense onto an  $(\text{NH}_4)_2 \text{SO}_4$  core.

Aerosol activate, form cloud condensation nuclei (CCN) and their droplet growth is characterized according to their mass accommodation coefficient and mixing states. A coupled analysis of laboratory CCN experiments and droplet growth modelling, Continuous Flow Streamwise Thermal Gradient CCN (CFSTGC) model, explores the effects of chemical composition on the droplet sizes when characterized by the hygroscopicity and the mass accommodation of water.

Results indicate that the final droplet sizes of activated inorganic salts and organic acids have different thermodynamic water uptake (hygroscopicity) but similar droplet kinetics. The hygroscopicities of pure and mixed compounds range from 0.1 to 1.2 and estimated mass accommodation coefficients can range over an order of magnitude (0.1 to 1.) Hence the observed kinetics of these compounds may not be divergent enough to result in a statistically significant difference in final droplet sizes. The more complex SOA ozonolysis show quantifiable differences in activated droplet sizes. The average hygroscopicity is  $\sim 0.1$  and the estimated accommodation coefficient increases from 0.05 to 0.15.

We discuss reasons why the differences in aerosol systems can have such a vast influence on droplet sizes.

**10CC.5**

**Springtime Secondary Particle Formation and Its Contribution to CCN in the Northeastern US.** FANGQUN YU, Gan Luo, James Schwab, G. Garland Lala, Kenneth Demerjian, *University at Albany, SUNY*

By acting as cloud condensation nuclei (CCN), atmospheric particles modify cloud properties and precipitation and thus affect the hydrological cycle and climate indirectly. New particle formation (NPF) is an important source of CCN in the troposphere. Here we study the springtime secondary particle formation and its contribution to CCN in the Northeastern US, through size-resolved aerosol simulations and comparisons with measurements obtained at the Pinnacle State Park in upstate New York, a rural site in the Northeastern US that is subject to the influence of anthropogenic emissions from the Ohio River Valley Region. The model employed for this study is WRF-Chem v3.7.1, with a size-resolved advanced particle microphysics (APM) module incorporated. We focus on two two-week periods (April 7-21, 2009 and May 7-21, 2012) when particle size distributions have been measured at the Pinnacle State Park. Strong NPF and growth events were observed in 19 out of the 28 days (68%). The model is able to capture most of event and non-event days. The non-event days are largely associated with cloudy or precipitation days when the solar radiation at the surface is low. Both the measurements and model simulations show that the strong NPF can increase CCN abundance by up to one order of magnitude. Based on WRF-Chem-APM simulations, secondary particles on average contribute ~90% to the CCN abundance at the PSP site while primary particles (mostly black carbon and primary organic carbon) contribute ~10%. On a regional scale, secondary particles contribute ~80-95% to CCN concentrations in most part of Northeastern US, highlighting the necessity for better representation of NPF in weather and climate models that take into account aerosol-cloud-precipitation interactions. The sensitivity of simulated CCN concentrations to the nucleation schemes and implications to simulated cloud properties and precipitation will be discussed.

**10CC.6**

**Particle-Resolved Modeling of In-Cloud Chemistry.** Matt Dawson, NICOLE RIEMER, Donald Dabdub, *University of Illinois at Urbana-Champaign*

Chemistry within aqueous cloud and fog droplets contributes to atmospheric S(IV) oxidation, the production of secondary organic aerosol, and plays an important role as a source or sink for a variety of trace gaseous species. Detailed mechanisms for atmospheric aqueous-phase chemistry have been developed, and have proven successful at modeling the processing of key atmospheric species in these systems.

However, due to the complex interactions between aerosol particles and cloud or fog droplets, large uncertainties remain in modeling the composition and properties of the gas and condensed phases in clouds and fogs, which directly affect their radiative properties and impact on climate.

In this presentation we focus on the question of how aerosol mixing state impacts the production of sulfate and secondary organic aerosol in clouds. To this end we developed an aqueous-phase chemistry module for the stochastic particle-resolved model PartMC-MOSAIC, based on the CAPRAM 2.4-reduced mechanism of Ervens et al. (JGR, 2003). Stochastic particle-resolved models are uniquely suited for this work as they explicitly track the composition of individual aerosol particles and droplets. They can therefore capture the effects of non-linearity in reaction rates that may occur due to differences in droplet composition in the highly externally mixed aerosol systems often found in the real atmosphere. We developed several scenarios representative of urban emission plumes for which the aerosol mixing states varied, and used these aerosol populations as inputs for particle-resolved cloud parcel model simulations. We will discuss the effects of particle mixing state and aqueous-phase chemistry on particle and droplet composition and properties as the aerosol populations undergo cloud processing.

**10EC.1**

**Harms and Risks of Nicotine: Implications for Electronic Cigarette Use.** NEAL BENOWITZ, Gideon St. Helen, *University of California San Francisco*

Electronic cigarettes (EC) generate an aerosol containing nicotine, propylene glycol, vegetable glycerin and flavorants. Based on studies of inhaled and exhaled aerosol, more than 90% of inhaled nicotine is systemically retained. The nicotine pharmacokinetic profile looks like a combination of pulmonary and upper airway absorption. The systemic dose of nicotine is highly variable, depending on the EC device, but can be similar to that from cigarette smoking. With ad libitum use nicotine is intermittently dosed resulting in a more sustained blood level profile in contrast to the peaks and troughs seen with cigarette smoking. The major safety concerns for nicotine are addiction, cardiovascular disease and reproductive disorders. Most of the cardiovascular harm from smoking is thought to derive from combustion products, including oxidant chemicals, volatile organic compounds, particulates and carbon monoxide. Nicotine produces hemodynamic effects related to catecholamine release, and may also contribute to an adverse lipid profile, insulin resistance and cardiac arrhythmias. Epidemiologic studies with smokeless tobacco, which delivers nicotine but not combustion products, suggest that nicotine can contribute to acute cardiovascular events, including sudden death, in people with cardiovascular disease. Short term use of nicotine appears to pose little risk. Based on animal studies nicotine probably has adverse effects on fetal brain and lung development, and may contribute to some complications of pregnancy. While nicotine use is not entirely safe, the risk of nicotine delivered by ECs is undoubtedly much less than the risk of cigarette smoking.

**10EC.2**

**Electronic Cigarettes and Cardiovascular Disease Risk.** DANIEL CONKLIN, Aruni Bhatnagar, *American Heart Association*

Electronic cigarettes (e-cigarettes) are new modes of nicotine delivery in which nicotine is transferred from the liquid to the vapor phase by heating nicotine in solution. Although these devices do not generate many of the harmful or potentially harmful constituents (HPHCs), generated by combustion in conventional cigarette smoke, the cardiovascular effects of e-cigarettes are unknown and their efficacy in promoting and sustaining cessation remains unclear. Currently, e-cigarettes are being marketed as cleaner and safer alternative to smoking that could help smokers quit smoking. Nevertheless, e-cigarette aerosols contain appreciable levels of carbonyls such as acrolein, formaldehyde and acetaldehyde, which within the concentration range reported in e-cigarettes, exert significant cardiovascular toxicity. Exposure to these aldehydes has been shown to be associated with increases in blood coagulation, mean arterial blood pressure, nasal inflammation and airway irritation. Moreover, even by itself, nicotine is a sympathomimetic drug that elicits hemodynamic and metabolic changes such as increases in blood pressure and coronary resistance and deterioration of arterial compliance; changes that could accelerate cardiovascular disease and trigger acute cardiovascular events. In agreement with this view, the use of e-cigarettes has been found to be associated with increases in heart rate, and systolic blood pressure. With some devices, the effects were similar in magnitude to those observed with conventional cigarettes. The dose-response relationship between smoking and cardiovascular mortality is non-linear, suggesting that reduction in HPHC concentrations in e-cigarette aerosols may not result in proportional harm reduction and decreased HPHC exposure may be off-set by increased use by individuals who believe that e-cigarettes are safer than conventional cigarettes. Thus, taken together, current evidence suggests that despite reduction in the content of several combustion products, e-cigarette use is associated with significant hemodynamic and metabolic changes that could induce significant cardiovascular injury.

**10EC.3****The Effects of E-cigarettes on Innate Defense in the Lung.**ROBERT TARRAN, *University of North Carolina at Chapel Hill*

E-cigarette vaping constitutes an alternative to tobacco smoking that is rapidly growing in popularity, especially amongst youth and young adults. Despite being touted as a nicotine replacement product, E-liquids typically have not undergone the rigorous toxicology screening and preclinical development seen with inhaled therapeutics. As such, little is known about their effects on the lung. E-liquids are usually a mixture of propylene glycol (PG)/vegetable glycerin (VG) along with nicotine and flavorings. However, there is considerable diversity amongst e-cigarette flavors and to date, approximately 7000 different flavors exist. We have collected washings and samples from both the upper and lower airways of non-smokers, e-cigarette vapers and regular tobacco smokers to (i) conduct a proteomic analysis of the airway surface liquid (ii) perform genomic analysis of airway epithelia and (iii) we have cultured human bronchial epithelia and chronically exposed them to e-cigarette vapors and e-liquids to perform functional studies. Our genomic and proteomic studies have revealed that e-cigarettes do indeed exert significant effects on the airways at the gene and protein level that surprisingly, are significantly different from those seen with cigarettes. Interestingly, these changes appear to be independent of the flavors used. Our studies in primary bronchial epithelia indicate that e-cigarette exposure causes significant changes in function, and additional effects of the flavors can be detected. These data and their implications for lung health will be discussed. However, it would appear that e-cigarettes exert effects on the human lung that are consistent with immunosuppression.

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**10EC.4****Cancer and Non-Cancer Risk from E-Cigarette Aerosol Toxicant Exposure.**SAMERA HAMAD, Stephanie S. Buehler, Vladimir Mikheev, Pamela I. Clark, Courtney A. Granville, *Battelle Public Health Center for Tobacco Research*

Electronic cigarettes are largely regarded as a safe alternative to combustible cigarettes, and a growing number of youth and young adults are experimenting with these relatively new products. However, little is known about real world exposure to e-cigarettes, and the subsequent health risk of vaping e-cigarettes. Publications to date report the presence of several carcinogens including formaldehyde, acetaldehyde, and acrolein in e-cigarette aerosols. Several behavioral parameters such as puff volume, puff duration and the number of puffs will modify overall exposure and subsequent risk. A preliminary study of e-cigarette real-world use behaviors among experienced vapers showed wide variability in average puff volumes (10 to 148 mL) and durations (0.7 to >5 seconds) across participants, indicating potentially wide variability in exposure across e-cigarette users. Additionally, the level of aldehydes present in e-cigarette aerosols is partially dependent upon the power applied to the heating element. Work from our TCORS has also demonstrate the presence of high concentrations of nano-sized particles in e-cigarette aerosols as compared to combustible tobacco products. The large surface area of nanoparticles may make them more bioactive due to their relatively large surface area. This talk will review the literature regarding the chemical and physical composition of e-cigarette aerosols and consider health risk from different exposure scenarios. Cancer and non-cancer risk associated with the exposure to these toxicants will be presented. As an example, Bekki et al. (2014) and Goniewicz et al. (2014) reported levels of formaldehyde at 13 to 374 ng/puff, and levels of acetaldehyde at 7 to 90 ng/puff. Assuming 100% deposition of these compounds, and 120 puffs per day for a period of 10 years, an accumulated lifetime cancer risk from aldehyde exposure of  $1.6 \times 10^{-7}$  to  $4.3 \times 10^{-6}$  was calculated. The potential public health implications from different exposure scenarios will be discussed.

**10EC.5**

**Key Parameters Affecting E-cigarette Emissions and Their Impacts on Indoor Exposures and Health Effects.** Mohamad Sleiman, Jennifer Logue, V. Nahuel Montesinos, Marta Litter, Marion Russell, Lara Gundel, HUGO DESTAILLATS, *Lawrence Berkeley National Laboratory*

In recent years, use of electronic cigarettes has grown exponentially. While some advocates embrace this new development as a harm reduction approach to curb consumption of conventional (combustion) cigarettes, most tobacco control scientists warn about potential negative impacts to public health associated with vaping in indoor environments. We identified key parameters influencing emissions from e-cigarette consumption (“vaping”) and their impacts on the formation of harmful emissions. The levels of carbonyls and volatile organic compounds in mainstream vapor were measured during e-cigarette use under controlled conditions. Levels and patterns of non-users’ exposures were estimated by measuring concentrations of nine toxicants in vapor exhaled by four users, followed by modelling that incorporated ventilation rates, vaping frequency and occupancy. We also monitored particulate emissions and deposition. The results of this study can inform decision makers on the need for regulating use of e-cigarettes indoors. Since harmful emissions originate from heating the common constituents present in every e-liquid (solvents such as propylene glycol and glycerin), protection of users from these undesired byproducts may be achieved by improving e-cigarette designs to reduce coil and vapor temperatures. Protection of non-users is most effective by restricting e-cigarette use in indoor environments.

**10EC.6**

**E-cigarettes: FDA Regulation and Research.** PRISCILLA CALLAHAN-LYON, *FDA Center for Tobacco Products*

Introduced into the US within the last decade, e-cigarettes, devices that in general deliver a nicotine containing aerosol to the user, raise challenging public health questions. Although the Center for Tobacco Products (CTP) does not currently regulate e-cigarettes or other electronic nicotine delivery systems, the Food and Drug Administration (FDA) has issued a proposed rule that would extend the agency’s tobacco authorities to regulate these products. CTP has identified e-cigarettes as a research priority as the Center is interested in understanding the impact of these increasingly prevalent and expanding products on the individual and population level health. Topics of particular interest to FDA include the short and long-term health effects associated with e-cigarette use and nonuser exposures, as well as reasons and patterns of use in current smokers (including use for cessation and dual use), former smokers and youth (including the impact of flavored products and transition to combusted products).

This presentation will provide an overview of FDA CTP regulatory authorities, including CTP’s authority to conduct research to inform tobacco product regulation to protect the public health. In addition, the presentation will discuss tobacco regulatory science, provide an overview of FDA’s currently funded e-cigarette research, and provide information about the Tobacco Regulatory Science Program, an interagency partnership that coordinates the collaborative tobacco research effort across FDA/CTP and NIH.

**10NS.1**

**Real-time Characterization of Isoprene Epoxydiols-derived Secondary Organic Aerosol (IEPOX-SOA) in Eastern China.** YUNJIANG ZHANG, Lili Tang, Yele Sun, Olivier Favez, Francesco Canonaco, Dantong Liu, John Jayne, Zhuang Wang, Philip Croteau, Alexandre Albinet, Manjula Canagaratna, Hongcang Zhou, Andre Prévôt, Douglas Worsnop, *NUIST / JSEM, China & INERIS / LSCE, France*

Isoprene (2-methyl-1,3-butadiene, C<sub>5</sub>H<sub>8</sub>), from biogenic emissions, is a significant source of global non-methane hydrocarbon in the atmosphere. Its oxidation products (isoprene epoxydiols, IEPOX) can form secondary organic aerosol (SOA) and exert potential impacts on air quality and regional climate. Although a few studies have reported the isoprene-related organic aerosol in China's atmosphere via filter-based measurements, real-time characterization of IEPOX-derived SOA (IEPOX-SOA) has never been performed to date.

Here we report the identification and quantification of IEPOX-SOA based on Aerosol Chemical Speciation Monitor (ACSM) measurements in Eastern China in summer 2013 along with multilinear engine (ME-2) analysis of OA spectra. The average mass concentration of IEPOX-SOA is  $0.33 \pm 0.19 \mu\text{g}/\text{m}^3$  for the entire study period, which accounts for 3.8% of total OA. IEPOX-SOA presents a strong diurnal cycle with a clear daytime increase related to photochemical production. The IEPOX-SOA correlated well with sulfate ( $r = 0.61$ ), suggesting that anthropogenic SO<sub>2</sub> emissions might affect the IEPOX-SOA formation in urban Nanjing. Potential source contribution function analysis shows that high IEPOX-SOA is primarily from the south of Nanjing with substantially large biogenic emissions. Our results suggest that the interactions between anthropogenic SO<sub>2</sub> and biogenic VOCs from regional transport might have played a key role in the formation of IEPOX-SOA in Eastern China.

**10NS.2**

**Enhanced Formation of Isoprene-derived Organic Aerosol in Sulfur-rich Power Plant Plumes during Southeast Nexus (SENEX).** LU XU, Ann M. Middlebrook, Jin Liao, Joost de Gouw, Hongyu Guo, Rodney J. Weber, Athanasios Nenes, Felipe Lopez-Hilfiker, Ben H. Lee, Joel A. Thornton, Charles Brock, J. Andrew Neuman, John B. Nowak, Ilana Pollack, Andre Welti, Martin Graus, Carsten Warneke, Nga Lee Ng, *Georgia Institute of Technology*

Isoprene is the most abundant non-methane hydrocarbon emitted from vegetation. The oxidation of isoprene via RO<sub>2</sub>+HO<sub>2</sub> pathway produces isoprene epoxydiols (IEPOX), which can uptake to acidic aqueous particles and produce secondary organic aerosol (i.e., denoted as isoprene-OA). We have observed a strong association between isoprene-OA and sulfate from ground measurements at the SOAS campaign. This association suggests that sulfate plays a critical role in isoprene-OA formation. However, mechanisms of the sulfate control on isoprene-OA formation is unclear, owing to the convoluted relationships between particle acidity, particle water, and sulfate.

In this study, we examine the effects of sulfate on isoprene-OA formation through airborne measurements in the southeastern United States during the Southeast Nexus (SENEX) field campaign. We sampled downwind from two power plants (i.e., Harlee Branch and Scherer) in Georgia. Harlee Branch emitted more sulfur dioxide (SO<sub>2</sub>) than Scherer and more aerosol sulfate was produced downwind. Interestingly, isoprene-OA formation was only enhanced in Harlee Branch plume, but not in Scherer plume. The contrast between two power plants provides an opportunity to examine the magnitude and mechanisms of sulfate on isoprene-OA formation. Isoprene-OA is estimated to decrease by  $0.23 \pm 0.08 \mu\text{g sm}^{-3}$  with  $1 \mu\text{g sm}^{-3}$  reduction in sulfate. Based on a parameterization of IEPOX reactive uptake, we find that sulfate enhances IEPOX uptake to particles and subsequent aqueous-phase reactions in the power plant plume, by enhancing both particle surface area and particle acidity, respectively. Finally, we use these findings to explain the observed relationships between isoprene-OA, sulfate, particle acidity, and particle water in previous studies.

## 10NS.3

**SOA Derived from Isoprene Epoxydiols: Insights into Formation, Aging and Distribution over the Continental US from the DC3 and SEAC4RS Campaigns.** PEDRO

CAMPUZANO-JOST, Brett Palm, Weiwei Hu, Douglas Day, Amber Ortega, Jose-Luis Jimenez, Jin Liao, Karl D. Froyd, Ilana Pollack, Jeff Peischl, Thomas Ryerson, Jason St. Clair, John Crouse, Paul Wennberg, Tomas Mikoviny, Armin Wisthaler, Luke Ziemba, Bruce Anderson, Simone Meinardi, Donald Blake, *CIRES, University of Colorado, Boulder*

Recent field and laboratory data show substantial evidence for the importance of isoprene-derived SOA in areas with strong isoprene emissions, such as the SE US. Under low-NO conditions (<100 pptv), the key gas-phase intermediate is believed to be isoprene epoxide (IEPOX), which can be incorporated into the aerosol phase by sulfate ester formation (IEPOX sulfate), direct hydrolysis, or other mechanisms. SOA formed by this mechanism (IEPOX-SOA) has a characteristic fragmentation pattern when analyzed by an Aerodyne Aerosol Mass Spectrometer (AMS) with an enhanced relative abundance of the C<sub>5</sub>H<sub>6</sub>O<sup>+</sup> ion. Using Positive Matrix Factorization (PMF) we have extracted and identified IEPOX-SOA factors for the all the AMS datasets recorded on flights on the NASA DC8 during the DC3 and SEAC4RS campaigns. These campaigns both sampled the SE US over the Spring of 2012 and the Summer of 2013, respectively

Based on this analysis, the contribution of IEPOX-SOA to total OA mass in the SE US was substantial for both DC3 and SEAC4RS flights (20-60%). IEPOX-SOA was also observed in isoprene-rich areas in the W US, albeit with smaller contributions (up to 10%). Highest concentrations of IEPOX-SOA were typically found downwind of source regions, where IEPOX is already depleted.

Main predictor for IEPOX-SOA was inorganic sulfate. At moderate aerosol water fraction a significant dependence can be observed on both total aerosol volume/surface and While organosulfates are generally not formed at higher pH/large liquid water fraction (LWC), they correlate reasonably well with IEPOX-SOA close to sources at low LWC.

IEPOX-SOA was detected up to altitudes of 5-6 km, with a somewhat different spectral pattern than the factor typically found at ground sites, This residual layer factor contributes a large amount of aerosol mass aloft, and could be due to aging of IEPOX-SOA under high RH/low ionic strength conditions at higher altitudes.

## 10NS.4

**Influence of Anthropogenic Emissions on the Production of Organic Particulate Matter from Isoprene Epoxydiols in Central Amazonia.** SUZANE DE SÁ, Brett Palm, Pedro

Campuzano-Jost, Douglas Day, Weiwei Hu, Jose-Luis Jimenez, Matt Newburn, Lizabeth Alexander, Gabriel Isaacman-VanWertz, Lindsay Yee, Allen H. Goldstein, Joel Brito, Samara Carbone, Paulo Artaxo, Stephen Springston, Rodrigo A. F. Souza, Antonio O. Manzi, Scot Martin, *Harvard University*

The atmospheric chemistry of isoprene produces a substantial fraction of the submicron organic particulate matter (PM) over forests. Isoprene epoxydiols (IEPOX) are produced in the gas phase from the reactions of photochemically produced OH with biogenically emitted isoprene when HO<sub>2</sub> pathways are favorable in the absence of extensive NO pollution. The reactive uptake of IEPOX in turn contributes significantly to the mass concentration of PM. The present study investigates anthropogenic influences on the production of IEPOX-derived PM over a tropical forest. The composition of submicron PM was measured with an Aerodyne Aerosol Mass Spectrometer (AMS) during the wet season of 2014 in central Amazonia at the GoAmazon2014/5 T3 site, downwind of Manaus, Brazil. Given the variability in local winds, the air masses sampled at T3 represented conditions ranging from background to polluted. The time series of the organic contribution to the mass spectra was analyzed by Positive Matrix Factorization (PMF). A factor associated with IEPOX-derived PM was resolved and labeled "IEPOX-SOA factor". The temporal correlation between the loadings of the IEPOX-SOA factor and measured sulfate mass concentrations as mediated by NO levels (using NO<sub>y</sub> as a surrogate) is explored. Results show that sulfate can be used as a first-order predictor of IEPOX-derived PM in the central Amazon forest. In addition, NO levels show a significant modulating role on IEPOX-derived PM chemistry in the region. The net influence of the city of Manaus in this context is also assessed, and polluted air masses were associated with lower loadings of the IEPOX-SOA factor compared to background conditions. The results are discussed taking into account the pre-existing background conditions and the city's two-lever effect as source of both sulfate and NO<sub>y</sub>, improving the understanding of the roles of anthropogenic sulfate and NO<sub>y</sub> in the production of organic PM in a tropical environment.

## 10NS.5

**Evaluating Anthropogenic Influence on Isoprene Oxidation during SOAS 2013 and GoAmazon2014/5.** Lindsay Yee, GABRIEL ISAACMAN-VANWERTZ, Rebecca Wernis, Nathan Kreisberg, Susanne Hering, Suzane de Sá, Scot Martin, Lizabeth Alexander, Brett Palm, Weiwei Hu, Pedro Campuzano-Jost, Douglas Day, Jose-Luis Jimenez, Anne Maria Hansen, Mads Bering, Marianne Glasius, Matthieu Riva, Jason Surratt, Juarez Viegas, Antonio O. Manzi, Eric Edgerton, Karsten Baumann, Rodrigo A. F. Souza, Paulo Artaxo, Allen H. Goldstein, *University of California, Berkeley*

Several studies have shown that anthropogenic influence alters the chemical mechanisms leading to secondary organic aerosol (SOA) formation from isoprene. In this work, we use tracer ratios to characterize the roles of sulfate and NO<sub>x</sub> chemistry on isoprene-derived SOA in two isoprene-rich forested environments. We deployed the Semi-Volatile Thermal desorption Aerosol Gas Chromatograph (SV-TAG) during the Southern Oxidant and Aerosol Study (SOAS) in the Southeastern U.S. in summer 2013 and during the wet and dry seasons of the Green Ocean Amazon experiment (GoAmazon 2014/5) in Central Amazonia. We measured oxidation products from isoprene at the molecular level in the gas and particle phases at hourly time resolution, including the isoprene/HO<sub>2</sub> pathway marker, 2-methyl tetrols and C<sub>5</sub>-alkene triols, and the isoprene/NO<sub>x</sub> pathway marker, 2-methyl glyceric acid. Ratios of these tracers provide a measure of the relative importance of competing chemical pathways and allow general conclusions about the mechanisms of isoprene oxidation in these environments. We also measured the concentration of isoprene-derived organosulfates collected on filters. On average, the isoprene HO<sub>2</sub> pathway tracers contribute approximately 10% of the organic mass during both field campaigns and isoprene-derived organosulfates are prevalent at concentrations often exceeding 100 ng/m<sup>3</sup> in both SOAS and the GoAmazon wet season. Using supporting measurements of particle composition, the influence of sulfate on isoprene-OA is clear for sulfate levels spanning three orders of magnitude across deployments. We further explore the differences in the tracer ratios across deployments to understand chemical factors affecting particle phase chemistry in these regions.

## 10NS.6

**Long Lifetime of Ambient Isoprene Epoxydiols-Derived Secondary Organic Aerosol (IEPOX-SOA) against OH Oxidation and Evaporation.** WEIWEI HU, Brett Palm, Douglas Day, Pedro Campuzano-Jost, Jordan Krechmer, Zhe Peng, Suzane de Sá, Scot Martin, Lizabeth Alexander, Karsten Baumann, Lina Hacker, Astrid Kiendler-Scharr, Abigail Koss, Joost de Gouw, Allen H. Goldstein, Roger Seco, Steve Sjostedt, Jeong-Hoo Park, Alex Guenther, Saewung Kim, Francesco Canonaco, Andre Prévôt, William Brune, Jose-Luis Jimenez, *CIRES, University of Colorado, Boulder*

Isoprene epoxydiols-derived secondary organic aerosol (IEPOX-SOA) can contribute substantially to organic aerosol (OA) concentrations in forested areas under low NO conditions, hence significantly influencing the regional and global OA budgets, accounting for example for 16-36% of the submicron OA in the SE US summer. Particle evaporation measurements during the Southern Oxidant and Aerosol Study (SOAS) in SE US of summer 2013 and the Green Ocean Amazon (GoAmazon2014/5) of dry season 2014 showed that ambient IEPOX-SOA likely exists mostly as oligomers. Thus it only evaporates slowly after dilution and is inaccessible to gas phase oxidation in the atmosphere. The OH aging process of ambient IEPOX-SOA was investigated with an oxidation flow reactor (OFR). The heterogeneous reaction rate coefficient of ambient IEPOX-SOA with OH radical ( $k_{OH}$ ) was estimated as  $4.0 \pm 2.0 \times 10^{-13} \text{ cm}^3 \text{ molec}^{-1} \text{ s}^{-1}$ , which is equivalent to more than a 2-week lifetime. A similar  $k_{OH}$  was found for IEPOX-SOA in ambient air in the Amazon rainforest. At higher OH exposures in the reactor ( $>1 \times 10^{12} \text{ molec. cm}^{-3} \text{ s}$ ), a mass loss of IEPOX-SOA is observed, due to heterogeneous reaction and volatilization of fragmented reaction products. We report for the first time OH reactive uptake coefficients ( $\gamma_{OH}=0.59 \pm 0.33$  in SE US and  $\gamma_{OH}=0.68 \pm 0.38$  in Amazon) for SOA under ambient conditions. A relative humidity dependence of  $k_{OH}$  and  $\gamma_{OH}$  was observed, consistent with surface area-limited OH uptake. These observations of physicochemical properties of IEPOX-SOA have important implications for ambient aerosol lifecycle and will help to constrain the impact of OA on air quality and climate.

**10SP.1****Direct Measurements of Time-Dependent Optical Extinction Cross-Sections of Single Aerosol Particles.**

JONATHAN P. REID, Michael I. Cotterell, Rose Willoughby, Hongze Lin, Andrew J. Orr-Ewing, *University of Bristol*

Aerosol particles scatter and absorb light, directly influencing the radiative balance of the atmosphere and climate. The optical cross-section depends on particle size, composition (refractive index) and morphology, and varies with the wavelength of incident light. In addition, the optical cross-section changes in response to environmental conditions (e.g. relative humidity), heterogeneous chemistry (e.g. the formation of light absorbing brown carbon components), and mixing state (e.g. internal and external mixtures). A refined model of optical extinction by atmospheric aerosol requires improved characterisation of the dependencies of refractive index on relative humidity and wavelength, and the ability to predict the refractive index for complex multicomponent particles. We will present a method for the accurate determination of the optical extinction cross-sections of an individual particle at multiple wavelengths and the dependence on environmental conditions. Such measurements provide accurate data for benchmarking and refining predictive models.

Cavity ringdown spectroscopy (CRDS) has become a widely used technique for interrogating the optical properties of ensembles of aerosol particles, both in field measurements and in laboratory studies. Uncertainties of  $\pm 2\%$  are typical in the determination of the real part of the refractive index and larger for the imaginary part. We will discuss the advantages of coupling CRDS with a single particle trap formed from a Bessel beam for studying the optical properties of accumulation mode aerosol; for example, this approach allows us to directly resolve the change in optical cross-section of a single particle with change in relative humidity. The refractive index can be retrieved at three wavelengths simultaneously with an accuracy of better than  $\pm 0.1\%$ . In addition, we will discuss the application of this approach to study the optical cross-sections of non-spherical, crystalline and multiphase particles, and to measurements of the complex refractive index of absorbing aerosol.

**10SP.2****Optical Trap and Laser Spectroscopy for Characterizing Single Airborne Aerosol Particles.** YONG-LE PAN, Chuji Wang, Joshua Santarpia, *US Army Research Lab.*

There is a need for improved real-time on-line instruments for studying and monitoring aerosols, especially bio- and chemical threats. Although some spectra-based technologies (mass, fluorescence, laser-induced-breakdown) have been developed, other technologies, e.g. Raman and absorption spectra can provide more information for better discrimination, but its signal is extremely weak from a single micron-sized aerosol particle. Collecting adequate spectra from individual single micron-sized particle requires measurement time of at least seconds. Therefore, combining optical trap and other laser spectroscopic technologies to allow better characterizing individual single particles and studying time evolution phenomena is highly desired. Here, we use our recently developed laser trapping setup, which allows us to trap either absorbing or transparent particles in air, and various laser diagnostic technologies to obtain elastic scattering pattern in the back and near back scattering direction, fluorescence spectra, Raman spectra, and cavity ring-down spectra (CRDS). Using these methods, the information about a single particle's morphology, vibrational transitions, and extinction efficiency are, for the first time, obtained from a few trapped bioaerosol aerosol particles in air.

This research was supported by the Defense Threat Reduction Agency (DTRA) and ARL mission funds.

**10SP.3**

**3-D Reconstruction of Individual Ambient Dust Particles to Study Variation in Aerosol Optical Properties.** DIANA ORTIZ-MONTALVO, Joseph Conny, Robert Willis, *National Institute of Standards and Technology*

Ambient particles are ubiquitous in the atmosphere and exert a strong influence on the climate by altering the Earth's radiative balance. Their optical properties depend highly on the shape and how the chemical compounds are arranged in its internal structure. The objective of this study is to characterize the morphology and composition of ambient dust particles and study their optical properties using a method that combines advanced microscopy techniques and optical property modeling. Focused ion-beam scanning electron microscopy and energy-dispersive x-ray spectroscopy (FIB-SEM-EDS) was successfully used to reconstruct the three-dimensional (3-D) configuration of particles. 3-D reconstruction included the particle's inherent shape, voids and inclusions whether the inclusions were light-absorbing or light-scattering phases. The 3-D reconstructions were then used in a discrete dipole approximation method (DDA) to determine their optical properties such as single-scattering albedo (SSA) and fraction of backscattered light. Optical properties were obtained using actual-shapes of the particles, as well as, (theoretical) equivalently-sized shapes that would scatter light isotropically: spheres, cubes, and tetrahedral. This presented an interesting opportunity to test the commonly used assumption in climate models that particles are spherical. Results from a limited number of samples indicate that the shape of the particle was the dominant factor affecting the variation of optical properties. Also, SSA for the tetrahedral geometric model was much closer to the albedo of reference particles. These findings perhaps suggest that the use of tetrahedral geometric models would be a better way of representing atmospheric dust in modeling studies, rather than commonly used spherical models. Lastly, the effect that size has on the optical properties of these 3-D reconstructions is currently being explored.

Overall, the use of 3-D reconstructions of individual particles offers a more realistic way of reproducing irregularly shaped ambient particles to study their optical properties with models such as DDA.

**10SP.4**

**Aerosol Studies Using a Linear Electrodynamic Quadrupole.** MATTHEW B. HART, Vasanthi Sivaprakasam, Paul Lane, Jozsef Czege, Jay D. Eversole, *Naval Research Laboratory*

The linear electrodynamic quadrupole (LEQ) is a charged particle trapping technique that our group at the Naval Research Laboratory has developed and improved on in the past couple of years. This experimental approach provides the opportunity to investigate individual aerosol particles in controlled environments over relatively long periods of time. The geometry of an LEQ allows semi-automated, high-efficiency trapping of single or multiple particles along its symmetry axis. The method can be used to confine particle along this axis in a continuously moving stream for large population statistical measurements as well as to hold them stationary for long-term study. Thus far we have maintained and made measurements on trapped particles ranging from 0.5  $\mu\text{m}$  to 60  $\mu\text{m}$  diameters using the same LEQ apparatus. Separate on-going programs in our group are utilizing this experimental platform, and across these studies single particle measurements include: imaging, charge determination, aerodynamic and thermodynamic properties (including evaporation & condensation), light scattering and optical spectroscopies such as fluorescence or Raman scattering. Here we present an overview and summary of the LEQ capabilities and examples of aerosol particle measurements as well as possible future applications.

**10SP.5**

**Multidimensional Characterization of Individual Aerosol Particles.** ALLA ZELENYUK, Dan Imre, David Bell, Jacqueline Wilson, Josef Beranek, *Pacific Northwest National Laboratory*

Small, ultrafine and fine, particles are ubiquitous in natural and human-made environments, playing an important role in many areas that have direct impact on our lives. The behavior and impacts of small aerosol particles depends on a number of their physical and chemical properties, many of which are strongly coupled. Traditional particle characterization approaches rely on a number of independent measurements that average over a heterogeneous mixture of particles of different properties and later attempt to draw correlations between all observables. As a result, major differences between individual particles are often overlooked.

We will present our unique approach to measure simultaneously, in-situ and in real-time, a large number of individual particles attributes, using our single particle mass spectrometers, SPLAT II and miniSPLAT, in combination with other instruments. This multidimensional single particle characterization yields comprehensive, quantitative analysis of individual particles with ultrahigh sensitivity, sub-nanometer precision and accuracy, and with high temporal resolution.

We will demonstrate the utility of this approach to characterize secondary organic aerosol, metal nanoparticles, and combustion-related particles. We will illustrate how we characterize in situ and in real time individual particle size, mass, density, chemical composition, morphology, phase, chemical diffusivity, viscosity, porosity, number concentration, size distribution. We obtain information on different aspects of particle shape, which include particle asphericity, asymmetry, and dynamic shape factors, in the transition and free-molecular regimes, and fractal dimension. We also measure particle hygroscopicity, particle activity as cloud condensation and ice nuclei, size-dependent evaporation kinetics, and rates of heterogeneous reactions. In addition, we will present a new approach to identify and separate particles of different shapes.

Most importantly, we will show that the very same instruments can be used in the laboratory and be deployed in the field, including onboard aircraft.

**10SP.6**

**Phase Separation, Morphology, and Diffusivity of alpha-Pinene Secondary Organic Matter Determined using Optical Tweezers.** KYLE GORKOWSKI, Neil Donahue, Ryan Sullivan, *Carnegie Mellon University*

Atmospheric aerosols contain a wide variety of organic and/or inorganic components and can phase-separate into distinct liquid phases, resulting in either a core-shell or a partial-shell particle morphology. Understanding and predicting when each of these morphologies forms is critical to understanding gas-particle interactions. We conducted experiments exploring phase-separation of droplets suspended using aerosol optical tweezers (AOT). The droplet levitation and the surface resonant whispering gallery modes (WGMs), retrieved in the cavity enhanced Raman spectrum, provide a unique direct and real-time assessment of the droplet's morphology.

We performed the first optical tweezers experiment on droplets to which secondary organic matter (SOM) was added through in situ precursor ozonolysis directly in the tweezing chamber. The alpha-pinene SOM formed a composite droplet with separate phases when added to an aqueous salt or a squalane droplet, producing a shell of secondary organic matter. Using this determined morphology and the rapid evaporation of squalane observed by Robinson et al. (2015) in an aerosol population chamber experiment, we can conclude that squalane has no observable diffusion limitations through alpha-pinene secondary organic matter. Using spreading coefficients, we can bound the surface tension of alpha-pinene SOM and conclude that the air-liquid surface tension of alpha-pinene SOM is less than or equal to that of squalane, 28 mN/m. This, in turn, helps to constrain the Kelvin diameter for condensation of alpha-pinene SOM onto ultrafine particles soon after nucleation in the atmosphere. Analysis of the WGMs in the Raman spectrum allows us to conclude that the nucleated submicron SOM particles that coagulated with the trapped droplet must quickly spread across the droplet under a timescale much shorter than the Raman spectrum acquisition time of 2 seconds, otherwise the WGMs would not have been present.

**11AC.1**

**Comprehensive Measurements of Gas- and Particle-phase Organic Carbon Formed in the Multigenerational Oxidation of Biogenic Hydrocarbons.** GABRIEL ISAACMAN-VANWERTZ, Jonathan Franklin, Rachel O'Brien, Christopher Lim, Paola Massoli, Andrew Lambe, John B. Nowak, Timothy Onasch, Manjula Canagaratna, Joseph Roscioli, Scott Herndon, John Jayne, Douglas Worsnop, Luping Su, Daniel Knopf, Pawel Misztal, Caleb Arata, Allen H. Goldstein, Jesse Kroll, *MIT*

Atmospheric oxidation processes quickly transform emitted organic compounds into a multiphase, chemically dynamic system of organic aerosol and gas-phase products. Particle-phase mass serves as a temporary sink for carbon that can impact the distribution of products and oxidation reactions, but the low-volatility gases that condense to form organic aerosol and exchange with particle-phase mass are difficult to measure. Consequently, attempts to understand the evolution of carbon through atmospheric oxidation has in nearly all cases resulted in a large fraction of "missing" or unidentified carbon. We present here results from laboratory oxidation experiments in which a large suite of state-of-the-art mass spectrometric and spectroscopic instrumentation was employed to measure organic compounds across nearly all volatilities and chemical functionalities typically observed in the atmosphere. Photochemical oxidation of common biogenic emissions was studied, spanning hours to days of simulated atmospheric aging, with a focus here on  $\alpha$ -pinene. New chemical ionization mass spectrometric instruments allowed for the quantification of low-volatility gases formed through these processes, and characterization of their role in aerosol growth. Through systematic variation of reaction conditions (e.g. with and without seed aerosol) coupled with measurements of low-volatility compounds, we explore the importance of measurement artifacts, especially vapor deposition to surfaces, on typical measurements and laboratory experiments. By observing all carbon through multiple generations of oxidation, we examine the transitions between particles and lower-volatility gases with unprecedented detail and place them in the context of current simplified (i.e. two-dimensional) model frameworks, providing a more complete understanding of the evolution of organics in the atmosphere as well as an updated assessment of the capabilities and limitations of current atmospheric instrumentation.

**11AC.2**

**Constraining Ambient Organic Aerosol Chemical Aging Rates Using the Pegasos Campaign Measurements.** ELENI KARNEZI, Benjamin Murphy, Spyros Pandis, *Carnegie Mellon University*

The effects of parameterization of chemical aging processes of atmospheric organic compounds on organic aerosol (OA) concentration and chemical composition are investigated by using the two-dimensional Volatility Basis Set (2D-VBS). The OA module simulates the primary and secondary OA mass as a function of volatility and oxygen to carbon ratio (O:C). The model is applied in the two different environments of the PEGASOS field campaigns during the summers of 2012 and 2013: the polluted Po Valley in Italy and the cleaner environment of Finland. The model predictions are compared with measurements both at the ground and aloft using a Zeppelin airship.

Different aging mechanisms were examined, taking into account various functionalization and fragmentation paths for biogenic and anthropogenic species. For the polluted Po Valley atmosphere in Italy, model predictions and measurements, both at the ground and aloft, suggested a relatively oxidized OA with little average diurnal variation. Simple functionalization schemes, more rigorous functionalization schemes accompanied with fragmentation varying in branching ratios, resulted in very different fractional attribution for OA to anthropogenic and biogenic sources. Total OA concentration and O:C were predicted within experimental error by a number of chemical aging schemes. In the Po Valley, anthropogenic SOA sources contributed between 15-25% of the total OA, while SOA from intermediate volatility compounds oxidation contributed between 20-35%. Biogenic SOA contributions varied from 15 to 45% depending on the modeling scheme. Other measurements were then used to further constrain the model.

The sensitivity of the model to the assumed vaporization enthalpy was also examined. The average OA and O:C diurnal variation and their vertical profiles showed a surprisingly low to modest sensitivity to this parameter independently for all aging schemes. This can be explained by the intricate interplay between the changes in partitioning of the semivolatile compounds and their gas-phase chemical aging reactions.

**11AC.3**

**Characterization of Multiple ACSMs Using Laboratory Secondary Organic Aerosol Generated with a Potential Aerosol Mass Oxidation Flow Reactor.** LEAH WILLIAMS, Andrew Lambe, Philip Croteau, John Jayne, E. Freney, Tanguy Amodeo, Michael Cubison, Julia Schmale, Hilkka Timonen, Laurent Poulain, Iasonas Stavroulas, Axel Eriksson, Stina Ausmeel, Francois Truong, Yunjiang Zhang, Alexandre Marpillat, Vincent Crenn, Emmanuel Tison, Véronique Riffault, Olivier Favez, Valérie Gros, Douglas Worsnop, *Aerodyne Research, Inc.*

The Aerosol Chemical Monitor Calibration Centre (ACMCC) organized a second large multi-institution inter-comparison of Aerodyne aerosol chemical speciation monitors (ACSMs) at the Laboratory for Climate and Environmental Science (LSCE) near Paris, France during March, 2016. Here, we present the results from multiple quadrupole (Q-ACSM) and time-of flight mass spectrometer (ToF-ACSM) instruments measuring secondary organic aerosol (SOA) generated from OH oxidation of naphthalene in a Potential Aerosol Mass (PAM) oxidation flow reactor. The SOA chemical composition corresponded to 1 to 10 days of atmospheric photo-oxidation and was used to test the variability in the mass spectra among 6 ToF-ACSMs, 4 Q-ACSMs and a high-resolution aerosol mass spectrometer (HR-AMS), particularly the variability in f44 (ratio of the signal at m/z 44 to total organics). Results from two weeks of ambient sampling will also be discussed.

**11AC.4**

**Secondary Organic Aerosol (SOA) and Ozone Formation from Photo-Oxidation of Unburned Whole Gasoline and Diesel.** WEIHUA LI, Chia-Li Chen, Lijie Li, Mary Kacarab, David R. Cocker III, *University of California, Riverside*

Direct evaporation from unburnt gasoline and diesel fuels is an established source of ozone and SOA forming hydrocarbon precursors. As new control technologies continue to decrease primary OA and gas-phase vehicle emissions, whole fuel evaporation becomes a more significant source of ambient aerosol formation. Therefore, determining the SOA forming potential of whole gasoline and diesel vapor is of significant interest. While SOA formation from some gasoline components such as aromatics have been individually studied under controlled conditions, there are only a few studies on how these complex mixtures behave in the atmosphere.

Given changes in fuel formulations over time, it is important to revisit whole gasoline as an important SOA precursor, especially in light of increased knowledge on the impact of reactivity on aerosol formation and improved atmospheric chambers and instrumentation. Multiple photo-oxidation experiments with the presence of NO<sub>x</sub> were conducted in the UCR CE-CERT dual 90m<sup>3</sup> smog chambers to investigate SOA and ozone formation from three different types of unburned fuels: commercial gasoline, commercial diesel, and reference fuels. Additionally, the fuels were also added to a surrogate mixture to best mimic the reactivity of an urban atmosphere. Liquid gasoline and diesel samples were collected at service stations during winter 2016 in Riverside, California and characterized by using gas-chromatography methods. Data will be presented comparing the aerosol formation from the different whole fuels in the presence of NO<sub>x</sub> and also in the controlled reactivity system. SOA bulk chemical composition characteristics in the different systems were identified by the HR-ToF-AMS. Physical properties of the resulting aerosol, such as density and volatility will also be presented. The goal of this work was to investigate the influence of fuel composition on SOA formation and properties and ozone formation.

**11AC.5**

**Impact of Ammonia on Dynamics of Anthropogenic SOA Formation and Composition.** MALLORY HINKS, Julia Montoya, Sergey Nizkorodov, Jeremy Horne, Donald Dabdub, *University of California, Irvine*

Ammonia enters the atmosphere through both natural and anthropogenic processes, with agriculture representing a significant emission source. The U.S. Department of Commerce estimated that 8.7 million metric tons of ammonia were produced in the U.S. in 2013 alone. This work investigates the effect that ammonia has on secondary organic aerosol (SOA) formation, optical properties, and composition through a combination of laboratory experiments and airshed modeling. We generate SOA via photooxidation of various precursors (toluene, n-hexadecane) in the Nizkorodov Lab smog chamber. These freshly produced SOA are then exposed to ammonia and the particle growth and VOC concentration is monitored. Samples of the SOA after addition of ammonia are collected and the nitrogen content is analyzed by DART-MS (Direct Analysis in Real Time Mass Spectrometry). The experimental results from this study will be incorporated into two models: 1) the UCI-CIT model, an airshed model that contains comprehensive SOA chemistry for the South Coast Air Basin of California and 2) a coupled meteorological-air quality model for continental-scale modeling of the U.S. The combination of comprehensive experimental and modeling studies will evaluate the impact of NH<sub>3</sub> on SOA formation, optical properties, and composition and ultimately air quality and climate.

**11AE.1**

**A Study of the Deficiencies of a DPM Personal Sampler Which Uses Impaction Size Selective Separation.** EMANUELE CAUDA, Maura Sheehan, *NIOSH*

The simultaneous presence of respirable mineral dust and Diesel Particulate Matter (DPM) in the mining environment is a challenge for assessing the exposure of miners to DPM. Studies conducted in the past by the National Institute for Occupational Safety and Health (NIOSH) identified two steps for conducting this assessment in non-coal mines in the United States: the size separation of the aerosol at a size of 0.8 micro-meter and the subsequent analysis of the collected smaller cut that is believed to be representative of the DPM portion with a minimal mine dust contribution. The analysis of the smaller size cut is conducted using the NIOSH5040 method. A sharp size separation is provided by a commercially available impaction stage. This study presents new evidence about the deficiency of the performance of this impactor when challenged with respirable dust levels typically present in an underground mine. Several impactors were exposed to different dust levels in a calm air chamber. The penetration efficiency of new clean impactors vs. impactors exposed to dust was investigated in a different chamber using spherical particles of known density. Finally, new clean impactors and impactors previously exposed to dust were used to sample DPM aerosol under controlled conditions. The collected DPM was analyzed with the NIOSH5040 method. Statistical analysis was used to compare the DPM aerosol quantified from the clean vs. loaded impactors. Results showed a significant difference in the penetration efficiency of the impactors previously exposed to dust. This difference causes significant differences in the collected DPM aerosol. The finding indicates that the impactor might produce an underestimation of the miners' DPM exposure if respirable mining dust is present.

**11AE.2**

**A Validated Sectional Aerosol Model Applied to Deposition in the Human Upper Airways.** EDO FREDERIX, Arkadiusz Kuczaj, Markus Nordlund, Bernard Geurts, *University of Twente, The Netherlands*

We develop a fully Eulerian sectional compressible aerosol model in which the droplet size domain is discretized in a number of bins and both the liquid and vapor concentrations are coupled to the mixture density. For each bin we solve the transport equations embodying the size-dependent effects of droplet drift, diffusion and sedimentation, and convection by the carrier fluid. The model is validated in an aerosol sampler geometry and a bent pipe finding good agreement with the available literature data. In this work we present simulations of aerosol deposition in a cast of the human upper respiratory tract, driven by the three important mechanisms of droplet drift, diffusion and gravitational sedimentation. These mechanisms are size-dependent, leading to non-trivial modulation of the initial droplet size distribution that results in complex deposition patterns depending on the local flow dynamics. The inertial deposition velocity at a wall is computed using two boundary treatments: a zero-gradient treatment and a corrected treatment, the latter using the analytical solution of the droplet trajectory near the wall. We find good agreement with deposition measurements using a fairly mono-dispersed aerosol with an approximate droplet diameter of 2.1 micro-meter, for steady-state inhalation, while using the corrected boundary treatment. The zero-gradient treatment is shown to overpredict deposition, in agreement with the available literature. Finally, we study the deposition patterns in the upper human airways of a large range of droplet sizes, spanning from the nanometer scale to beyond the micrometer scale. In this size range we capture the diffusion-driven and inertia-driven deposition regimes, as well as an intermediate regime in which diffusion and inertia are of comparable importance.

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**11AE.3**

**Wood Smoke Exposure as Measured by Low-cost Air Quality Monitors.** Nadezda Zikova, Thomas Twomey, PHILIP K. HOPKE, David C. Chalupa, David Rich, Andrea R. Ferro, *Clarkson University*

Particulate matter (PM) has been linked to adverse respiratory and cardiovascular health effects. Enforcement measures for reducing PM or gaseous emissions that form secondary PM have generally reduced contributions from power production, industry, traffic, etc. However, PM concentrations from wood combustion (WS) have been increasing with the increasing use of wood for heating in the United States. Evidence to date suggests that wood combustion particles do not have toxicity that differs from that of urban PM. However, the emissions and chemical composition of wood smoke particles depend strongly on the combustion device, type of wood, and operating conditions. The current regulatory measurement network is not able to cover large spatial variability in WS concentrations, nor predict indoor concentrations strongly associated with human exposures.

We conducted a measurement campaign in Rochester, NY (pop. 210,000) where prior work found up to 30% of the winter PM<sub>2.5</sub> was from wood burning. 52 low cost PM monitors (Speck; Airviz Inc., Pittsburgh, PA), were located at 25 residential sampling sites (1 indoor, 1 outdoors) with wood burning appliances between November 2015 and March 2016. They measured 1-minute particle number concentrations and estimated particle mass concentrations between 0.5 and 3 micro-meter. Additionally, a CO monitor was placed in each house to help distinguish between combustion and non-combustion sources of indoor PM. The study participants also completed a survey on house type and age, heating fuel and frequency, and other activities influencing indoor air quality data. Data analysis includes indoor/outdoor and spatial-temporal relationships of PM in the area and the contribution of WS to personal PM exposures. The indoor/outdoor ratio is calculated and compared to house type, ventilation etc. The spatial variability of outdoor PM concentrations in the county is described, and the proportion of wood smoke in the outdoor and indoor PM concentrations is estimated.

**11AE.4**

**Is Smoke on Your Mind?: Using Social Media to Improve Estimates of Smoke Exposure.** Bonne Ford, Moira Burke, William Lassman, Gabriele Pfister, JEFFREY R. PIERCE, *Colorado State University*

Exposure to poor air quality is associated with negative impacts on human health. A large natural source of PM in the western U.S. is from wildland fires. Accurately attributing health endpoints to wildland-fire smoke requires a determination of the exposed population. This is a difficult endeavor, because most current methods for monitoring air quality are not at high temporal and spatial resolutions. Therefore, there is a growing effort to include multiple datasets and create blended products which can exploit the strengths of each dataset. In this work, we use a social-media dataset of self-reported smoke/haze/pollution to improve population-level exposure estimates for the summer of 2015, which was a particularly smoky year in the U.S. We compare this dataset to several other datasets that are commonly used for estimating exposure to wildland-fire smoke, such as satellite observations, surface measurements, and model (WRF-Chem) simulated surface concentrations.

**11AE.5**

**Intra-urban Spatial and Temporal Variations in Fine Particle Number, Mass Concentration, and Size Distributions.** ALBERT A. PRESTO, Naomi Zimmerman, Hugh Li, Peishi Gu, R. Subramanian, Allen Robinson, Joshua Apte, *Carnegie Mellon University*

Human exposure to PM<sub>2.5</sub> is linked with myriad health effects, including asthma, cancer, and premature death. While most air pollution epidemiology focuses on the effects of exposure to PM<sub>2.5</sub> (or PM<sub>10</sub>) mass concentrations, exposure to particle number, especially for ultrafine particles (UFP) smaller than 100 nm, is an area of emerging concern. Toxicological studies suggest that UFP may be more harmful per unit mass than the larger particles that dominate PM<sub>2.5</sub> mass.

Spatial and temporal variations in PM<sub>2.5</sub> mass and UFP number concentrations create exposure gradients, both between cities and within cities, and can generate zones of excess risk. This study investigates spatial and temporal variations in PM<sub>2.5</sub> mass, UFP number concentrations, and particle size distributions in a representative US city (Pittsburgh, PA). Data were collected using a combination of distributed real-time, stationary monitors and mobile monitoring. We will present results from spatially distributed measurements with focus on three specific environments: upwind of the urban area, urban high traffic, and urban outflow. Analyses will focus on potential factors driving concentration and exposure gradients, e.g., anthropogenic emissions, regional new particle formation events, and land use/urban form.

**11CA.1****Aerosol Emissions from Western U.S. Wildfires and Correlation with Combustion Efficiency.** SONYA

COLLIER, Shan Zhou, Timothy Onasch, Dan Jaffe, Lawrence Kleinman, Arthur J. Sedlacek, Nicole Briggs, Jon Hee, Edward Fortner, John Shilling, Douglas Worsnop, Robert J. Yokelson, Caroline Parworth, Xinlei Ge, Jianzhong Xu, Zachary Butterfield, Duli Chand, Manvendra Dubey, Mikhail Pekour, Stephen Springston, Qi Zhang, *University of California, Davis*

Wildfires are important contributors to atmospheric aerosols and a large source of emissions that impact regional air quality and global climate. In this study, wildfire emissions in the Pacific Northwest region of the United States were characterized using real-time measurements near their sources using an aircraft, and farther downwind from a fixed ground site located at the Mt. Bachelor Observatory (~ 2700 m a.s.l.). The characteristics of aerosol emissions were found to depend strongly on the modified combustion efficiency (MCE), a qualitative index of the combustion processes of a fire. Organic aerosol emissions had negative correlations with MCE, whereas the carbon oxidation state of organic aerosol increased with MCE. The relationships between the aerosol properties and MCE were consistent between fresher emissions (~1 hour old) and emissions sampled after atmospheric transport (6 - 45 hours), suggesting that organic aerosol mass loading and chemical properties were strongly influenced by combustion processes at the source and conserved to a significant extent during regional transport. These results suggest that MCE can be a useful metric for describing aerosol properties of regionally transported wildfire emissions and their impacts on regional air quality and global climate.

**11CA.2****Chemical Composition and Optical Properties of Wildland and Agricultural Biomass Burning Particles Measured Downwind during the BBOP Study.** TIMOTHY ONASCH,

John Shilling, Joda Wormhoudt, Arthur J. Sedlacek, Edward Fortner, Mikhail Pekour, Duli Chand, Shan Zhou, Sonya Collier, Qi Zhang, Lawrence Kleinman, Douglas Worsnop, Robert J. Yokelson, Kouji Adachi, Peter Buseck, Andrew Freedman, Leah Williams, *Aerodyne Research, Inc.*

The Biomass Burning Observation Project (BBOP), a Department of Energy (DOE) sponsored study, measured emissions from wildland fires in the Pacific Northwest and agricultural burns in the Central Southeastern US from the DOE Gulfstream-1 airborne platform over a four month period in 2013. The chemical composition of the particulate emissions were characterized using an Aerodyne Soot Particle Aerosol Mass Spectrometer (SP-AMS) and Single Particle Soot Photometer (SP2) and will be presented in the context of the fire location, combustion conditions, and optical property measurements, including extinction and single scattering albedos. The SP-AMS was operated with both laser and resistively heated tungsten vaporizers, alternatively turning the laser vaporizer on and off. With the laser vaporizer off, the instrument operated as a standard high resolution AMS. Under these sampling conditions, the non-refractory chemical composition, including the level of oxidation (i.e., O:C, H:C, and organic mass/organic carbon ratios, OM:OC), of the biomass burning particles was characterized as a function of the fuel type burned, modified combustion efficiency, and degree of aging during downwind transport. With the laser vaporizer on, the SP-AMS was also sensitive to the refractory black carbon (rBC) content, in addition to the non-refractory components. Information on the mass of rBC, the OM/rBC ratio, and the Rbc (coat-to-core) ratio was examined, focusing on correlations with the simultaneous optical measurements.

**11CA.3**

**Influence of Wildfires on Aerosol Chemistry in the Western US and Insights into Atmospheric Aging of Biomass Burning Organic Aerosol: Results from BBOP.** SHAN ZHOU, Sonya Collier, Dan Jaffe, Nicole Briggs, Jon Hee, Arthur J. Sedlacek, Lawrence Kleinman, Qi Zhang, *University of California, Davis*

Biomass burning (BB) is one of the most important, yet poorly characterized, contributors to atmospheric aerosols on a global scale. Wildfire, in particular, represents a highly variable and typically uncontrollable source of BB emissions that impact regional air quality and global climate. As part of the DOE Biomass Burning Observation Project (BBOP) in summer 2013, we characterized the chemical composition of non-refractory submicron aerosols (NR-PM<sub>1</sub>) heavily impacted by wildfire emissions in the Pacific Northwest region of the United States at the Mt. Bachelor Observatory (MBO, ~ 2763 m a.s.l.), using a High Resolution Time-of-Flight Aerosol Mass Spectrometer (AMS). Clean periods without BB influence were characterized by low NR-PM<sub>1</sub> mass and high mass fraction of ammonium sulfate. The average NR-PM<sub>1</sub> mass concentration increased substantially for periods impacted by transported BB plumes, and organic aerosol (OA) accounted on average for 94.6% of the NR-PM<sub>1</sub> mass. Positive Matrix Factorization (PMF) of the AMS data identified five distinct OA factors, including three types of BBOA: a fresh semi-volatile BBOA-1 (O/C = 0.33), an intermediately oxidized BBOA-2 (O/C = 0.62), and a highly oxidized, low-volatility BBOA-3 (O/C = 1.07). BBOA-2 and BBOA-3 together accounted for an average ~52% of the total OA mass. Additionally, analysis of persistent BB plume events transported from single fire sources indicates that longer photochemical processing led to higher BBOA oxidation degree and higher mass fractional contribution of the chemically aged BBOA-2 and BBOA-3.  $\Delta\text{OA}/\Delta\text{CO}$  enhancement ratios showed little change for BB plumes transported primarily at night versus daytime, although substantial chemical transformation in OA was observed for daytime plumes due to photo-oxidation. These results suggest insignificant net OA production arising from photo-oxidation in BB plumes and that SOA formation due to heterogeneous oxidation was almost entirely balanced by OA volatilization.

**11CA.4**

**Airborne-Based Levoglucosan Measurements and the Role of Biomass Burning during the WINTER Campaign.** AMY P. SULLIVAN, Hongyu Guo, Rodney J. Weber, *Colorado State University*

One of the main sources of organic aerosols (OA) is biomass burning. In particular, during winter, residential burning is likely to dominate over wildfires and prescribed burning. Therefore, in the winter, it is important to be able to determine the contribution of residential biomass burning to the total OA concentration. Smoke marker measurements provide one of the most common methods to make this determination. The Wintertime Investigation of Transport, Emissions, and Reactivity (WINTER) Campaign provided an opportunity to explore this as it was an aircraft-based study aimed at examining daytime and nighttime wintertime chemistry along the East Coast of the United States. Therefore, we collected levoglucosan data, a smoke marker, from aboard the C-130 aircraft during the 13 research flights. Results were obtained by coupling a Particle-into-Liquid Sampler (PILS) with a fraction collector to provide off-line samples for levoglucosan analysis by high-performance anion-exchange chromatography with pulsed amperometric detection. In this work, results from these measurements will be presented. The correlation of levoglucosan with OA and carbon monoxide will be explored. A determination for the contribution of residential biomass burning across the sampling region will be provided.

**11CA.5**

**Identifying the Main Sources of Brown Carbon in the Atmosphere.** IMAD EL HADDAD, Nivedita Kumar, Joel Corbin, Kaspar Rudolf Daellenbach, Dario Massabò, Emily Bruns, Athanasia Vlachou, Carlo Bozzetti, Jay Slowik, Paolo Prati, Urs Baltensperger, Jean-Luc Jaffrezo, Luka Drinovec, Grisa Mocnik, Martin Gysel, Andre Prévôt, *Paul Scherrer Institute*

Atmospheric brown carbon (BrC) contributes significantly to aerosol absorption in the atmosphere, especially at lower wavelengths. This fraction of the organic aerosol is composed of a large number of complex chromophores. The main processes by which these compounds are introduced in the atmosphere or formed through atmospheric oxidation remain virtually unknown and, as a result, the contribution of BrC to atmospheric absorption is highly uncertain. Here, using factorization techniques, we combine offline aerosol mass spectrometry and light absorption measurements to identify the main primary and secondary sources of BrC, at two contrasted urban sites in Switzerland over a yearly cycle. We determine that biomass burning is the major source of BrC at both sites, with humic-like substances contributing greatly to this absorption. Through complementary smog chamber experiments, we investigate the optical properties of biomass burning emissions as a function of aging.

**11CM.1**

**Ash Loading Behavior on Sintered Metal Fiber Filter Media at Elevated Temperature.** QISHENG OU, Matti Maricq, David Y. H. Pui, *University of Minnesota*

Filtration is considered as the most economical control technique to effectively remove airborne particles in nanometer size range. Many filtration systems are operated at high temperature, such as in advanced coal power plants, engine exhaust after-treatment, and chemical and petrochemical processes. Besides the conventional fabric bag and ceramic filter media, metallic filter media is seeing more applications because of its high porosity and strength, good thermal resistance, and good optimization between efficiency and back pressure. Besides post cleaning, pulse or backflush cleaning, some of filter media can be thermally cleaned by high temperature, such as engine exhaust filters. However, unburned ash cannot be removed by this method and can accumulate and cause a rise of back pressure.

In this study, laboratory-generated ash nano-particles are loaded onto flat sheet sintered metal fiber media, and its pressure drop evolution over ash loading are characterized under constant and varied temperature profiles. The sintering behavior of ash particles within metal fiber matrix is characterized by scanning electron microscopy, and its effect on filter backpressure and efficiency are evaluated using aerosol methods. Factors affecting the sintering and loading process are studied, including ash particle composition, primary particle size, loading rate, media characterization, test temperature and temperature evolution profile. A semi-empirical model is developed to predict the backpressure and efficiency of an ash-loaded filter media undergoing sintering at different temperatures. Good agreement is found to our measurements. The applicability of the model and the implication of the test results on ash accumulation on metal fiber based automobile engine exhaust filter will be discussed.

**11CM.2**

**Evaluation of Low-Cost Materials for VOC Removal in Nail Salons.** AARON LAMPLUGH, Sankaranarayanan Ravichandran, Shelly Miller, Lupita Montoya, *University of Colorado Boulder*

Nail salon workers are often occupationally exposed to compounds like xylene, toluene, and formaldehyde, which are known to cause skin and eye irritation, respiratory problems, allergies, and cancer. According to the Bureau of Labor Statistics, Asian, Latino, and African American employees account for 72% of the “Miscellaneous Personal Appearance Workers” subgroup, which includes manicurists, pedicurists, and skin care specialists. Consequently, related health effects in this industry affect minority populations in disproportionate ways in the United States.

Exposure to hazardous indoor air pollutants is traditionally mitigated by increasing natural ventilation or by installing mechanical ventilation systems. There are, however, limitations to these control strategies. Results from previous work in our group showed the removal of formaldehyde by porous media like expanded clay, Growstone and coco coir using an architectural module and column studies. Previous research in our lab also demonstrated that synthetic jet actuators (SJAs) can induce fluid vectoring and increase contaminant uptake by sorption materials.

This research further investigates the use of low-cost materials (e.g., coco coir and biochar) to remove formaldehyde from indoor air through sorption processes. The potential enhancement of the rate of removal is also being investigated using localized ventilation generated by SJAs. The combination of these mechanisms will then be investigated in real occupational environments like nail salons.

**11CM.3**

**A Comparison of Respirable Welding Fume Aerosol Exposure Reduction by Low-cost and Commercial Local Exhaust Ventilations.** JUN WANG, Heng Wang, Marcio Bezerra, *University of Oklahoma*

Most welders experience fume exposure which leads to serious adverse health effects, due to the presence of particulate toxic metals and gaseous pollutants in the welding fume. The high concentration of welding fume aerosols existing in the welder's breathing zone created a challenge to the conventional general exhaust ventilation. In addition, most welding activities occur in poorly to none ventilated areas. Local exhaust ventilation (LEV) is an emission point fume removal device to control the occupational exposures to airborne toxins. The portable nature of LEV made it a desirable device to reduce welding fume exposure. However, the cost of commercially available LEV is still high (\$2,000~\$10,000 per workstation) and thus limiting its application. Meanwhile, low-cost LEV can be made through retrofitting inexpensive shop vacuum which is commonly seen in small businesses. The study aimed to evaluate the fume aerosol removal performance of a low-cost LEV and a commercial LEV. A welder wore a cyclonic respirable particulate sampler while performing gas metal arc welding on stainless steel metal plates. The ventilation rates of both LEVs were examined using a hot-wire anemometer. The amount of fume collected on the filters were gravimetrically determined, while the carcinogen content such as hexavalent chromium was digested and analyzed by an ion chromatograph. In addition to the personal breathing zone sampling, real-time particle concentration and size distribution measurement were made with several GRIMM aerosol spectrometers located next to the welding area. The results showed low-cost LEV in the circulating mode was not as effective as the commercial LEV. The low-cost LEV in the exhaust mode can perform at the same level of commercial LEV as the welder's exposure was reduced to 90% of the control non-ventilated condition. However, certain measures should be taken when modifying shop vacuum to reduce risks of flammability and penetration of nano-sized fume aerosols.

**11CM.4**

**Particulate Hexavalent Chromium, Aerosol Size Distribution, and Respiratory Deposition of Pulsed Metal Inert Gas Welding Fume.** JUN WANG, Marcio Bezerra, Heng Wang, James Regens, *University of Oklahoma*

Metal inert gas (MIG) welding fume contains high concentration of nano- to submicron-sized aerosols enriched with toxic metals such as hexavalent chromium. The fume forms in the extreme high-temperature welding arc zone through melting and evaporating the welding filament. Occupational inhalation exposure to welding fume can cause various carcinogenic, pulmonary, and neurological adverse effects. Pulsed MIG welding was created to reduce the heat input to the welding arc zone by high-frequency current fluctuation comparing to the steady current feed in non-pulsed MIG welding. Pulsed MIG welding was proved to improve the weld quality through cooler arc and less molten metal, while the benefits of fume reduction is still a hypothesis. The goal of this study was to investigate the pulse parameters (current, frequency, and time percentage) on formation and characteristics of welding fume aerosols. A pulsed MIG welder was placed in a conical metal fume chamber and welding with different combinations of pulse parameters as well as baseline (non-pulsed) were conducted through beading on 308L stainless steel plates. Particle size distribution was measured by a scanning mobility particle sizer and an aerodynamic particle sizer. Respiratory deposition fractions for head airways, tracheobronchial, and alveolar regions were estimated based on a simplified model. Hexavalent chromium content was determined by analyzing fume samples through an ion chromatography. The statistical results indicated the dominant parameter of particle emission characteristics was the pulse current. The pulsed welding did not drastically change the geometric distribution of the particle sizes comparing to the non-pulsed welding. However, pulsed welding reduced the total fume and hexavalent chromium emissions, without compromising the weld quality. Lower pulse current produced the least particle number concentrations ( $3.0E7$  #/cm<sup>3</sup> fine particles and  $0.7E4$  #/cm<sup>3</sup> coarse particles) and for more upper respiratory tract deposition.

**11CM.5**

**Investigation of Breathing Frequency and Inhalation Flow Rate on the Performance of Respirator Filter Medium.** QIANG WANG, Laleh Golshahi, Da-Ren Chen, *Virginia Commonwealth University*

Filter media for respirator applications are typically exposed to cyclic flows, different from the constant flow adopted in standard testing for respirator filter media. To understand the actual performance of respirator filter media, it is necessary to study the particle penetration through respirator filter media under simulated cyclic flows. In this study, a new method was proposed to investigate the individual impacts of breathing frequency (BF) and peak inhalation flow rate (PIFR) on the performance of respirator filter media. Testing filter media were placed in a standard filter holder (47 mm in diameter) and challenged with DMA (differential mobility analyzer)-classified NaCl particles with the most penetration particle size (MPPS), which was measured at the equivalent-MIRF (mean inhalation flow rate) flow condition prior to the cyclic flow testing. Two CPCs (condensation particle counters) were applied to measure the particle concentration at the upstream and downstream of filter media. Filter penetration at selected DMA-classified particle sizes was derived as the ratio of downstream and upstream aerosol concentrations of test filter media. Experiments were performed under selected cyclic flows with three peak inhalation flow rates (PIFRs), i.e., 9.42, 13.6 and 18.14 LPM, and three breathing frequencies i.e., 6, 12, and 25 breaths per minute (BPM). Six filter media (including two composite media) were tested. The effect of BF and PIFR on the particle collection efficiency of respirator filter media was thus concluded for the collected. The detail of this study will be presented in the talk.

Keywords: Respirator filter media, Breathing frequency, peak Inhalation flow rate, Particulate matter (PM), cyclic flow

**11RR.1****Airborne Soil Organic Particles Generated by Precipitation.**

Bingbing Wang, Tristan Harder, Stephen Kelly, Dominique Piens, Swarup China, Libor Kovarik, Keiluweit Marco, Arey Bruce, Mary Gilles, ALEXANDER LASKIN, *Pacific Northwest National Laboratory*

Airborne organic particles play a critical role in Earth's climate, public health, air quality, and hydrological and carbon cycles. However, sources and formation mechanisms for semi-solid and solid organic particles are poorly understood and typically neglected in atmospheric models. Laboratory evidence suggests that fine particles can be formed from impaction of mineral surfaces by droplets (Joung & Buie, 2015). Here, we use chemical imaging of particles collected following rain events in the Southern Great Plains, Oklahoma, USA and after experimental irrigation to show that raindrop impaction of soils generates solid organic particles. We find that after rain events, sub-micrometre solid particles, with a chemical composition consistent with soil organic matter, contributed up to 60% of atmospheric particles. Our irrigation experiments indicate that intensive water impaction is sufficient to cause ejection of airborne soil organic particles from the soil surface. Chemical imaging and micro-spectroscopy analysis of particle physico-chemical properties suggest that these particles may have important impacts on cloud formation and efficiently absorb solar radiation. We suggest that raindrop-induced formation of solid organic particles from soils may be a widespread phenomenon in ecosystems such as agricultural systems and grasslands where soils are exposed to strong, episodic precipitation events.

**11RR.2****New Particle Source Identification in Antarctica – Results from the 2ODIAC Field Campaign.**

Michael Giordano, Lars Kalnajs, Anita Avery, J. Doug Goetz, Sean Davis, Terry Deshler, Anondo Mukherjee, Andrew Slater, PETER DECARLO, *Drexel University*

Understanding the sources and evolution of aerosols is crucial for constraining the impacts that aerosols have on a global scale. One of the major outstanding questions in aerosol science is the source and evolution of the Antarctic aerosol population. Real-time, high-resolution chemical speciation is necessary to identify aerosol sources but this data is lacking over the continent. However, the 2ODIAC (2-Season Ozone Depletion and Interaction with Aerosols Campaign) field campaign in 2014 and 2015 saw the first ever deployment of a real-time, high resolution aerosol mass spectrometer (HR-ToF-AMS) to the continent. Data from the AMS, and a suite of other aerosol and meteorological instruments, is used to investigate the relative importance of sulfate to the total Antarctic aerosol number population. The sulfate contribution is shown to undergo three distinct phases as seasons shift from winter to summer. The first phase, in the Austral winter, is dominated by highly aged sulfate particles which comprise the majority (>50%) of the aerosol population. The second phase, previously unidentified, is the generation of a sub-40nm aerosol population of unknown composition when daily high solar irradiation is between 100-300 Wm<sup>-2</sup>. The third phase is marked by an increased importance of non-sea-spray derived sulfate to the total aerosol population (oxidation of dimethyl-sulfide, DMS). The conclusions that the third phase is due to phytoplankton production are constrained using PMF analysis on the AMS data set.

**11RR.3**

**Airborne Observations of Aerosol Composition in the Summertime Arctic.** MEGAN WILLIS, Julia Burkart, Jennie L. Thomas, Franziska Kollner, Johannes Schneider, Heiko Bozem, Peter M. Hoor, Amir A. Aliabadi, Hannes Schulz, Andreas Herber, W. Richard Leitch, Jonathan Abbatt, *University of Toronto, Toronto, Canada*

The Arctic is a complex and poorly understood aerosol environment, impacted by strong anthropogenic contributions during winter to spring, and by regional sources in cleaner summer months. Our understanding of summertime Arctic aerosol and cloud remains incomplete, in part due to a scarcity of measurements focusing on the role of regional sources in shaping aerosol chemical and physical properties. To aid in addressing these uncertainties we made measurements of aerosol physical and chemical properties aboard an aircraft, as part of the NETCARE project, allowing measurements from 60 to 3000 meters over ice and open water. This summertime campaign was based in the Canadian High Arctic, at Resolute, NU (74°N), in a general time period and location that was shown to have high biological activity in the surface ocean. Here, we focus on observations of sub-micron aerosol composition from an aerosol mass spectrometer during two general time periods. First, under stable and regionally influenced atmospheric conditions with relatively low carbon monoxide and black carbon concentrations (< 100 ppbv and < 50 ng/m<sup>3</sup>, respectively), we observed organic aerosol (OA)-to-sulfate ratios ranging from ~0.5 to greater than 6 with evidence for enhancement within the lower boundary layer. Methanesulfonic acid (MSA), a marker for the contribution of ocean-derived biogenic sulphur, was also observed in sub-micron aerosol. MSA-to-sulfate ratios ranged from near zero to ~0.3 and tended to increase within the lower boundary layer, suggesting a contribution to aerosol loading from the ocean. Second, under less-regionally influenced conditions our study area was impacted by a combination of sources including biomass burning emissions from the North West Territories, bringing higher black carbon and OA concentrations, as well as marine emissions from Hudson and Baffin Bays. With these observations we explore the composition and formation processes contributing to cloud condensation nuclei in the summertime Arctic.

**11RR.4**

**Arctic Ocean and Prudhoe Bay Influences on Arctic Aerosol Chemistry.** Matthew Gunsch, Rachel Kirpes, Tate Barrett, Claire Moffett, Rebecca Sheesley, KERRI PRATT, *University of Michigan*

Unprecedented summertime Arctic sea ice loss is opening the region to increased oil and gas extraction activities and ship traffic. Arctic aerosol emissions are expected to increase with increasing anthropogenic activities and production of sea spray aerosol. These particles have significant climate effects, including interacting with radiation, forming cloud droplets and ice crystals, and depositing onto surfaces. Given the complexity and evolving nature of atmospheric particles, as well as the challenges associated with Arctic measurements, significant uncertainties remain in our understanding of particle sources, evolution, and impacts in the Arctic. Atmospheric measurements and sampling were conducted in Barrow, Alaska during August-September 2015 and Oliktok Point, Alaska during August-September 2016 to characterize the chemical composition and mixing states of atmospheric particles. Real-time aerosol time-of-flight mass spectrometry (ATOFMS) and computer-controlled scanning electron microscopy with energy dispersive X-ray spectroscopy (CCSEM-EDX) were utilized to measure the size and chemical composition of individual particles. Additionally, organic carbon, elemental carbon, and inorganic ion concentrations, as well as size-resolved particle number concentrations, were measured to provide a full suite of atmospheric aerosol chemical composition data. Aerosol particle mixing state was observed to vary between Arctic Ocean and Prudhoe Bay influence, with significant secondary processing observed for the particles with air masses traveling to Barrow from Prudhoe Bay, the largest oilfield in North America.

**11RR.5**

**State-of-the-art New Particle Formation Research at the High-Altitude Site Jungfraujoch.** ERIK HERRMANN, Federico Bianchi, Jasmin Tröstl, Carla Frege, Ugo Molteni, Stephan Henne, Nicolas Bukowiecki, Martin Gysel, Ernest Weingartner, Josef Dommen, Urs Baltensperger, *Paul Scherrer Institute*

Model studies suggest that up to 45% of cloud condensation nuclei (CCN) are the result of new particle formation (NPF) in the atmosphere with a significant fraction produced in the free troposphere (FT). NPF has been extensively studied and is therefore reasonably well understood in the planetary boundary layer (PBL). At high altitude, however, the level of understanding is much lower, with fewer data sets, shorter observations, and less sophisticated instrumentation. As a consequence, global models continue to consider free tropospheric nucleation merely via the sulfuric acid-water pathway.

Starting in 2013, NPF at high altitude has been the focus of a number of completed, on-going and planned campaigns at the Jungfraujoch research station (3580 m a.s.l.) in the Swiss Alps. These campaigns saw the first deployments of an API-TOF and a CI-API-TOF at high altitude to investigate the chemical composition of nucleating clusters. In addition, a nano-SMPS, a particle size magnifier, and a neutral cluster and air ion spectrometer were employed to physically characterize particle formation and early growth. Also, the contribution of NPF to CCN numbers was investigated. The FLEXPART model and trace gas observations were used to determine how PBL influences affect nucleation. Since October 2014, aerosol measurements at a nearby site (Jungfraujoch East Ridge, 3700 m a.s.l.) allows for a closer look at how nucleation varies locally.

The most recent Jungfraujoch nucleation research has so far been published in two dedicated manuscripts (Bianchi et al., *Science*, 2016; Tröstl et al., *JGR-A*, 2016) and as part of a long-term analysis (Herrmann et al., *JGR-A*, 2015). Findings include that nucleation is mostly driven by highly oxygenated multifunctional compounds (HOMs), but also sulfuric acid-ammonia events have been observed. We also found that NPF is limited to a narrow window of opportunity after significant PBL contact of an air mass.

**11SP.1**

**Changes in the Single Particle Fluorescence of Biological Particles Exposed to Outdoor Environments and Their Relationship to the Atmospheric Chemistry.** JOSHUA SANTARPIA, Sean Kinahan, Andres Sanchez, Don Collins, Yong-Le Pan, Steven Hill, Shanna Ratnesar-Shumate, Thomas Hawkyard, *Sandia National Laboratories*

Biological aerosols are studied for many reasons, including their effects on cloud properties as both cloud condensation and ice nuclei. Predominantly, however, biological aerosols are studied because of their effects on human, plant and animal health. This can range from allergy to disease and is often concerned with the detection and measurement of bioaerosols used as biological weapons. Changes that occur to biological particles when exposed to certain ambient conditions have been shown to affect the ability to measure them through common techniques. Over the last several years, changes in biological particles exposed to ambient conditions in both Adelphi, MD and Houston, TX have been studied. In general, single particle fluorescence measurements have proven the most useful in understanding the chemistry affecting these particles. These studies are accomplished by seeding particles into a chamber exposed to ambient conditions for periods of several hours. The chambers used in this study employ a rotating drum constructed with an FEP Teflon film to allow sunlight to penetrate and an ePTFE membrane to allow ambient trace gases to permeate into the drum, while still containing the biological particles being studied. Biological aerosol particles were sampled with a TSI UV-APS (ex. 355 nm), a Single Particle Fluorescence Spectrometer (ex. 351 and 263 nm) an AGI-30 impinger and recently, a WIBS 4A. Collected aerosols were assayed for viability/infectivity and PCR. Solar intensity, relative humidity and ozone concentration were measured locally, and other meteorological data and air quality measurements were retrieved from local air quality monitoring sites. An aggregate of results and conclusions from these studies will be presented.

**11SP.2****Mixing of Secondary Organic Aerosols from Terpenes: Effects of Relative Humidity, Temperature and Oxidation State.**

QING YE, Mary Alice Upshur, Ellis Shipley Robinson, Regan Thomson, Ryan Sullivan, Franz Geiger, Neil Donahue, *Carnegie Mellon University*

While practically all chemical transport models assume instantaneous ideal mixing of organic constituents from various sources, very few experimental studies have been performed to prove this assumption. Specifically, direct investigation on mixing of semi-volatile organic compounds (SVOCs) produced from secondary organic aerosol (SOA) formation is scarce. In this work, we study mixing dynamics of SOA generated from mono-terpenes (alpha-pinene and limonene) and a sesquiterpene (beta-caryophyllene), with a focus on probing any diffusion or volatility limitation that may influence effective absorption of SVOCs. By using isotopically labeled precursors and quantitative single particle mass spectrometry, we are able to separate different SOA populations after we combine them into a uniform container. We then analyze their mixing via SVOC exchange. We will also explore the mixing process under various atmospherically-relevant temperatures, relative humidities and oxidation states.

Our preliminary results show that SOA from alpha-pinene ozonolysis is able to uptake SVOCs on a timescale shorter than one hour, indicating that there are no significant diffusion barriers in the condensed phase. By quantifying the extent of vapor exchange, we show that SOA from alpha-pinene ozonolysis contains 20%{40% effective semi-volatile material depending on the total SOA concentration. However, SOA from ozonolysis of beta-caryophyllene resists SVOC uptake under low and moderate RH on the timescale of several hours. At 50% RH, the resistance diminishes and mixing occurs. This work, complemented by existing SOA rheological studies in the literature, will provide valuable information to the treatment of SOA partitioning in chemical transport models, and ultimately improve our prediction of air quality and climate change.

**11SP.3****Comparison of Nanosecond and Femtosecond Laser Ablation in Single Particle Mass Spectrometry.**

RAMAKRISHNA RAMISETTY, Ahmed AbdElMonem, Xiaoli Shen, Harald Saathoff, Thomas Leisner, Claudia Mohr, *Karlsruhe Institute of Technology*

Single particle mass spectrometry is a valuable technique for the analysis of size, composition, and mixing state of individual aerosol particles. Laser ablation is the dominant method for desorption and ionization of the particles. Due to their relatively high power, UV wavelength, and good trigger options, excimer lasers are often used to realize desorption and ionization in one single step. With the advent of high-energy, ultra-short pulse lasers, i.e. femtosecond (fs) laser ablation allows for precise removal of material with high spatial and depth resolution. Ultra-short pulses are less thermal diffuse and cause less collateral damage than longer pulses.

In this work we use the laser ablation aerosol time-of-flight single particle mass spectrometer LAAPTOF (Aeromegt GmbH), originally equipped with a 193 nm excimer laser. This work will discuss mass spectra from the original excimer laser LAAPTOF in comparison with spectra from the same instrument coupled to an fs-laser with similar pulse energy but longer wavelengths. Since triggering of typical fs-lasers is hard to realize, some technical changes were applied allowing the acquisition of mass spectra with hit rates comparable to the original set up. Differences in the mass spectra observed for single size particles of polystyrene, SiO<sub>2</sub>, NH<sub>4</sub>NO<sub>3</sub>, NaCl, and custom made core shell particles will be discussed for different focus positions of the laser, for different laser power, and also for different wavelengths.

**11SP.4**

**Two-Color Digital Holography: Simultaneous Particle Imaging and Scattering Pattern Measurement.** MATTHEW BERG, *Mississippi State University*

The recent availability of high resolution optoelectronic sensors has revived holography as a useful technique to study aerosol particles. By placing a two-dimensional detector in a collimated laser beam, the interference pattern produced by a particle in the beam can be easily measured. This pattern is the particle's in-line hologram and useful information can be extracted from it directly. For example, applying a Fourier-transform operation yields a silhouette-like image of the particle, thus revealing its size and shape without a priori information. We will present our new laboratory work that employs two wavelengths of light and digital holography to image particles and measure their two-dimensional light scattering patterns. Both the imaging and pattern measurement are achieved simultaneously so that a particle's scattering pattern can be unambiguously associated with its physical image.

**11SP.5**

**Analysis of the Formation Process of Crystalline Microparticles from Evaporation of Monodisperse Solution Droplets.** Alberto Baldelli, REINHARD VEHRING, *University of Alberta*

The particle formation process from evaporating, aqueous microdroplets containing one or two solutes, sodium nitrate and potassium nitrate, was studied. Individual microdroplets in a droplet chain were analyzed during and after the evaporation process. The aerodynamic diameter of the droplets and the resulting particles was measured as a function of time during the complete drying process. The droplets were generated using a piezoceramic dispenser with an inner diameter of 30  $\mu\text{m}$ . The initial droplet diameter varied from 70 to 85  $\mu\text{m}$ . These droplets were injected into a dry laminar gas flow and microparticles in a diameter range of 4 to 10  $\mu\text{m}$  were extracted after the evaporation was complete. Initial conditions differed in drying gas temperature, 25 to 150°C, initial solution concentrations, 5-10-5 to 10 mg/ml, and sodium to potassium molar ratios of the two crystallizing solutes, 30:70, 50:50, 70:30, and 100:0. Properties of the collected microparticles, such as morphology and particle density by electron microscopy, internal structure by focused ion beam milling, solid phase by low-frequency shift Raman spectroscopy, and near surface elemental composition by energy-dispersive X-ray spectroscopy, were studied and correlated with a particle formation model which predicted the onset of saturation and crystallization on the surface of the droplets. The model accounted for changes of material properties during the drying process. The interpretation of the experimental results showed that longer time available for crystallization correlates with larger crystal size, higher degrees of crystallinity, and lower particle density in the final microparticles. Furthermore, the solute which reached supersaturation first was enriched near the surface of the microparticles. These results provide a basis for rational design of multi-component crystalline microparticles.

**12AC.1****Role of Sub-2 nm Particles in New Particle Formation.**SHANHU LEE, *University of Alabama in Huntsville*

Atmospheric new particle formation starts with the formation of clusters and the subsequent growth of these clusters. There have been several different theories of the role of these newly formed clusters, and some of the theories even contradict to each other. Direct measurements of atmospheric sub-2 nm particles in various atmospheric environments are also lacking, and this hampers the understanding of the role of these clusters playing in new particle formation processes. Here, we present a series of measurements of sub-2 nm particles made with particle size magnifier (PSM) in several different locations in the United States, including the marine boundary layer, polluted continental sites, and forests that are remote or affected by transported sulfur plumes. Our results show that in these different environments, sub-2 nm particles exist only when there are sufficient sulfuric acid concentrations. Our results are thus different from other observations made in the Finnish boreal forest, which show that sub-2 nm particles are present during day and night, and regardless of sulfuric acid concentrations. This difference indicates that different new particle formation mechanisms, as opposed to a universal mechanism, should be applied in different atmospheric conditions. Our measurements also show that these sub-2 nm particles grow differently, under different atmospheric conditions, depending on available condensable species.

**12AC.2****Nanoparticle Growth Measurements in a Flow Tube Reactor.**MURRAY JOHNSTON, Chris Stangl, Justin Krasnomowitz, Andrew J. Horan, Michael Apsokardu, *University of Delaware*

New particle formation (NPF) is observed around the world and is thought to contribute substantially to the concentration of cloud condensation nuclei (CCN). Newly formed particles must grow quickly if they are to reach the relevant size range to serve as CCN. In order to better predict the frequency, growth rates, and climatic impacts of NPF, knowledge of the chemical mechanisms by which nucleated nanoparticles grow is needed. We have constructed and tested a flow tube reactor that allows reactant concentrations and reaction times to be systematically varied. The reaction time can be as long as ~40 min, making it possible to investigate processes with atmospherically relevant growth rates approaching 10 nm/hr for 10 nm dia. particles. Initial experiments are focused on distinguishing the contributions of sulfuric acid and oxidized organics to particle growth using chemical composition measurements with the nano aerosol mass spectrometer (NAMS). The experimental approach allows the organic molecular growth rate to be quantified through comparison with condensational growth by sulfuric acid. These experiments and initial results will be presented.

**12AC.3**

**Composition and Volatility of the Aerosol Products of Reactions of Catechol, an Important Biomass Burning Emission, with Hydroxyl and Nitrate Radicals.** ZACHARY FINEWAX, Paul Ziemann, Joost de Gouw, *University of Colorado*

Biomass burning emits a complex mixture of gas and particle phase organic compounds into the atmosphere that affect climate, visibility and air quality. Because biomass burning is not only a large source of primary organic aerosol, but also a potential source for secondary organic aerosol (SOA) precursors, it is important to determine the mechanisms by which SOA is formed from the volatile organic compounds emitted. Catechol, a dihydroxybenzene isomer, is emitted from wood burning (likely as a product of lignin pyrolysis), and although modeling studies have identified it as a potentially significant SOA precursor, its ability to form SOA had not yet been thoroughly investigated in the laboratory. In the studies described here, catechol was introduced into an 8000 L environmental chamber composed of PTFE Teflon and reacted with hydroxyl (OH) radicals in the presence of NO<sub>x</sub> and with nitrate (NO<sub>3</sub>) radicals, under dry conditions. Gas- and particle-phase products were analyzed using real-time and offline mass spectrometry as well as gas and liquid chromatography. Both reactions form SOA in high yields, with 4-nitrocatechol being the major product. Measurements of the vapor pressure of 4-nitrocatechol conducted using temperature-programmed thermal desorption particle beam mass spectrometry indicate that at typical atmospheric aerosol loadings this product will be semi-volatile and thus present in both the gas and particle phase, consistent with observations from biomass burning affected regions of the atmosphere. The mechanism of catechol oxidation differs from that of non-oxygenated aromatic compounds, as evidenced by the SOA composition and product yields.

**12AC.4**

**Rapid Autoxidation of Squalene Aerosol by Hydroxyl Radicals Forms Multifunctional Hydroxyperoxides.** NADJA HEINE, Kevin Wilson, *Lawrence Berkeley National Laboratory*

As the most abundant unsaturated constituent of skin lipids, squalene plays an important role in indoor air quality, and serves as a proxy for unsaturated hydrocarbons in the atmosphere. Once in contact with oxidants in air, photochemical transformations readily occur, leading to fragmentation, isomerization and/or functionalization. The products of these transformations may pose significant risks to human health due to the oxidative stress following inhalation or due to contact with skin. While ozonolysis of squalene has been studied intensively, little is known about the kinetics, reaction pathways and product formation following reactive uptake of hydroxyl radicals (OH), in particular under environmental conditions.

Aerosol continuous flow reactor measurements in combination with vacuum ultraviolet photoionization aerosol mass spectrometry and high resolution mass spectrometry allow the chemical composition of an aerosol to be precisely determined and monitored over the course of chemical processing. In this study, the dependence of OH concentration ( $[OH]=10^5-10^8$  molec./cm<sup>3</sup>) on the oxidation of squalene aerosol is explored, and the impact of relative humidity (RH) on product formation is investigated. The reaction mechanism is constrained by a stochastic kinetics model.

With decreasing [OH], an unexpectedly large acceleration in the effective heterogeneous OH reaction rate was found. This acceleration originates from free radical chain reactions, propagated by activated alkoxy radicals, and formation of OH inside the particle. At high [OH], however, chain termination reactions prevail. Analysis of reaction products with high resolution mass spectrometry reveals the formation of highly oxidized multifunctional reaction products. Comparison to a stochastic kinetics model suggests that these products are multifunctional hydroxyperoxides (QOOH), formed via inter- or intramolecular H-abstraction. Their quantity strongly depends upon relative humidity, and is highest under dry conditions.

The effects of QOOH on indoor air quality and skin are yet unknown, however the structurally similar squalene peroxide (formed outside via UVA/UVB and photooxidizer) has been shown to cause inflammatory skin diseases such as skin cancer and skin ageing. The rapid chemical transformation under low [OH] conditions might suggest that oxidation of unsaturated organic particles may play a more prominent role than expected.

**12AC.5**

**Advances in Computational Tools For Functional Group Analysis of Organic Aerosols.** SATOSHI TAKAHAMA, Matteo Reggente, Giulia Ruggeri, Adele Kuzmiakova, Fabian Bernhard, Barron Henderson, Ann Dillner, *EPFL*

The molecular diversity of compounds in atmospheric organic aerosol (OA) poses challenges for measurement and modeling of these complex mixtures. Common methods to interpret OA composition in atmospheric or laboratory measurements and numerical simulations include speciated molecule concentrations and atomic ratios. Functional group (FG) abundance in OA provides an intermediate chemical resolution that retains source class fingerprints, capability for OA mass estimation, and physicochemical properties such as hygroscopicity, volatility, and reactivity. However, extracting FG content from measurements such as infrared (IR) absorption spectra or numerical models have been impeded by our lack of computational tools required to harvest this information. We therefore present two sets of tools we have recently developed to accomplish model and measurement interpretation through FGs.

First, we describe tools based on chemoinformatic algorithms for extracting FG abundances from molecularly speciated measurements and simulation. We demonstrate its application to GC-MS measurements and simulations of secondary OA formation using the Master Chemical Mechanism v3.2 with gas/particle partitioning. These FG abundances are compared against observed FG abundances from IR spectroscopy.

We further present chemometric tools for FG estimation of OA using IR spectroscopy. While the sample collection and signal acquisition can be relatively simple by this technique, the processing of the IR spectrum requires several algorithms to correct for substrate interferences and relate the remaining analyte absorbance to abundances of vibrational modes present in the organic mixture. Judicious selection of algorithms permit not only quantification of FG abundance, but statistical identification for the most relevant absorption bands related to concentrations of collocated measurements (such as organic and elemental carbon measured by thermal optical methods). We demonstrate its application to samples routinely collected in the IMPROVE network.

**12AE.1**

**Does it Blend? Combining Observations and Model Output to Determine Health Implications of Wildfire Smoke Exposure.** WILLIAM LASSMAN, Bonne Ford, Ryan Gan, Gabriele Pfister, Sheryl Magzamen, John Volckens, Emily Fischer, Jeffrey R. Pierce, *Colorado State University*

Exposure to high concentrations of particulate matter (PM) present during acute pollution events is associated with adverse health effects. While many anthropogenic pollution sources are regulated in the United States, emissions from wildfires are difficult to characterize and control. With wildfire frequency and intensity in the western U.S. projected to increase, it is important to determine more-precisely the effect that wildfire emissions have on human health.

Three tools are frequently used to determine population-level exposure to ambient air pollution: (1) in-situ monitors that provide exact surface concentrations but with limited spatial resolution, (2) satellite observations that provide broad spatial coverage limited surface-level detail, and (3) chemical transport models (CTMs) that provide spatially continuous surface information but with limitations in model accuracy. Wildfires present challenges to all three of these approaches: wildfires are rapidly evolving and highly heterogeneous, making accurate modelling of air quality challenging; the altitude of a biomass-burning plume is dependent on both the fire properties and the meteorological conditions, making it challenging to determine surface concentrations from satellite observations; and the steep concentration gradients of wildfire smoke may be too narrow for even a dense surface site network to resolve.

In this presentation, we will show that combinations of the three approaches can capitalize on their individual strengths while mitigating their weaknesses. We use the Weather Research and Forecasting model with Chemistry (WRF-Chem), MODIS and GOES satellite observations, and in-situ PM monitors. We blend these observations together to produce surface-concentration estimates that are more accurate than the individual approaches alone. Finally, we present an application of our exposure model in a health effects analysis to estimate the association of smoke exposure on cardiopulmonary hospitalizations during the 2012 Washington State wildfire season.

**12AE.2**

**Examining Nanoparticle Oral Exposure Using a Multi-Vessel Gastrointestinal Apparatus.** JESSICA AXSON, Andrew Ault, Justin Keeney, Sun Chenxi, Ingrid Bergin, Martin Philbert, Andrew Maynard, *University of Michigan, Ann Arbor MI*

Nanoparticles (NPs) are present in a wide variety of commercial products and industrial processes. One way NPs can enter the human body is through oral exposure. Examining the fundamental physicochemical changes in NP size under conditions representative of the gastrointestinal (GI) tract is important for elucidating the impacts of NPs on the human body. To examine the change in NP characteristics as they are digested in vitro, a well-known and well-characterized pharmaceutical drug dissolution testing apparatus, the USP II, was utilized. Prior NP studies have rotated or stirred the media with in heated baths, with subsequent additions of media representing that from gastrointestinal compartments. In this work, a three vessel USP II apparatus was designed to mimic conditions and movement within the gastrointestinal system. Using this approach we will be able to monitor the simultaneous movement and changes to NP as they go from one gastrointestinal compartment to the next, in the stomach, duodenum, and jejunum. In this study, we examined 20 nm citrate coated silver nanoparticles (AgNP), Ni-NP, and CoO-NP within the USP II multivessel system (MVS). Particles were monitored in situ for changes in diameter using nanoparticle tracking analysis (NTA) and separately for changes in surface structure, including the formation of a protein corona, using scanning electron microscopy with electron diffraction x-ray spectroscopy (SEM-EDX). This research is supported through NIH Grant U01ES020128.

**12AE.3**

**Prediction of Delivery of SOA to Air-Liquid Interface Cells in Vitro Using Electrostatic Precipitator.** ZECHEN YU, Myoseon Jang, Huanhuan Jiang, Tara Sabo-Attwood, Sarah Robinson, *University of Florida*

In vitro studies using human airway lung cells have been frequently exploited to reduce animal use for the hazard screening of potential pulmonary toxic aerosols and augment understanding of cellular biological mechanisms in small quantities of aerosol. In particular, air-liquid interface (ALI) cell exposure method has been used to mimic the exposure of airway epithelial in pulmonary system to air pollutants. In order to better characterize the cellular responses of in vitro human airway cells to atmospheric organic aerosols, both efficient collection of aerosols and accurate dose prediction are essential. In this study, SOA was generated via ozonolysis of alpha-pinene and d-limonene using an indoor smog chamber. The produced SOA was efficiently delivered to ALI cells by a commercialized air-liquid exposure device (CULTEX RFS Compact) that was connected to an electrostatic precipitation (ESP). The in vitro ALI cells are cultured on the insert membrane and hosted by the exposure device. The SOA dose model was established based on several physical parameters, i.e. particle size, the deposition voltage, sampling flow rate and particle loss to the sampling lines. The feasibility of dose model was demonstrated against the filter mass of terpene-ozone SOA ( $R^2=0.93$ ). A clear dose-response relationship was obtained between SOA dose and the oxidative potential, which was measured using dithiothreitol assay. The dose-response relationship between toluene SOA and cellular responses (IL-8) was observed using the CULTEX RFS Compact ALI cell exposure system. The dose model integrated with exposure system are suitable for applying to toxic study of SOA.

**12AE.4**

**Establishment and Characterization of a Mouse Chamber for Investigating Health Effects.** XINZE PENG, David R. Cocker III, David Lo, Emma Aronson, *University of California, Riverside*

Recently we completed a new 540 L chamber for studying the exposure of mice to multiple air contaminants. The chamber can simultaneously control for multiple VOCs, particulate size and mass concentrations (synthetic or directly from source), active soils and/or pollens. The design is a result of a collaboration between the UC Riverside School of Medicine, CE-CERT, and plant/botany sciences. The system provides for controlled and well characterized whole animal exposures (typical duration of 1-2 weeks) where dosage is by inhalation of the air pollutants. Uniform dispersion and exposure stability of each class of air pollutants was characterized. Stability, range, and characterization of the system are summarized along with generation of air pollutants by the test subjects.

**12AE.5**

**Weathering and Heating of a Carbon Nanotube/Epoxy Composites and the Impact on Particle Release and Toxicity.** Lukas Schlagenhauf, Bahareh Kianfar, Tina Buerki-Thurnherr, Yu-Ying Kuo, Yeon Kyoung Bahk, Adrian Wichser, Frank Nüesch, Peter Wick, JING WANG, *ETH Zurich/Empa*

Weathering causes a weakening of the nanocomposite matrix, and thus can induce a release of embedded carbon nanotubes (CNTs) when an abrasion process is applied. In this study, the impact on the release of particles from a CNT/epoxy nanocomposite by two weathering processes was investigated, for immersion in water and UV-light exposure. We measured the water uptake kinetics and chemical changes on the surface due to UV exposure. No additional release of CNTs due to weathering was detected when an abrasion process was applied. The toxicity tests revealed that abraded particles from the nanocomposites did not induce additional acute cytotoxic effects compared to particles from the neat epoxy.

One of the applications is to use the CNTs as flame retardants in nanocomposites. We performed experiments to decompose the samples in a furnace by exposure to increasing temperatures at a constant heating rate and under ambient air or nitrogen atmosphere. Different samples were investigated, including a neat epoxy, nanocomposites with 0.1 wt% and 1 wt% CNTs, and nanocomposites with functionalized CNTs. The results showed that the added CNTs had little effect on the decomposition kinetics of the investigated samples, but the weight of the remaining residues after decomposition was influenced significantly. Analysis of collected particles by TEM revealed that no detectable amount of MWCNTs was released, but micrometer sized fibrous particles were collected.

**12CA.1**

**Molecular Chemistry of Brown Carbon (BrC) in Biomass Burning Aerosols.** PENG LIN, Julia Laskin, Sergey Nizkorodov, Alexander Laskin, Nir Bluvshstein, Yinon Rudich, *Pacific Northwest National Laboratory*

Atmospheric brown carbon (BrC), which represents a poorly-defined collection of particulate organic compounds that efficiently absorb solar radiation in the ultraviolet (UV) and visible (Vis) region, is ubiquitously found in the global troposphere. Biomass burning (BB), in forms of wildfire and prescribed fire, is suggested to be a significant source of BrC in the atmosphere. In this study, the molecular level chemical composition of BrC from BB smoke particles and BB influenced atmospheric aerosols was investigated with a HPLC/PDA/HRMS platform. In contrast to the extremely compositional complexity and diversity of BrC freshly emitted from BB, the chemical composition of BrC in atmospherically aged BB aerosols was relatively simple, where majority of the light absorption can be explained by nitro-phenolic compounds and their derivatives. The results indicate that atmospheric aging processes play important roles in regulating the light absorption properties and chemical characteristics of BrC emitted from BB. The chemistry of BrC during the aging processes was revealed through a series laboratory controlled aging experiments on BB smoke particles and mimic standard compounds.

**12CA.2**

**Evolution of Optical Properties of Brown Carbon Aerosols as a Function of Atmospheric Aging.** BENJAMIN SUMLIN, Robert Pattison, Rajan Chakrabarty, *Washington University in St Louis*

Long-lasting smoldering phases of wildfires emit large amounts of brown carbon (BrC) aerosol, a component of organic carbon which absorbs incoming solar radiation in the near ultraviolet visible spectrum. There is a currently a large gap in our knowledge of intensive optical properties of BrC aerosols, and how these properties evolve as a function of atmospheric processing. With increase in atmospheric residence time, these aerosols could be subjected to physicochemical alterations which could in turn affect their radiative properties. In this study, a Potential Aerosol Mass (PAM) reactor was used to simulate atmospheric oxidation processes on timescales ranging from one to several days. Smoldering combustion of Alaskan peat land samples was conducted at the Washington University Biomass Burning Chamber, and the emitted BrC aerosols were "aged" to different timescales using a PAM reactor under the combined influence of OH, O<sub>3</sub>, and UV light. Photoacoustic spectrometers with integrated nephelometers were used to measure in real-time the absorption and scattering coefficients and single scattering albedo of the aerosols at 375, 405, 532, 671, and 1047 nm wavelengths. In addition, a three-wavelength TSI nephelometer (450, 550, and 700 nm) was used to measure the mean hemispherical backscatter fraction and asymmetry parameter. Electron microscopy analysis of the BrC aerosols revealed a spherical morphology, which facilitated the calculation of their index of refraction using Lorenz-Mie theory. This talk will provide a comprehensive comparison of the measured optical properties of both fresh and aged BrC aerosols in the 375 – 1047 nm (UV-Vis-IR) spectrum.

**12CA.3****How the Characterization and Model Representation of Biomass Burning Emissions Affect SOA Predictions.**

KELLEY BARSANTI, Lindsay Hatch, Brian K. Lamb, Christine Wiedinmyer, Robert J. Yokelson, Serena H. Chung, *University of California, Riverside*

Biomass burning (BB) is the second largest global emissions source of non-methane organic compounds (NMOCs), and thus potentially a significant source of secondary organic aerosol (SOA) on local to global scales. Until recently, a large mass fraction of NMOCs in BB emissions (up to 80%) has remained uncharacterized or unidentified. Models used to simulate the air quality and climate impacts of BB thus have relied on very limited chemical characterization of the emitted compounds. Recent application of advanced analytical techniques have enabled identification and quantification of an unprecedented fraction of BB NMOCs, including previously unspciated intermediate volatility organic compounds (IVOCs). In this work, BB emissions profiles have been updated using these recent data; the sensitivity of predicted SOA mass concentrations to differences in emission speciation profiles have been evaluated using box model (0-D) and chemical transport model (3-D) simulations. The updated BB emissions speciation profiles lead to markedly different surrogate compound distributions than the default speciation profiles. The resultant effects on predicted SOA mass concentrations, and the implications of using traditional approaches for mapping individual compounds to mechanism species, will be presented.

**12CA.4****Free Tropospheric Brown Carbon: Radiative Impact and Sources.** YUZHONG ZHANG, Haviland Forrister, Yuhang Wang, Athanasios Nenes, Rodney J. Weber, *Georgia Institute of Technology*

Observations from recent aircraft campaigns over the continental United States (DC3, SEAC4RS) have shown that brown carbon (BrC) is prevalent in the troposphere, and enriched with respect to BC at high altitude (5–12 km). However, the radiative impact and sources of this high-altitude BrC is largely unknown. Using radiative transfer calculations constrained by DC3 and SEAC4RS observations, we find that BrC ( $3.5 \text{ Wm}^{-2}$ ) can be responsible for  $\sim 35\%$  of the instantaneous (noontime, solar zenith angle  $25^\circ$ ) radiative absorption at the tropopause by aerosols ( $10 \text{ Wm}^{-2}$ ). Although the concentration of BrC at high altitude was lower than that at low altitude ( $<5 \text{ km}$ ), they contributed almost equally to the radiative forcing at the tropopause, underscoring the radiative impact of high-altitude BrC. Analysis of DC3 deep convection data shows that BrC in outflow was  $\sim 70\%$  of that in inflow. In contrast, only  $\sim 25\%$  BC got through. This suggests that deep convection may be an important transport mechanism of BrC to high altitudes. The mechanism may also involve processing by ice cloud and/or condensation of semi-volatile compounds.

**12CA.5****Molecular Characterization of Brown Carbon in Fine****Particulate Matter in China.** CAIQING YAN, YuryDesyaterik, Jeffrey Collett, Mei Zheng, *Peking University*

Brown carbon has been recognized as potential important contributor to climate change. High level of light-absorbing brown carbon has been found and reported in China. However, little is known about the relationship between chemical composition of brown carbon and its optical property. In this study, atmospheric brown carbon at an urban site located in Beijing and a suburban site in Hebei provinces, China were investigated. High performance liquid chromatography equipped with a UV/Vis absorbance detector and a time-of-flight (ToF) mass spectrometer (LC/DAD-ESI-HRTOFMS) was applied to determine elemental compositions of light-absorbing organic compounds, in order to better understand the light-absorbing properties of brown carbon and detailed chemical composition of individual organic compound that can absorb light. Our results showed that nitrophenols and aromatic carbonyls were major atmospheric light-absorbing organic compounds. Compounds with elemental formula such as C<sub>6</sub>H<sub>5</sub>NO<sub>3</sub>, C<sub>6</sub>H<sub>5</sub>NO<sub>4</sub>, C<sub>7</sub>H<sub>7</sub>NO<sub>3</sub> and C<sub>7</sub>H<sub>7</sub>NO<sub>4</sub> were major light absorbers found in almost all the ambient samples. More light absorbers (e.g. C<sub>8</sub>H<sub>6</sub>O<sub>4</sub>, C<sub>8</sub>H<sub>9</sub>NO<sub>3</sub>, C<sub>8</sub>H<sub>9</sub>NO<sub>4</sub>, C<sub>9</sub>H<sub>16</sub>O<sub>4</sub>, C<sub>10</sub>H<sub>7</sub>NO<sub>3</sub>) were found in winter samples than summer samples. Comparison of brown carbon chromophores were performed between summer and winter in Beijing, as well as urban versus suburban sites. The change of light absorbers in atmosphere and its associated potential sources will be further discussed.

**12CM.1****Enhancement of Nanoparticle Removal for HVAC and Indoor Air Cleaner Filters by Adding Nanofibers.** SHENG-CHIEH CHEN, Min Tang, David Y. H. Pui, *University of Minnesota*

Pleated electret HVAC filters are often used in residence to mitigate the particles that originate both indoors and outdoors. However, there are two concerns about the performance of electret media: 1. low efficiency at particle diameter of 10-30 nm at initial filtration condition, which represent the MPPS (most penetrating particle size) and 2. significant efficiency reduction during the loading process. In this study, a filter media prototype composed of commercial HVAC electret media and nanofiber layer was proposed and tested. For the initial efficiency, it was found that the nanofiber layer of the composite media can increase the efficiency at the MPPS (20-30 nm) significantly. Besides, the new media made a fully use of both the mechanical force and electrostatic charge as it has good performance over the loading process as shown in the following. The loading performance of the new media was evaluated by polydisperse NaCl particles which mimicked the size distribution of typical atmospheric PM<sub>2.5</sub>. It was found that the efficiency only decreased 5.1, 11.0, 14.4, 11.6, 5.7 and 5.3% compared with the initial efficiency for particles with sizes of 50, 80, 100, 200, 300 and 500 nm respectively. This reduction due to the shielding of fiber charge was less than 1/3 in comparison with the solely electret layer without adding nanofibers. Surprisingly, the overall loading FOM (figure of merit) of the composite media was close to that of electret media, indicating there was a negligible trade off pressure increase by adding the nanofiber layer. In conclusion, this type of combination provided a unique structure to take advantage of electret media and nanofiber layer.

**12CM.2**

**Modeling Concentrations of Ultrafine Particles and Volatile Organic Compounds Resulting from Emissions from Desktop 3D-Printers with Multiple Filaments in an Office Space.** PARHAM AZIMI, Torkan Fazli, Brent Stephens, *Illinois Institute of Technology*

Desktop 3D-printers are rapidly gaining in popularity and fused filament fabrication (FFF) 3D-printers are currently the most widely used technology. Unfortunately, a few recent studies have also shown that potentially hazardous gases and particles are emitted from many FFF 3D-printer and filament combinations. However, there are currently no comprehensive studies of the likely human exposures to 3D-printer emissions in realistic indoor environments. Here we use recent measurements of emission rates of both UFP and three speciated VOCs from a variety of desktop FFF 3D-printer and filament combinations to model the magnitudes of human exposures to these same pollutants that would likely be present inside a one-story small office building using a multi-zone airflow and contaminant transport analysis modeling software. We also evaluate the likely impacts of four potential control strategies, including: (i) upgrading the central HVAC filtration; (ii) operating a portable, stand-alone air-cleaner (iii) installing spot ventilation systems; and (iv) reducing the printer emissions with a custom-made enclosure. Results demonstrate that the predicted maximum hourly exposures to UFPs emitted from the 3D-printers in the near-distance zone range from  $\sim 90$  #/cm<sup>3</sup> for Laybrick to  $\sim 83,000$  #/cm<sup>3</sup> for polycarbonate and ABS filaments, while the UFP concentration in the “adjacent” zone is  $\sim 88\%$  lower than the near-distance zone. Almost none of the particles can reach to the “far” zone. Results for speciated VOC emissions show similar trends, as the predicted maximum hourly exposure to emitted VOCs in “near-distance” zone ranged from  $\sim 0.7$  to  $82$   $\mu\text{g}/\text{m}^3$  for lactide and caprolactam, respectively, while VOC concentrations in the adjacent and far zones were  $\sim 74\%$  and  $\sim 99\%$  lower than the near-distance zone, respectively. Fully effective spot ventilation showed the maximum removal (close to 100% for both UFPs and VOCs) in all zones, while upgrading the central HVAC filtration to MERV 16 had the lowest effectiveness.

**12CM.3**

**Identifying Regimes of Mercury Adsorption Enhancement and Inhibition within Electric Utility ESPs.** HEREK CLACK, *University of Michigan*

Early mercury emissions control tests operated on the presumption that mercury adsorption within electrostatic precipitators (ESPs) was the result of accumulated fly ash or sorbent deposits on internal ESP collection electrodes. Later developments revealed the role of suspended aerosols, either ash or powdered mercury sorbents. A continuing, implicit assumption has been that the two mechanisms contribute in an additive fashion to overall mercury removal efficiency. The present study computationally models the fluid and electric fields, and the charged aerosol kinematics and mass transfer to demonstrate for the first time that the two mechanisms are coupled. Weakly adsorbing fly ash or sorbent deposits contribute little to overall removal efficiency. However, strongly adsorbing deposits produce mercury-lean regions in which adsorption by suspended particles is diminished. Overall removal efficiency for the two coupled mechanisms is shown to be less than the sum of their individual contributions.

**12CM.4**

**Effect of Slip Flow on the Filtration Performance of Nanofiber Filter.** HYUN-JIN CHOI, Toshiyuki Fujimoto, Li Bao, Yuki Inui, Takafumi Seto, Yoshio Otani, *Kanazawa University*

Air filter plays important role in various industrial fields such as air cleaning, particle sampling, and respiratory protection because of its simple structure and readiness of application with a relatively low cost. The conventional filtration theory suggests that the collection performance be improved by reducing the fiber diameters. Therefore, air filters made of nanofibers are of great concern in order to achieve a high collection efficiency and a low pressure drop at same time due to slip flow effect. In the present work, we studied the slip flow effect on the collection efficiency of particles through both experiments and numerical simulation with Langevin's equation. In the experiments, a new type of fluororesin nanofiber filter with the mean fiber diameter of 99.4 nm was prepared as a test filter medium and the effect of inhomogeneity factor on the filtration performance was investigated. In obtaining the inhomogeneity factor, we conducted the measurement of pressure drop at reduced pressures to exclude the slip flow effect on the drag force. As a result, we found that, for the nanofiber filter with the inhomogeneity factor of 6.5, the slip flow effect on the collection efficiency appears in the vicinity of Most Penetrating Particle Size (MPPS) which is the transition regime from Brownian diffusion and interception.

**12CM.5**

**Atmospheric Simulation within the WRF Model for SALSCS Evaluation.** QINGFENG CAO, Lian Shen, David Y. H. Pui, *University of Minnesota*

A Solar-Assisted Large-Scale Cleaning System (SALSCS) was proposed previously, which was aimed at generating large quantities of air flow for air pollution remediation. Numerical models were developed within ANSYS Fluent to estimate the flow rate driven by each SALSCS system to be  $2.64 \times 10^5$  m<sup>3</sup>/s. To evaluate how much air pollution the SALSCS system is able to clean up for a city area, our current work involves utilizing the Weather Research and Forecasting (WRF) model to simulate the atmospheric flow with air pollution considered over the terrain of Beijing city and its surrounding regions. The flow rate generated by each SALSCS has been implemented into the WRF model by specifying the updraft velocity at the grid cells occupied by the system in the computational domain according to the previously obtained flow rate. Locations of the total six SALSCS systems are determined in the surrounding regions of Beijing. Air pollution over the Beijing terrain and clean air emitted by each of the six SALSCS are modeled as tracers which are passive scalars in the current model. 2D and 3D visualizations of the air pollution and clean air has been created to show the transient processes of the air pollution mitigation by SALSCS and transportation of both the air pollution and clean air driven by the winds under certain meteorological conditions. Quantitative analysis has also been conducted on the tracer fields for evaluating the ability of SALSCS of remediating air pollution and emitting clean air into the atmosphere above the city.

**12RR.1****Laboratory Studies of Freshwater Aerosol Production.**

NATHANIEL MAY, Jessica Axson, Peter Tirella, Andrew Ault, Kerri Pratt, *University of Michigan*

Wave breaking induced bubble bursting can eject particles from freshwater bodies into the atmosphere in the form of lake spray aerosol (LSA), similarly to the formation of sea spray aerosol (SSA) in marine environments. LSA may impact climate significantly in areas with large bodies of freshwater, such as the Great Lakes, by scattering solar radiation and acting as seeds for cloud formation. However, the relationship between the concentration and composition of inorganic ions, organics, and biological material in freshwater and the physiochemical properties of LSA that control climate impacts are not well understood. The production of particles from freshwater may also pose a currently unknown public health risk if toxic harmful algal bloom products present in freshwater bodies are aerosolized with LSA. With HABs becoming increasingly common in freshwater bodies, it is important to assess the extent that organic and biological material is incorporated into the LSA population. Determining how freshwater composition affects the physiochemical properties of LSA particles is therefore crucial for understanding the potential regional climate and health effects of LSA. To study this phenomenon, a laboratory LSA generator was used to produce particles from freshwater samples collected over multiple seasons from locations of varying organic and biological content, including those with harmful algal blooms present. Particles were analyzed for size and chemical composition to determine how seasonal and spatial variations in freshwater composition impacts LSA production and physiochemical properties. By understanding how the composition of freshwater affects the production of LSA, this study will provide novel insights into the impacts of freshwater environment on the atmosphere.

**12RR.2****Metal Composition and Source Identification of Particulate Matter around a Shrinking, Saline Lake (Salton Sea) via Pb Isotope and Metal Ratio Analysis.**

ALEXANDER FRIE, Justin Dingle, Samantha Ying, Roya Bahreini, *University of California Riverside*

The composition and source of ambient particulate matter (PM) were investigated at the Salton Sea, California. Understanding PM composition around the Salton Sea is particularly important as water inputs into the sea decrease and playa is exposed, potentially greatly increasing playa-sourced dust emissions in the Salton Sea Basin. Size-resolved day and night PM samples were collected via a Micro Orifice Uniform Deposit Impactor (MOUDI) in August of 2015 and February of 2016 at Salton City, CA, and in August 2015 at Bombay Beach, CA. Soil samples from exposed playa and non-playa soils were collected in August 2015. PM and soil samples were acid-digested and analyzed for total Ca, Na, As, Al, Cr, Cu, Fe, Mn, Ni, Zn, V, Ba, Cd, Co, Se, Sn, Ti, K, Th and for Pb207, Pb206, and Pb208 isotopes via Q-ICP-MS. Pb isotopic ratios, metal concentrations relative to Fe, and metal covariability will be used to examine the relative importance of exposed playa and arid soils as dust sources in the region. Variation in these parameters will be investigated in relation to ambient relative humidity, average wind speed and direction, and winter/summer seasonality.

**12RR.3**

**Regionally Specific Saharan Dust Transport.** Carmen Lamancusa, KRISTINA WAGSTROM, *University of Connecticut*

With the Saharan desert contributing more to atmospheric dust at the global level than any other source, it is important to understand and quantify how dust from different sub-sections of the region travel globally. Most studies of Saharan dust only examine the full Saharan region rather than treating all the sub-regions. In this study, we investigate twelve sub-regions in the Saharan Desert and determine how transport of dust from each region varies when compared to its neighboring regions. We also investigate overall trends, particularly when comparing northern to southern regions and eastern to western regions.

We use the GEOS-Chem 3D global atmospheric chemistry model to the global transport of dust emitted from each Saharan sub-region. Comparing the dust transport from each region allows us to isolate differences in expected impacts from dust suspended in each region. In the regions examined, there was more latitudinal transport in the northern regions than the southern regions. Additionally, we investigated seasonal variation and found that dust emitted between April and June experienced longer transport distances than dust emitted during other months. Furthermore we discuss how this data compares to satellite observations of sub-Saharan dust transport and the insights garnered through this comparison.

**12RR.4**

**Study of Ambient Aerosol in Riverside, California.** HEEJUNG JUNG, Yue Lin, Roya Bahreini, Akua Asa-Awuku, Kihong Park, Seung-Bok Lee, Gwi Nam Bae, *University of California, Riverside*

Riverside, CA is known for abundance of SOA during photochemical season. The study aims to relate the particle effective density and solid vs total particle size distribution measurement to the mixing state of the aerosol and to estimate potential health effects from particles. The ratio of volatile and non-volatile particles was measured and evaluated with respect to particle number, surface area, and mass. A catalytic stripper (CS) was used with a SMPS system to remove volatile component in ambient aerosol for size distribution measurement. Particle size distributions measured with and without a catalytic stripper will be presented. Particle effective density was also measured semi-continuously at the same location. BC was measured using MAAP and aethalometer. AMS was used to measure chemical composition of non-refractive PM.

In addition, there is an increased interest to monitor temporarily and spatially resolved ultrafine particle concentrations in ambient air. Total particle number (TPN) concentrations measured by earlier studies showed an anti-correlation with PM<sub>2.5</sub> therefore not appropriate as a metric for monitoring. Solid particle counting method is a well-established technique to measure emissions from vehicle exhaust. It eliminates contribution of semivolatiles using a volatile particle remover and achieves more consistent and repeatable measurement for vehicle exhaust particle emissions. This study applied a similar approach to measure solid particle size distributions in ambient air in Riverside, CA.

**12RR.5**

**Transboundary Health Impacts of Transported Global Air Pollution and International Trade.** Qiang Zhang, Xujia Jiang, Dan Tong, STEVEN DAVIS, Hongyan Zhao, Guannan Geng, Tong Feng, Bo Zheng, Zifeng Lu, David Streets, Jintai Lin, Ruijing Ni, Dabo Guan, Michael Brauer, Randall Martin, Hong Huo, Zhu Liu, Da Pan, Haidong Kan, Kebin He, *University of California, Irvine*

The work we will present is currently under review, and we would prefer to refrain from submitting a detailed abstract until the paper is published. We will update the abstract as soon as possible.

**12SP.1**

**Raman Spectroscopy of Aerosol and Vapor Chemical Warfare Agents.** ERIK EMMONS, Francis D'Amico, Gary Kilper, Steven Christesen, Aime Goad, David Sickenberger, Jeys Thomas, Roshan Aggarwal, Mitesh Amin, Michelle Clark, Lewis Farrar, Bradford Perkins, *U.S. Army Edgewood Chemical Biological Center*

We have developed a Raman spectroscopy system for detecting vapor and aerosolized chemical warfare agents for the purpose of providing warning of potential attacks. The instrument is capable of single or few aerosol particle detection under favorable conditions. A high-power 10 W 532 nm laser is used to excite Raman scattering from a vapor or aerosol jet that it crosses at 90 degrees. A high-efficiency spectrometer system is then used to detect the scattered light. Two lenses are used to collect the scattered light emitted towards and away from the spectrometer entrance slit, and all the Raman scattered light is directed to the entrance slit. In addition, an inertial concentrator is used to increase the detection efficiency of aerosolized samples, and an optional photobleaching cell can be used to reduce material fluorescence. Tests with live chemical agents have shown the ability to detect and identify threat materials such as GB (sarin) and VX nerve agents in both vapor and aerosol form in real time. Measurements of simulants and agents will be presented. In addition, morphology dependent resonance has been observed for some highly fluorescent aerosol particles where only one or a few particles are being measured at a time. The instrument may have additional applications in basic research, environmental monitoring, and atmospheric science.

**12SP.2**

**Investigation of Enhanced Raman Spectroscopy of Aerosol Particles.** VASANTHI SIVAPRAKASAM, Matthew B. Hart, Jay D. Eversole, *Naval Research Laboratory*

Raman spectroscopy is a widely used technique to measure vibrational and rotational molecular modes which can provide very specific spectral signatures for chemical identification. However, typically low Raman scattering cross-sections have been a barrier to using this technique for in-situ characterization of environmental aerosols or monitoring hazardous materials present in the air. We are currently exploring a technique to obtain an enhanced Raman signal by combining metallic nanoparticles (MNPs) with larger aerosol particles (Sivaprakasam et. al. 2014). In this aspect, our approach could be regarded as an extension of surface enhanced Raman scattering (SERS). We plan to compare measurements of spontaneous Raman spectra with MNP-enhanced Raman spectra using identical aerosol particles under controlled conditions. The repeatability of spectral response and enhancement factors, and their dependence on factors such as, MNP composition, MNP concentration and aerosol composition will be investigated.

In order to study Raman spectral signatures from aerosol particles with controlled composition and size, we have constructed an experiment where aerosol particles are suspended for extended periods of time (up to hours) using a linear electrodynamic quadrupole (LEQ) trap. Aerosol particles are created and charged using a customized nozzle-reservoir droplet generator, and particles ranging from 1 micron to 60 microns in diameter have been successfully generated and maintained. For validation and calibration, droplets of materials such as glycerol and dibutyl sebacate are being studied, using a 532 nm laser for excitation. We plan to expand the study to include other materials (laser dyes and proteins). Raman spectra from both aerosol particles and bulk samples each with and without the addition of MNPs will be compared. The latest results in terms of spectral signatures resulting the addition of the MNP's to these materials will be presented.

**12SP.3**

**Single-Particle Morphology from Two-Dimensional Autocorrelation of Angularly-Resolved Light Scattering.** KEVIN APTOWICZ, Daniel Landgraf, Jason Zallie, Gorden Videen, Steven Hill, Ronald Pinnick, Yong-Le Pan, *West Chester University*

The morphology of atmospheric aerosol particles varies greatly from homogenous spheres to complex agglomerates. This diversity of particles morphologies challenges radiative models and remote sensing techniques since the light scattering behavior of aerosols is greatly influenced by particle morphology. In this work, we explore aerosol morphology at the single-particle level by capturing and analyzing angularly-resolved light scattering patterns. In particular, we calculate the two-dimensional autocorrelation of over 30,000 single-particle light-scattering patterns from atmospheric aerosol particles in Las Cruces, NM. The size and shape of the central peak of the autocorrelation function provides insight into particle morphology. By parameterizing the central peak of the autocorrelation function, the diverse range of particles morphologies in our dataset can be grouped into subpopulations. Preliminary results suggest one population consists of sphere and sphere-like particles such as liquid particles with or without inclusions. The second population appears to represent complex agglomerates, which are likely solid-like particles. We also explore how the optical properties, like the scattering phase function, vary between the different subpopulations.

**12SP.4**

**Optical Configurations for Photophoretic Trap of Single Airborne Particles in Air.** ZHIYONG GONG, Yong-Le Pan, Chuji Wang, *Mississippi State University*

Optical trapping has become an emerging tool in single aerosol study. Different from optical tweezers, which employs a tightly focused beam to trap non-absorbing particles, photophoretic trapping is able to trap a variety of light absorbing particles due to the strong photophoretic force (PPF) induced by the differences in the surface temperature and accommodation coefficient of the particle. There are plenty of complicated trapping schemes based on PPF available for aerosol research. We demonstrate six different types of simple schemes to explore the full potential of diversity of the photophoretic trapping. Their 21 variants are constructed by varying instrumental parameters, e.g., laser source, power, beam shape, and focusing optics. The trapping performance and quality of those trapping schemes are evaluated in terms of four key aspects: simplicity, robustness, flexibility, and efficiency. Among the six types of schemes, some of which have been reported before; but a new, simple single-beam scheme using the confocal design is introduced, in which one trapping beam is converted to two virtually counter-propagating beams. This new and versatile trapping scheme has the leveraged advantages of the single-beam traps and the robustness of the counter-propagating beam traps. The new trapping scheme is further integrated into the cavity ringdown spectroscopy technique to show application of the photophoretic trapping. The detailed design, construction, and evaluation of the six types of trapping schemes and their 21 variants may offer researchers of interest a freedom of choice in their own applications of optical trapping.

**12SP.5**

**Single Nanoparticle Characterization with a Laser Induced Plasma.** ANDREW J. HORAN, Justin Krasnomowitz, Murray Johnston, *University of Delaware*

Online determination of the chemical composition of nanoparticles poses a significant measurement challenge. The size and heterogeneity of individual nanoparticles in environmental samples require a technique which is both sensitive and robust across compositions. To this end, in both the laboratory and field, a laser induced plasma has been used to determine the elemental composition of individual nanoparticles with the Nano Aerosol Mass Spectrometer (NAMS). The laser radiation quantitatively converts the nanoparticle into multiply charged, positive, atomic ions, whose relative intensities yield the elemental composition. Most applications of this method have involved quantification of low atomic number non-metals (C, O, N, S, Si) in particles that are a few tens of nanometers in diameter. We have recently extended the technique to particles up to 100 nm and above, and we have characterized its ability to detect and quantify elements over a broader range of elements across the periodic table. Particle size and composition dependencies give insight into the mechanism of vaporization and ionization. For example, the ability to quantify metals in nanoparticles can be predicted using melting point as a proxy. Applications to a variety of particle types will be presented along with comparisons to more conventional analytical techniques.