Controlling Factors for Smoke Emissions from Urban and Wildland Fuels

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News Media Images
South Fork/Salt Fires Near
Ruidoso, NM 2024 ~25K acres

NEW MEXICO TECH
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Los Alamos
NATIONAL LABORATORY
EST. 1943

American Association for Aerosol Research
AAAR

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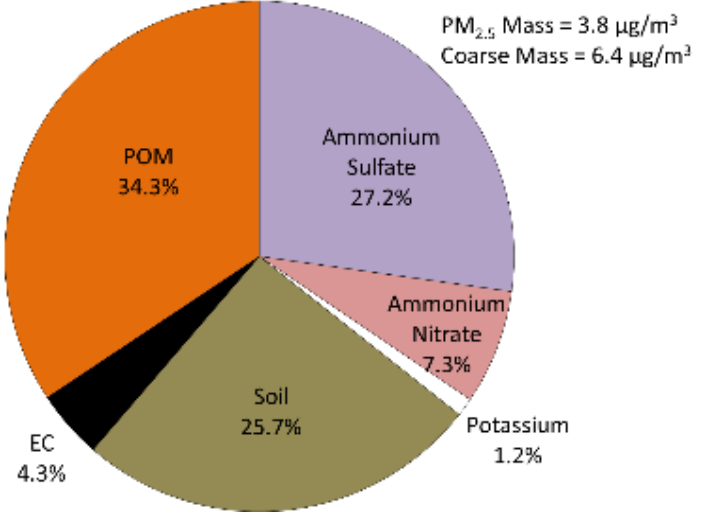
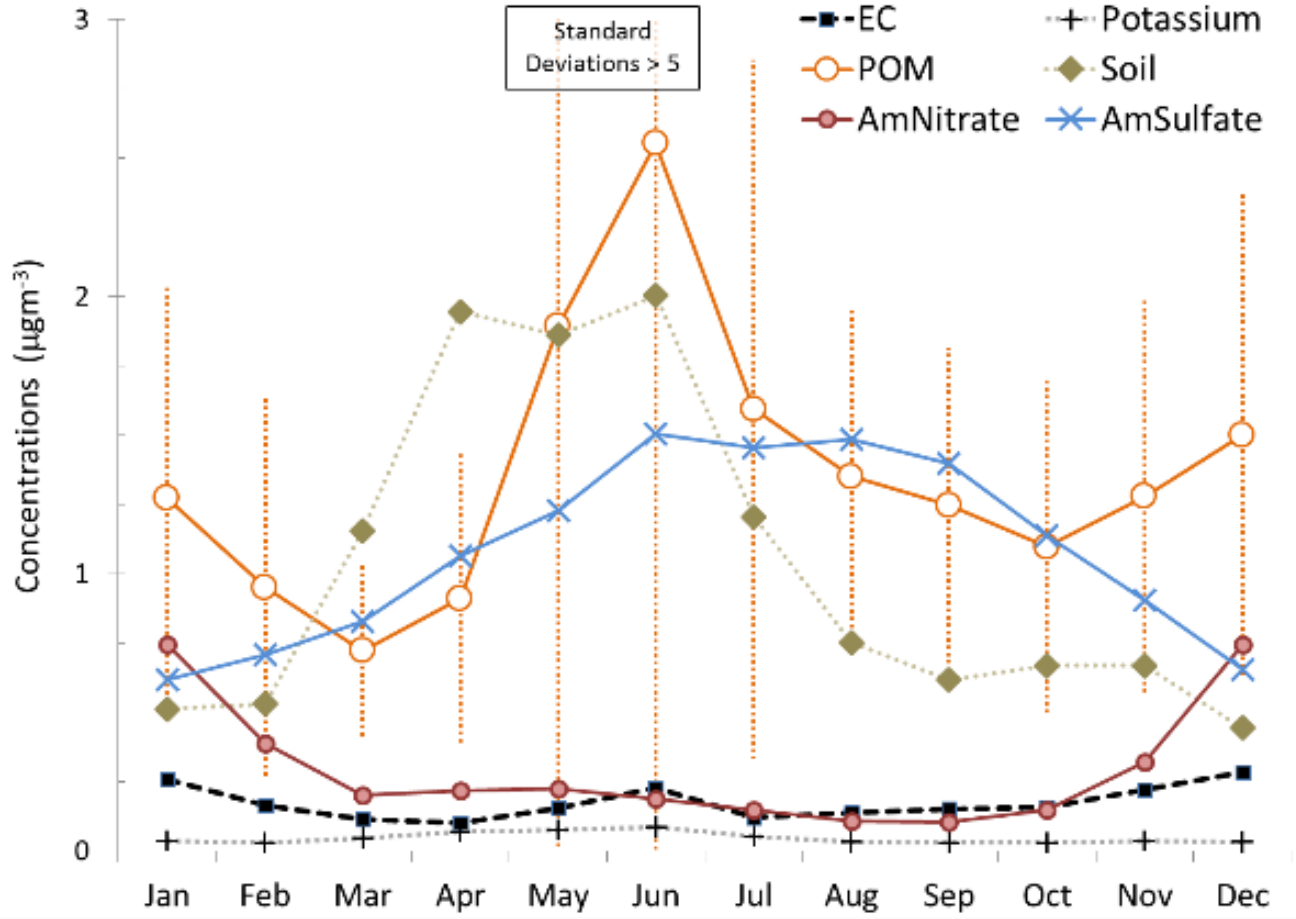
Southwest US $PM_{2.5}$ Air Quality

$PM_{2.5}$ is typically mixture of organic carbon, elemental carbon, salt species, soil dust species

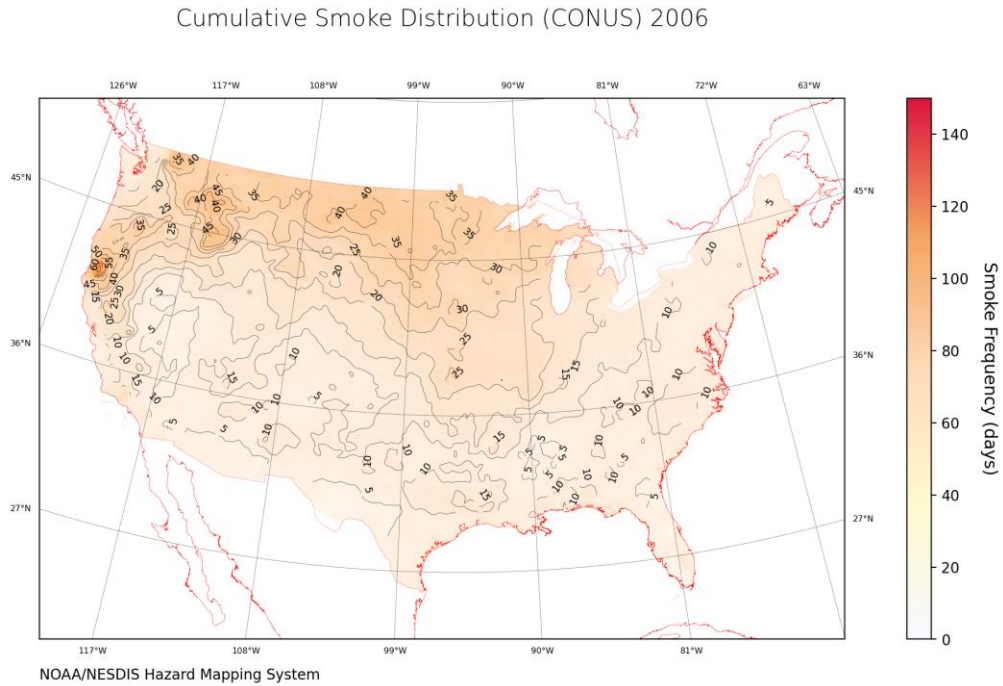


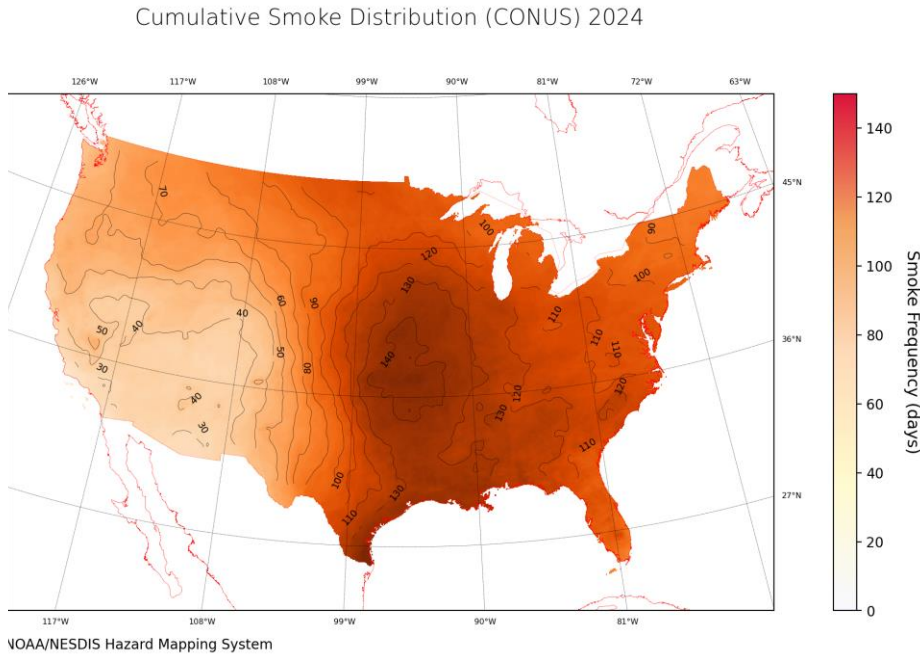


Bosque del Apache IMPROVE station (2000-2014 data)

- Peak in dust + smoke in April-July
- Winter secondary peak in POM, NH_4NO_3, EC
- Summer peak in $(NH_4)_2SO_4$

Biomass Smoke Exposure: Not just the West (NOAA)





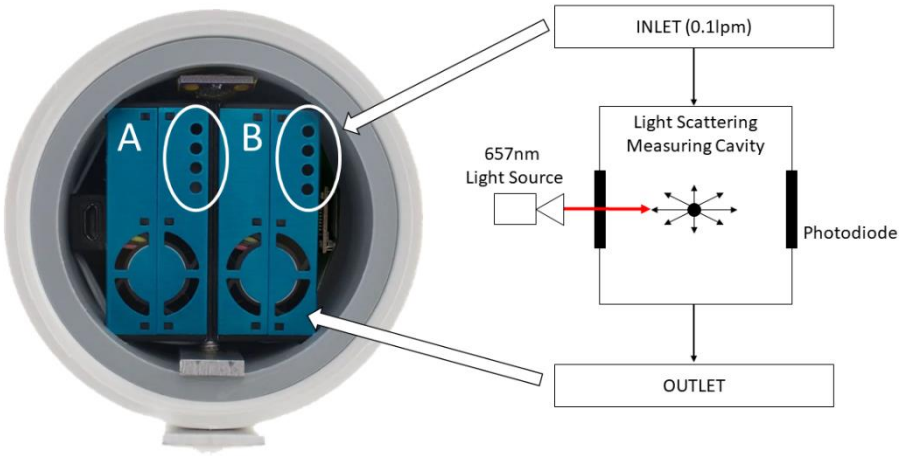
Parameters of Interest

Parameter	Description	Units	Techniques	Notes & Relevance
σ_{abs}				
σ_{scat}				
Å, b	Ångtröm exponent, backscatter fraction	----------	Wavelength dependence and direction of absorption or scatter	Determines radiation reflected to space
ω or S				– $_{bs}$
N_{to}				
D_g				CN,
σ_g	deviation	----------	SMPS)	ribution
f(RH) *gRH)*	Hygroscopic growth	----------	Controlled RH nephelometry, H-CAPS PMssa	Aerosols water uptake key to radiative effects
MCE	Combustion Efficiency	----------	CO & CO_2 Instruments	$\frac{\Delta CO_2}{\Delta CO_2 + \Delta CO}$

- These two integrated over the column give aerosol optical depth
- These are key variables that parameterize aerosol effects in climate & visibility models

Purple Air Sensor and Microaethalemeter

- Cost-effective sensor (~$300) and light weight (~1kg)
- Utilizes two, redundant PlanTower PMS5003 sensors
  - Measures PM_{10}, $PM_{2.5}$, and $PM_{1.0}$ [µg/m^3]
  - Records T, P, and RH from other sensors
- Light scattering based sensor
  - 657nm light source
- Corrections for moderately aged smoke have been constructed (Holder et al., 2020)
  - Over measures low concentrations
  - Non-linear transition
  - Under measures high concentrations
- Multiwavelength UV-IR aerosol light absorption from BC concentrations
- Dual spot operation for minimization of non-idealities



Laboratory Experiments: Low-Cost Sensors vs. Benchtop

FEM Beta Attenuation

Filtered Air

Aerosol Generator

Dryer

Dead Volume

16.7lpm - 2.5µ Cyclone

Dead Volume

Nephelometer

TAP and/or aeth

x2

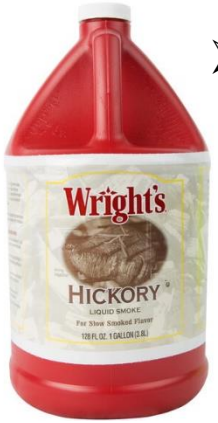
x 1

ThermoScientifc PDR Combination Light Scattering and Backup Filter

Near FRM Filter Sampler

Lab Validation Experimental Iterations

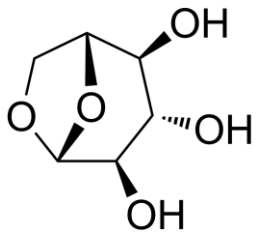
- Real Laboratory Generated Smoke: Too Variable for Day+ Experiments

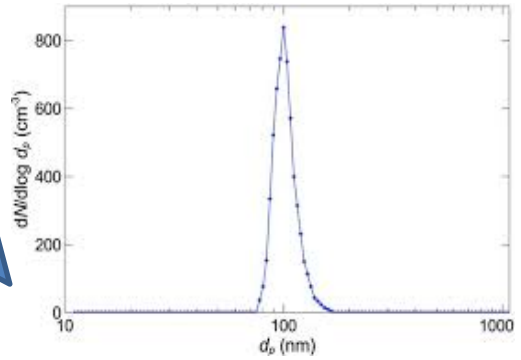


- Liquid Aerosol and Semivolatile: Filter Discrepancies

- Step Back to Something Simple and Known: Ammonium Sulfate

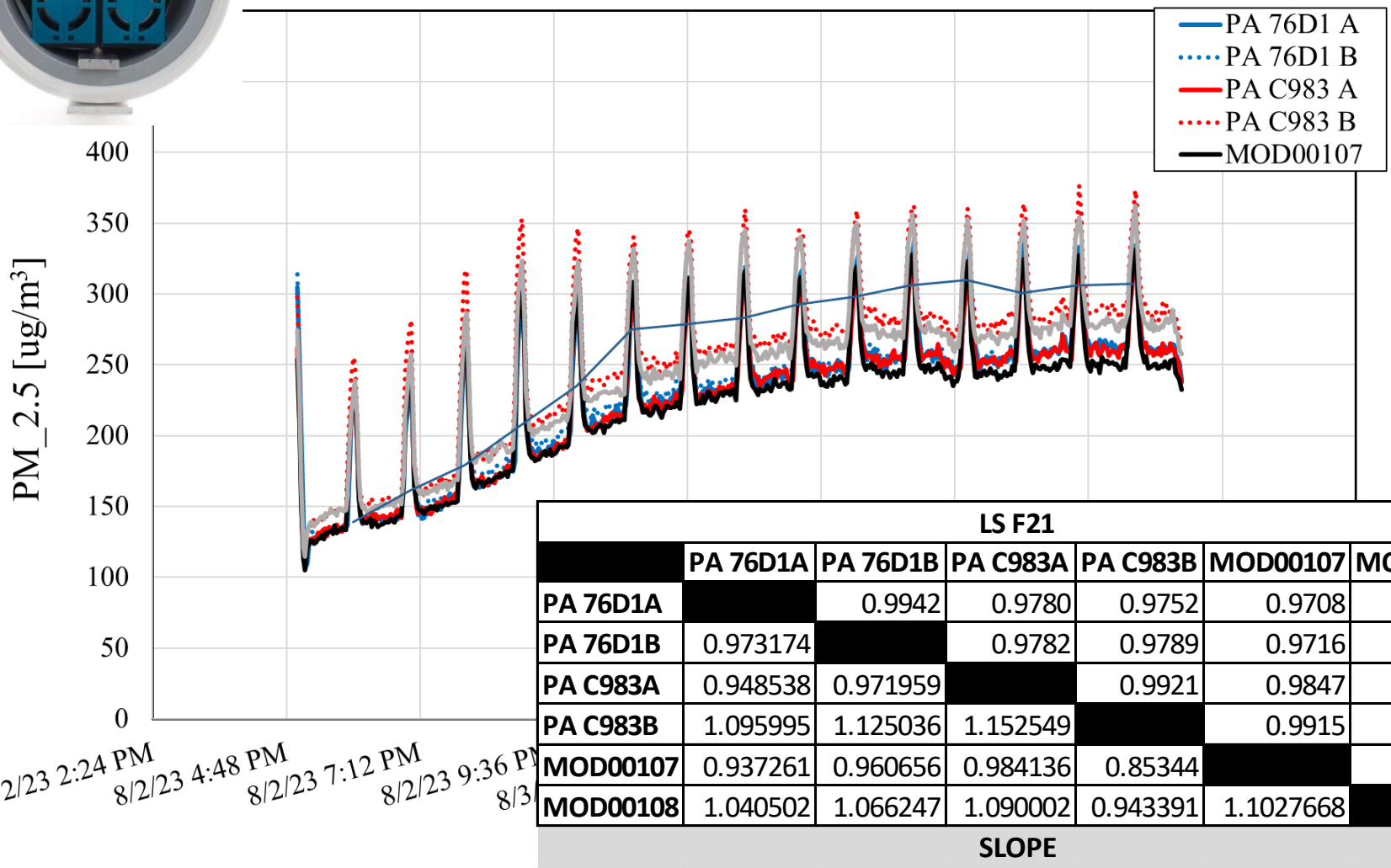
- Reintroduce More Complexity: Smoke Filter Extractions, Soot and biomass smoke proxies





- Explicitly probe the size dependence

Online Sensor Agreement in Laboratory (Artificial Smoke)

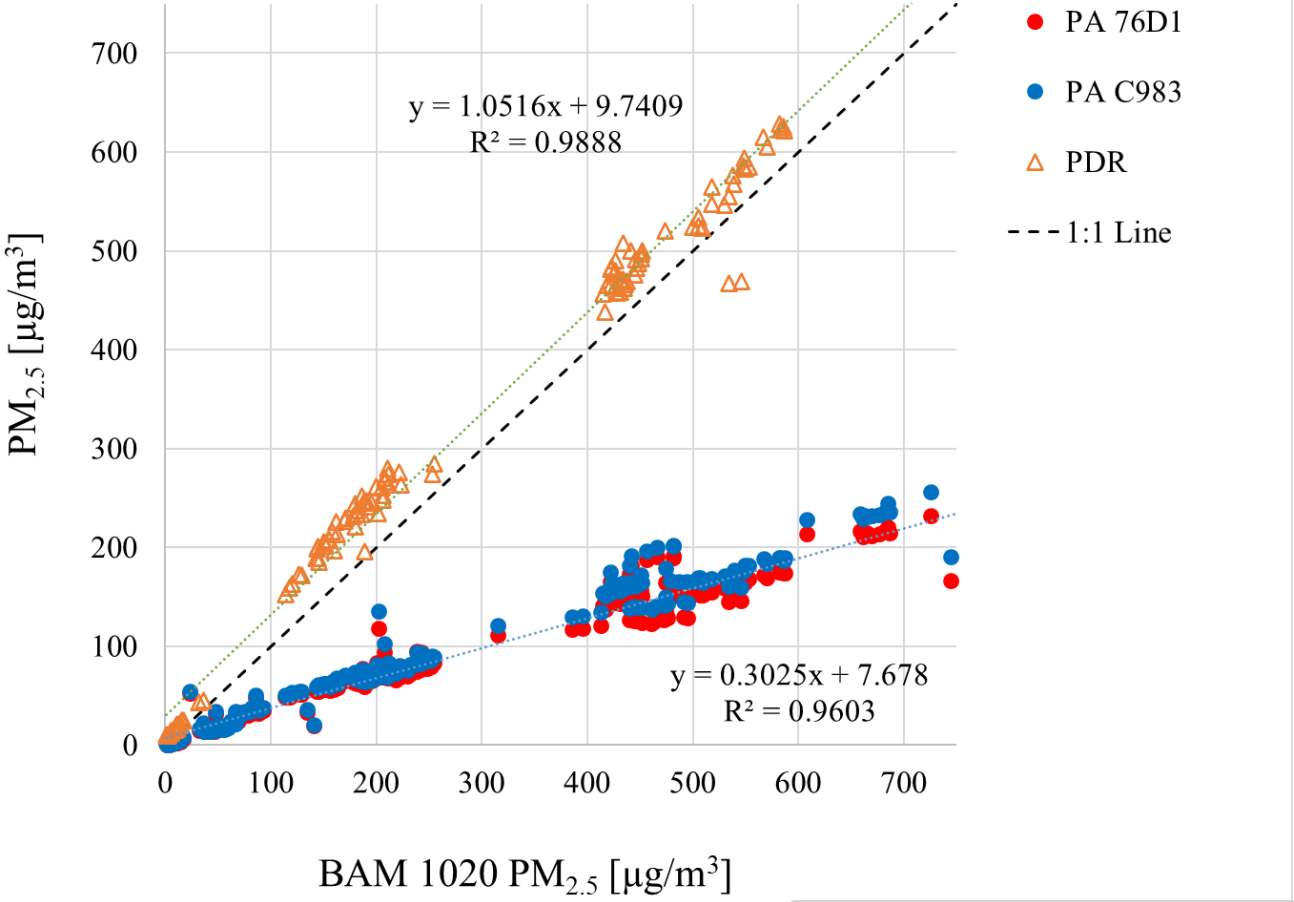


LS F21						
	PA 76D1A	PA 76D1B	PA C983A	PA C983B	MOD00107	MOD00108
PA 76D1A		0.9942	0.9780	0.9752	0.9708	0.9762
PA 76D1B	0.973174		0.9782	0.9789	0.9716	0.9765
PA C983A	0.948538	0.971959		0.9921	0.9847	0.9855
PA C983B	1.095995	1.125036	1.152549		0.9915	0.9884
MOD00107	0.937261	0.960656	0.984136	0.85344		0.9922
MOD00108	1.040502	1.066247	1.090002	0.943391	1.1027668	
SLOPE						

R^2

- Online Agreement Quite Good
- Need More Effort to Compare to FEMs, FRMS with Non-volatile Aerosol

Can we take the raw data from the PurpleAir and get a reasonable [$PM_{2.5}$]?

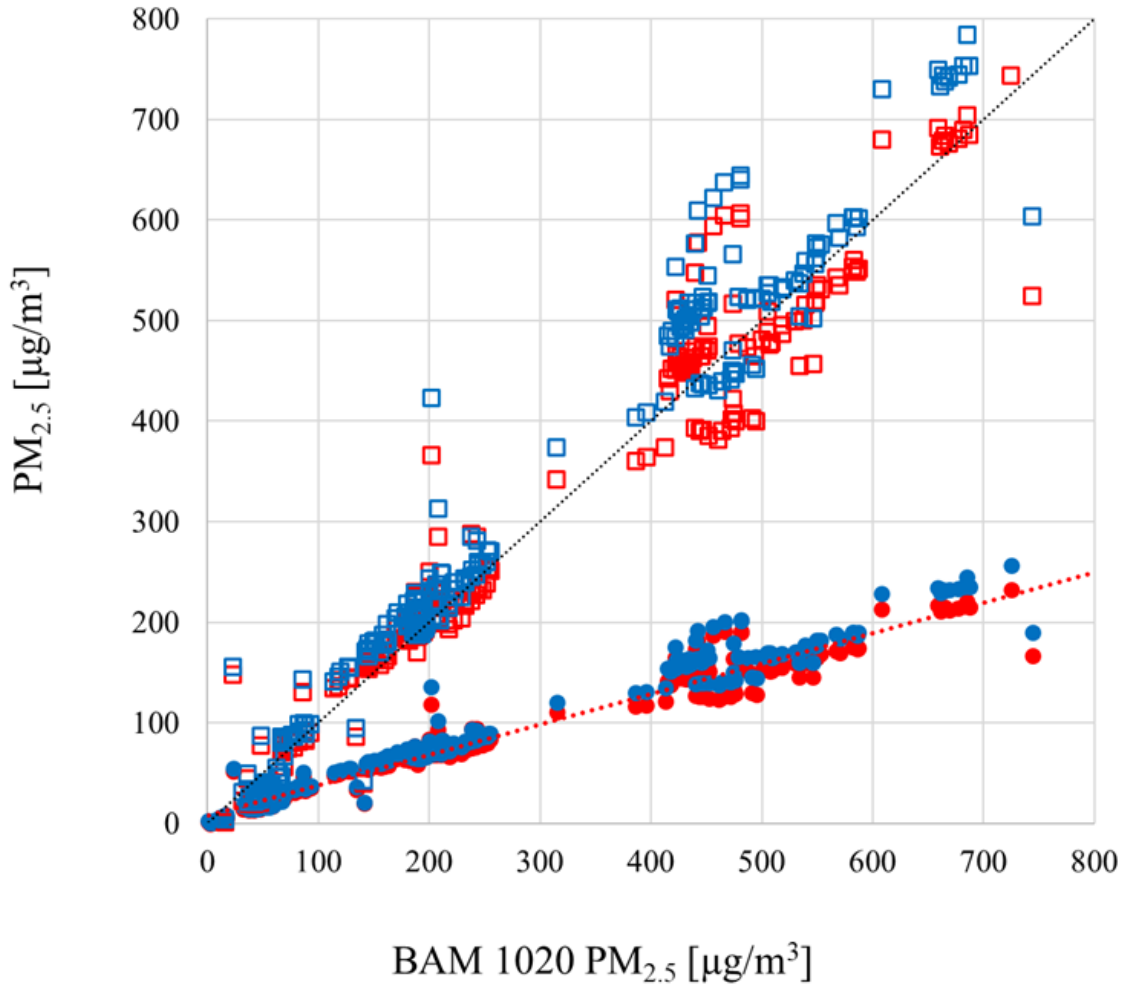


Dry polydisperse Ammonium Sulfate with D_g < 50 nm

Dry polydisperse Ammonium Sulfate with D_g ~ 40-50 nm

Exp. #	ARA	BAM	PDR Filt.	PDR Opt.	PA B51C AVG	PA C983 AVG
AS 500	410.84	434.5	614.81	468.7	146.52	160.25
082524 AS	27.03	11.25	12.35	19	4.23	5.08
082624 AS	156.73	155.39	207.73	266.73	93.84	102.26
082824 AS	191.63	208.12	271.11	256.66	73.09	78.15
090124 AS	476.73	552.05	728.96	587.35	167.53	180.9

Can we take the raw data from the PurpleAir and get a reasonable [$PM_{2.5}$]?....



Dry polydisperse Ammonium Sulfate with D_g < 50 nm

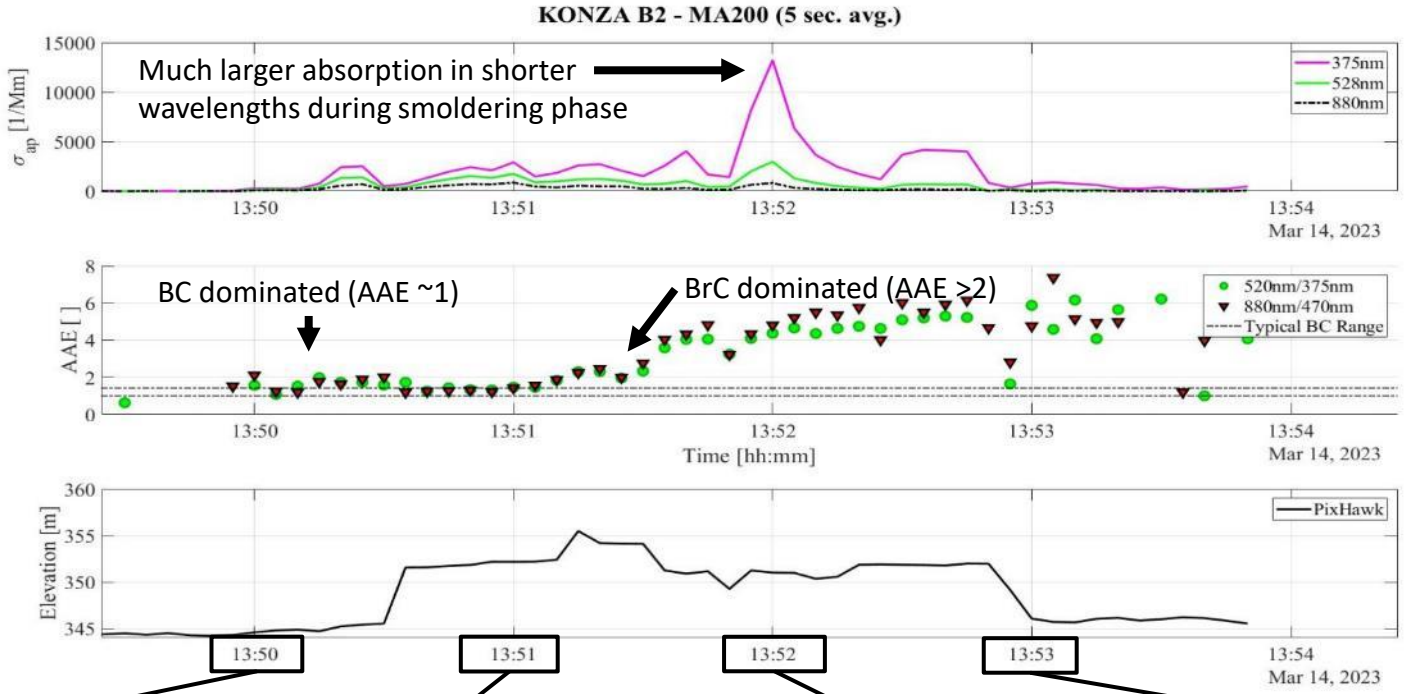
- .....maybe if the aerosol of interest is calibrated to (size, refractive index)

Ambient Konza Prairie Fires Light Absorption (Manhattan, KS)

σ_{ap}

AAE
(wavelength dependence)

z (m)



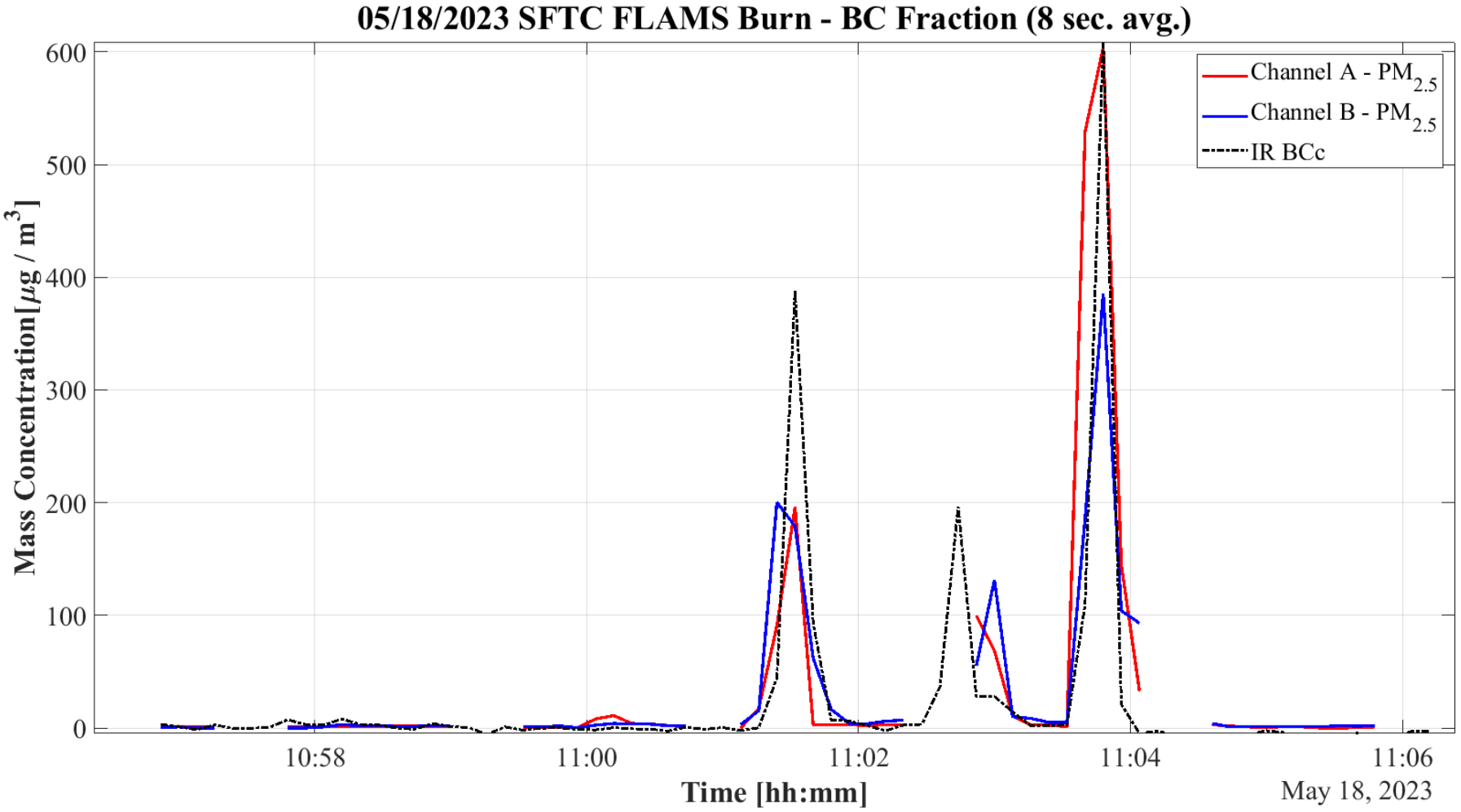
Take off

Black carbon dominated
(Intense flaming)

Brown carbon sampling
(Primarily smoldering)

Landing
(Smoldering remnants)

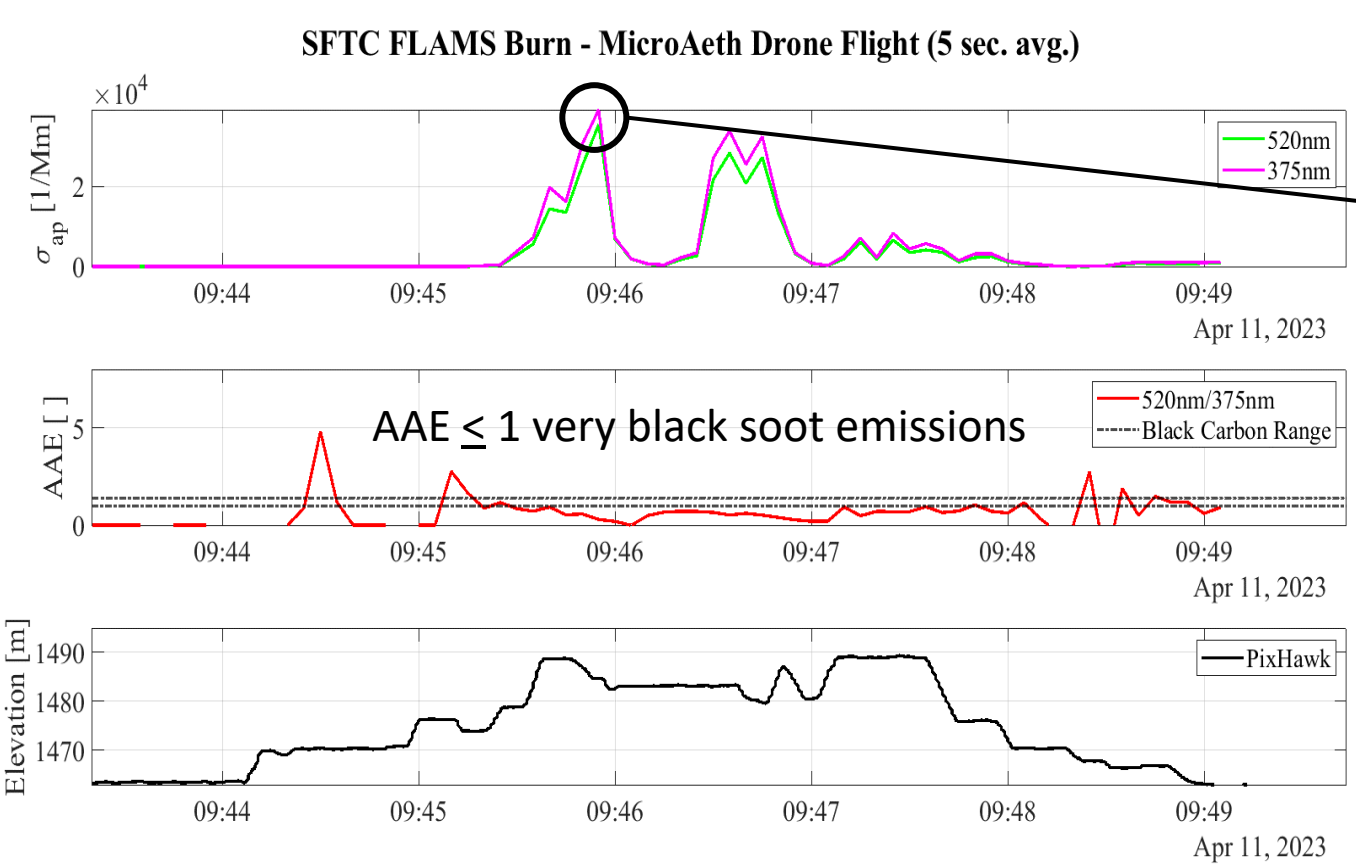
Drone Measurements of Fuel Spill Burn
New Mexico Fire Training Academy

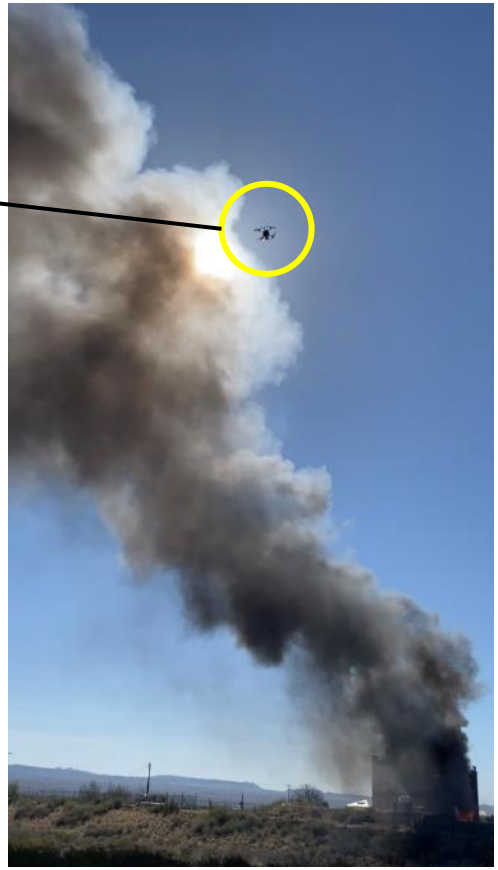


- For small (Dg,n <100nm) and very dark smoke emissions the PurpleAir sensors miss a significant fraction of the PM2.5 mass concentration

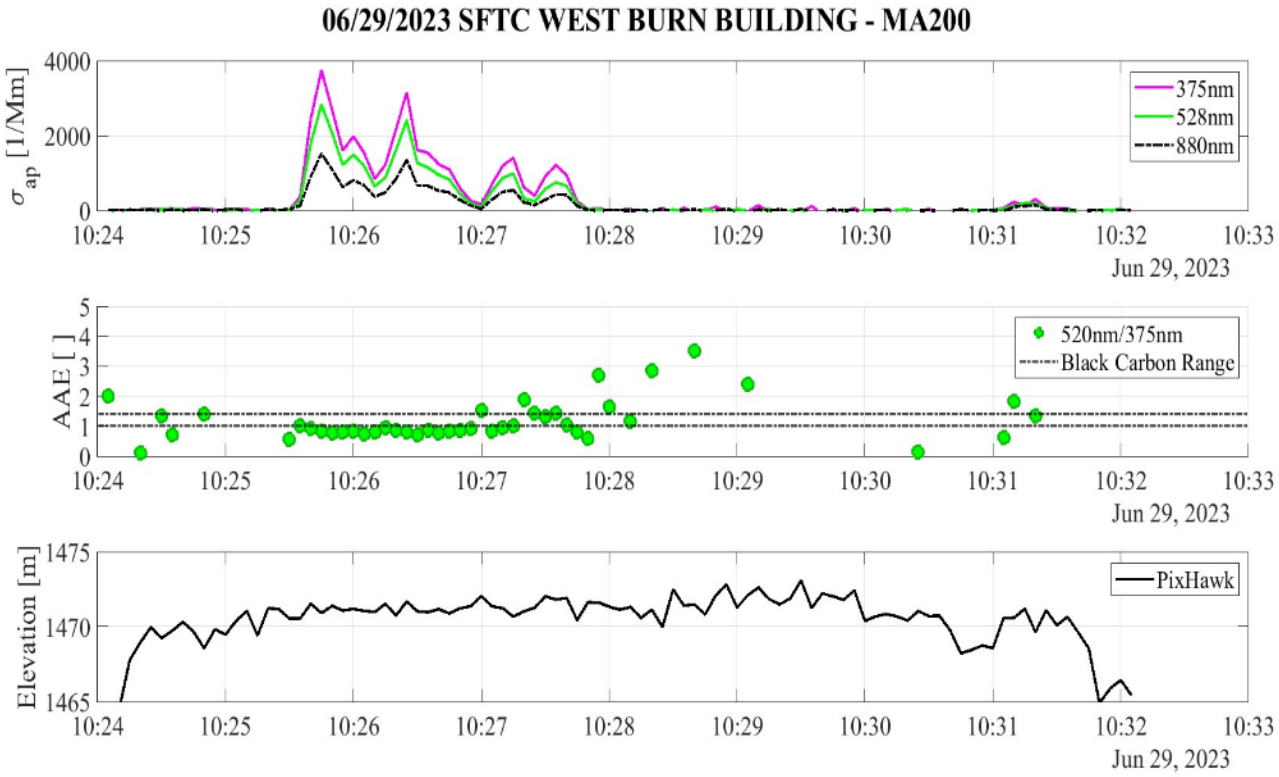
New Mexico State Fire Training Center

Diesel Fuel Spill Burn Light Absorption
New Mexico Fire Training Academy



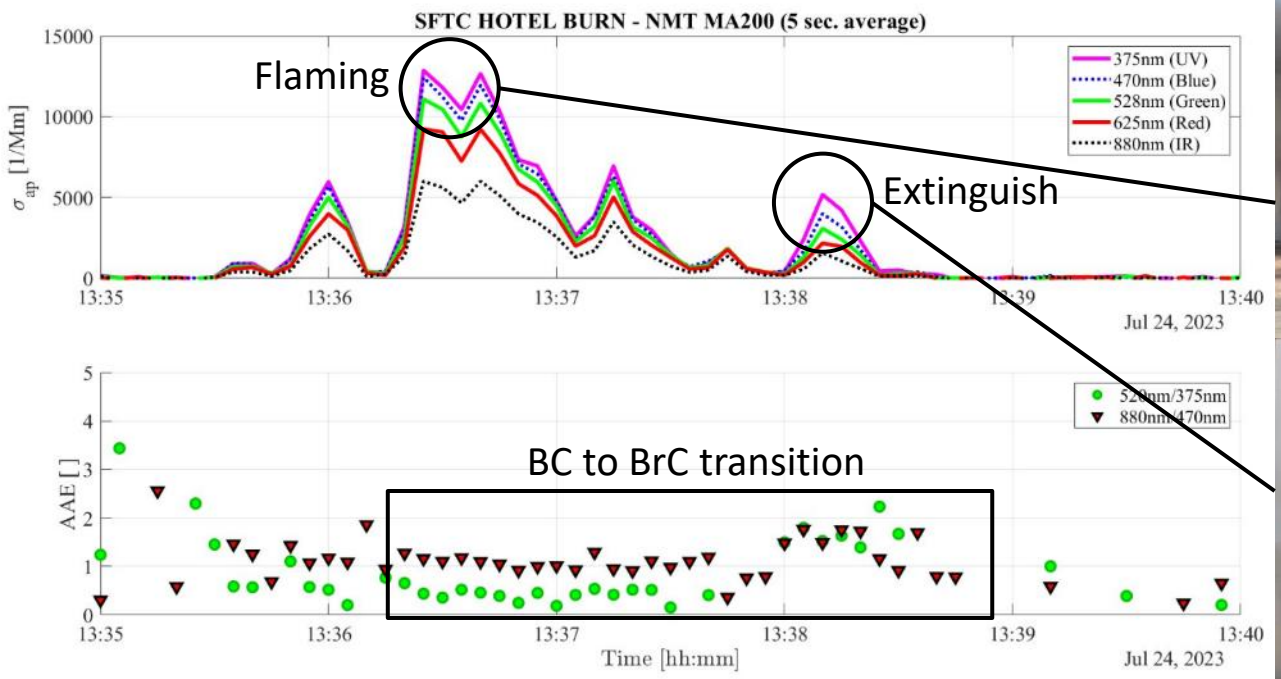


Building Burn Light Absorption
New Mexico Fire Training Academy



- Typical Fuel: Wood pallets on a pool of diesel fuel

Hotel Room Burn Light Absorption
New Mexico Fire Training Academy



Conclusions

1) Field measurements are showing **consistency** with what we observed in the lab (Flaming/smoldering, BC vs. BrC)
2) Combustion **temperature/phase** plays a key role for aerosol physical properties
3) Biomass burning aerosol properties—an important climate component—are diverse, variable and **fuel/phase specific**
4) Sensors such as PA strongly benefit from an **aerosol-specific ground truth**
5) Pursuing further **field measurements** and **sensor validation studies** (urban & wildland fuels)

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