Aerosol Chemical Composition and Cloud Interactions: Findings from the SCILLA Campaign

Bradley Ries[1], Alexander B. MacDonald[1], Dongli Wang[2], Minghao Han[1] Sierra Bollinger[3], Mason Leandro[4], Lisa Welp-Smith[5], Patrick Chuang[4], Mikael Witte[3], Andrew Metcalf[2], Don Collins[1], and Roya Bahreini[1]

[1]UC Riverside, [2]Clemson University, [3]Naval Postgraduate School, [4]UC Santa Cruz, [5]Purdue University

Abstract

The SCILLA (Southern California Interactions of Low cloud and Land Aerosol) campaign was a comprehensive airborne research project aimed at investigating aerosol-cloud interactions and their impact on regional climate and air quality.

The driving hypothesis of SCILLA was that Atmospheric turbulence generated by coastal topography mixes aerosols from the LA basin into the cloud layer near the Channel Islands.

In June 2023, we conducted 21 research flights onboard a Navy Twin Otter aircraft, equipped with a suite of instruments including a mini Aerosol Mass Spectrometer (mAMS). Our flights sampled diverse locations near the coastal pollution sources of Los Angeles Basin (which often are transported over the water) and off of the coast of San Diego, including nearshore and offshore areas, San Clemente Island, and various cloud regimes (in-cloud, below-cloud, above-cloud and in the cloud wake of the island).

The mAMS alternated sampling through an isokinetic inlet in cloud-free air, a Counter-flow Virtual Impactor (CVI) in clouds, and an oxidation flow reactor. This investigation focuses on a subset of flights to investigate how atmospheric aging and cloud interactions in the marine environment affect aerosol composition. For this, we will analyze compositional data only through the isokinetic inlet (under clear sky) from a subset of flights during a common wind pattern known as the Catalina eddy. (Figures 1, 2)

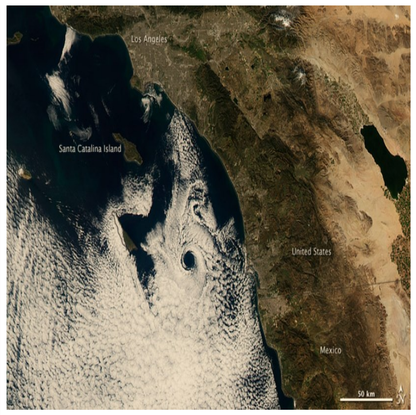


Figure 1. Typical Catalina eddy – courtesy of NASA MODIS

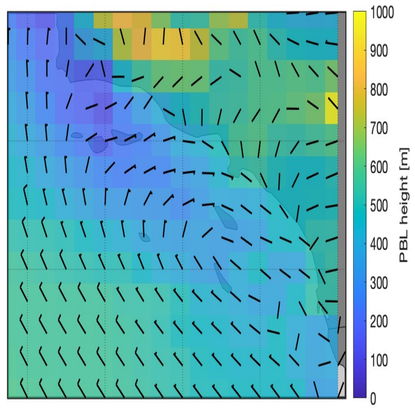


Figure 2. June 29th 2023 Wind direction map highlighting Catalina eddy – courtesy of Mikael Witte

Methods

Data Collection Period: June 5th thru June 30th, 2023.

Flight Operations:

- Departure location: Montgomery-Gibbs Airport in San Diego, CA
- Target Region: Coastal area surrounding San Clemente Island

Sampling Strategy:

- Flights divided into modular segments based on location relative to the island
- **Upwind Module**: Sampling on the west and north-west side of the island to capture pre-island atmospheric conditions
- **Downwind Module**: Sampling on the east and south-east sides of the island to capture post-island atmospheric conditions

Flight Profiles:

- Each module consisted of multiple legs with distinct sampling objectives: (Figure 4)
- **Cloud Sampling Legs**: Sampling above, inside, and below cloud layers to capture variability of chemical composition
- **Saw-Tooth Legs**: Zig-zag flight pattern was employed to investigate cloud edge effects
- **Spiral Descent/Ascent Legs**: Vertical profiles were obtained through controlled spiral maneuvers

Figure 3. Photo from inside cabin above cloud top – courtesy of Lisa Welp-Smith

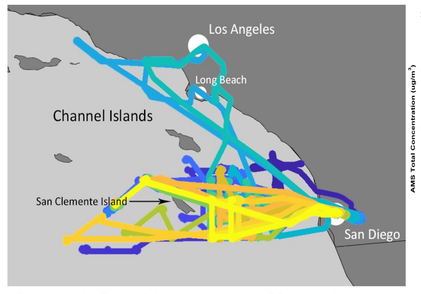


Figure 4. Flight tracks of all 21 flights – courtesy of Mikael Witte

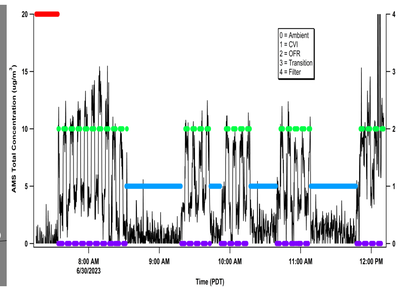
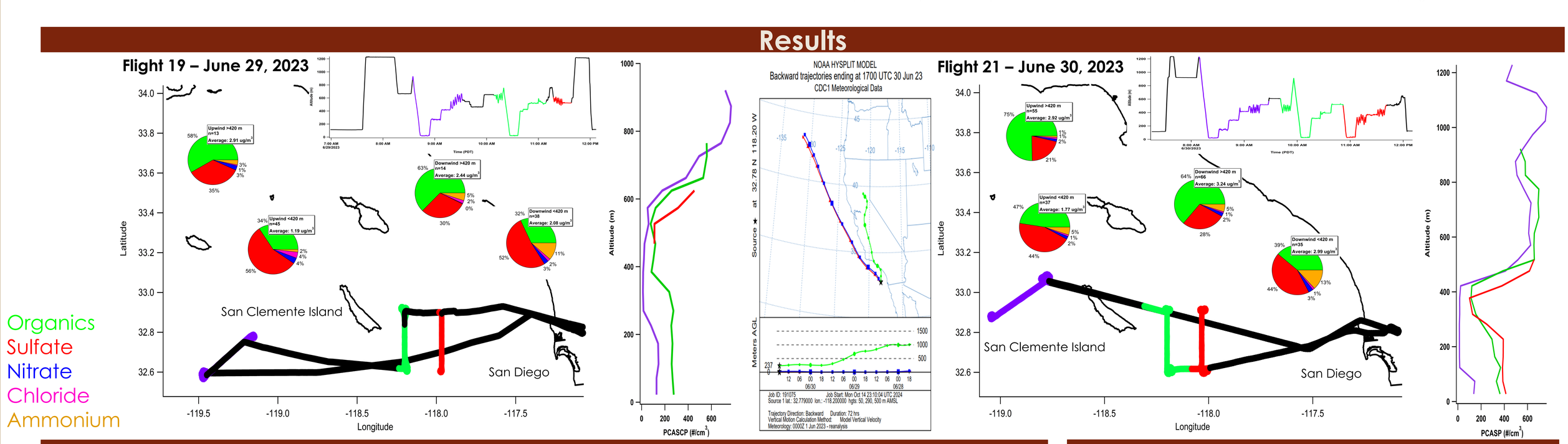


Figure 5. June 30th, 2023 Example of different sampling conditions

Results



Organics
Sulfate
Nitrate
Chloride
Ammonium

Discussion

- During strong Catalina eddy weather pattern upper layer aerosols are likely from the LA basin
  - Above MBL, aerosol dominated by OA while blow MBP, aerosol dominated by SO_4^{2-}
- Turbulence caused by San Clemente Island can mix aerosols down into MBL
  - Higher PCASP at lower altitudes in downwind profiles
  - Higher total mAMS concentrations in downwind profiles
- Changes in composition also confirm mixing aerosols down
  - Contribution of ammonium increases at lower altitudes in downwind profiles

Future Work

- Analyze compositional differences at different altitudes and in/out of clouds on other flights
- Investigate differences in composition between ambient/CVI sampling techniques
- Incorporate other instruments to obtain more comprehensive understanding of how differences in composition affect cloud properties

Acknowledgements:

We would like to acknowledge the support of the Atmospheric System Research branch of the Department of Energy. Also, a huge thank you to entire team that made this possible. Thank you specifically to the Naval Postgraduate School and Mikael Witte for leading this project. Thank you to the team at CIRPAS who maintained the aircraft and installed the instruments, specifically Roy Woods, Dennis Hamaker, and Greg Cooper. Lastly, thank you to the Montgomery-Gibbs airport for graciously hosting us for the entire campaign.