

ARM



ARM Tethered Balloon System (TBS): TBS Science

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2023 ARM/ASR JOINT USER FACILITY AND PI MEETING

Results from:

- TBS at TRACER
- TBS at SGP
- TBS at SAIL
- TBS INP Measurements at SGP and SAIL
- FY24 TBS Campaigns
- Potential FY25 operating locations



Scientific Challenge

FY2023 FICUS award to chemically characterize and speciate organic aerosols with vertical resolution to identify tracers of aqueous organic aerosol formation

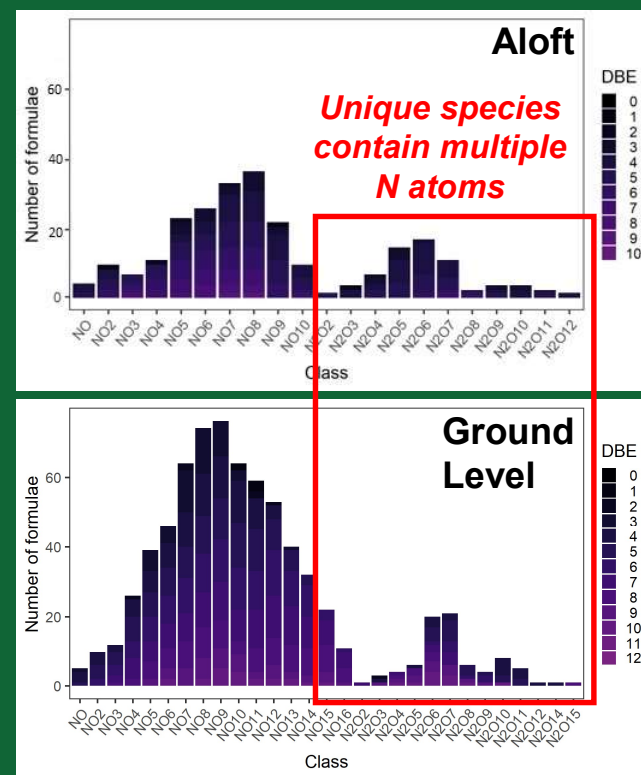
Approach

- Collect filter samples with EMSL STAC/TBAC onboard ARM TBS during Tracer 2022 and at SGP summer 2023
- Addition of FROST sampler for VOC profiles at SGP 2023
- Analyze filter samples at EMSL using NanoDESI-HRMS, CCSEM/EDX, and at UC Berkeley using GCxGC-HRMS

Initial Findings from TRACER 2022

- **Initial NanoDESI-HRMS results show unique nitrogen-containing molecular formulae aloft, in particular those with 2 Ns**
- Enhanced N signals correlate with HYSPLIT back trajectories pointing to terrestrial origins instead of marine origins
- Compounds with nitrogen in molecular formulae may be potential tracers of aqueous chemical processes and terrestrial transport

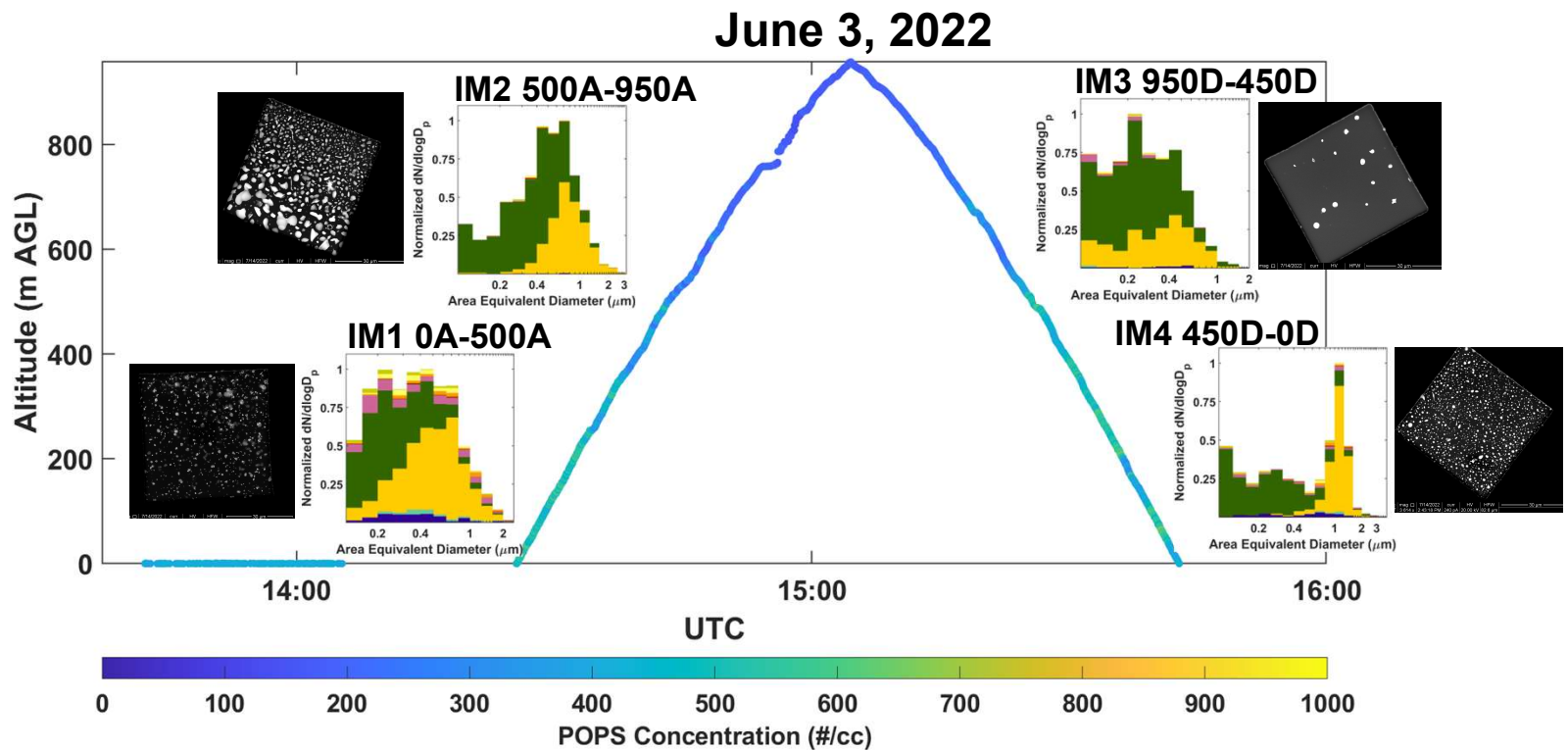
TRACER June 3, 2022 CHNO Species



Initial Findings from TRACER 2022 (cont'd).

- Initial CCSEM/EDX results show sulfate and carbonaceous particles dominate at all altitudes
- The size distribution of sulfate particles is changing across altitudes

■ Na-rich
 ■ Na-rich/Sulfate
 ■ Sulfate
 ■ Carbonaceous
 ■ Dust
 ■ Biological
 ■ Si+S
 ■ K+S
 ■ Other



Results courtesy of Lindsey Yee and Allen Goldstein of UC Berkeley and EMSL PNNL





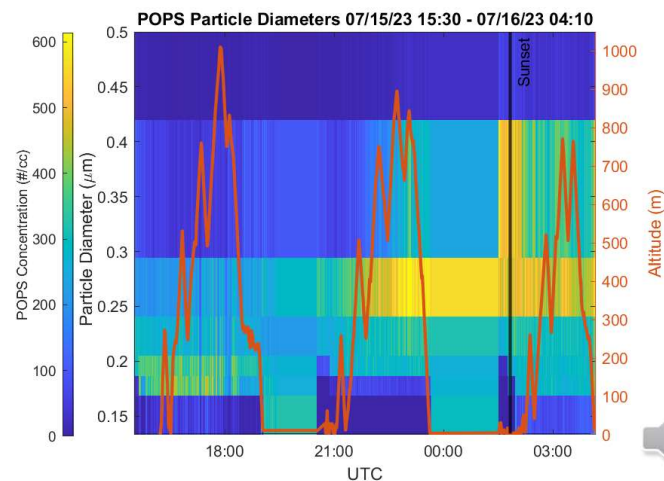
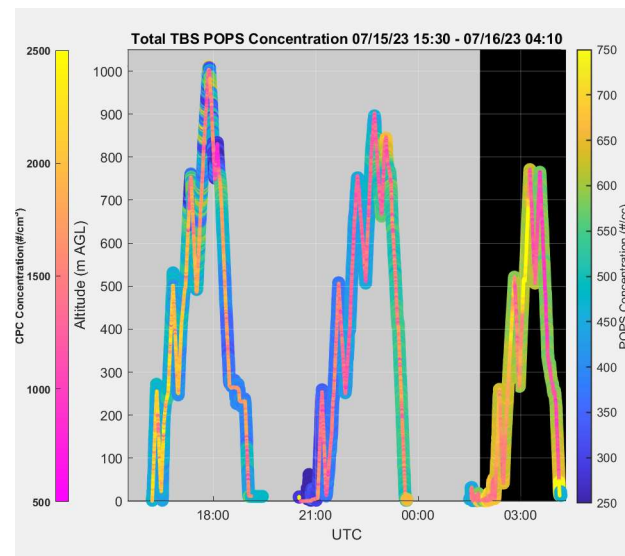
TBS aloft at SGP at 23:00 local time on 7/15/23.

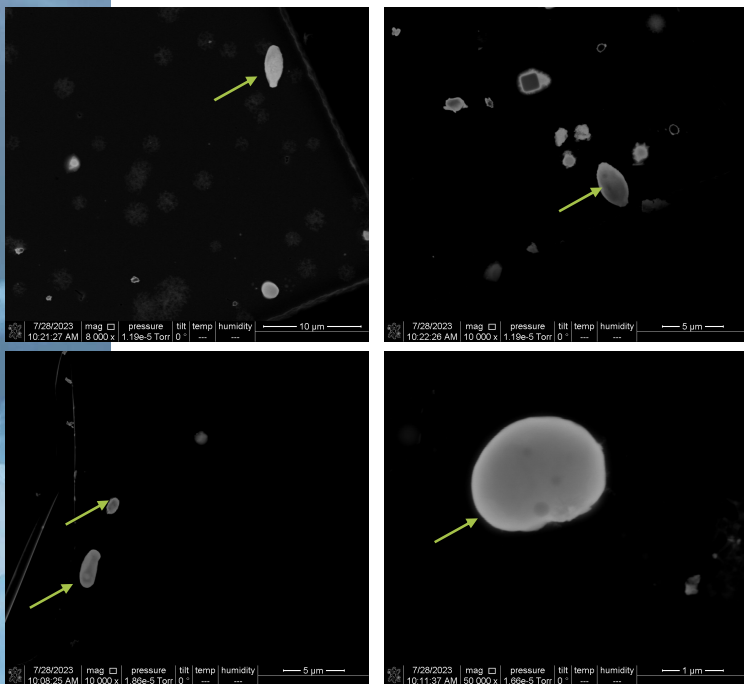
TBS night flights at SGP began in July 2023 to capture the chemical evolution of aerosols during initiation, growth, propagation, and decay of convective cells.

The FROST (Fielded Remote Organic Sampling Technology) VOC sampler was also operated to collect vertical profiles of volatile organic compounds for gas phase chemical composition.

Initial observations:

- total POPS concentration roughly doubled immediately after sunset
- increase in CPC particle concentration immediately after sunset
- mean particle diameter began to increase in late afternoon (220-335 nm) in comparison to 150-195 nm particles which led the number fraction in the morning

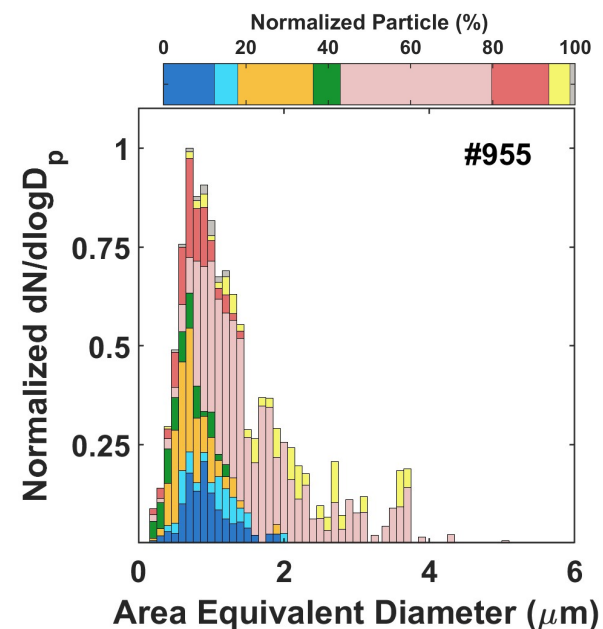
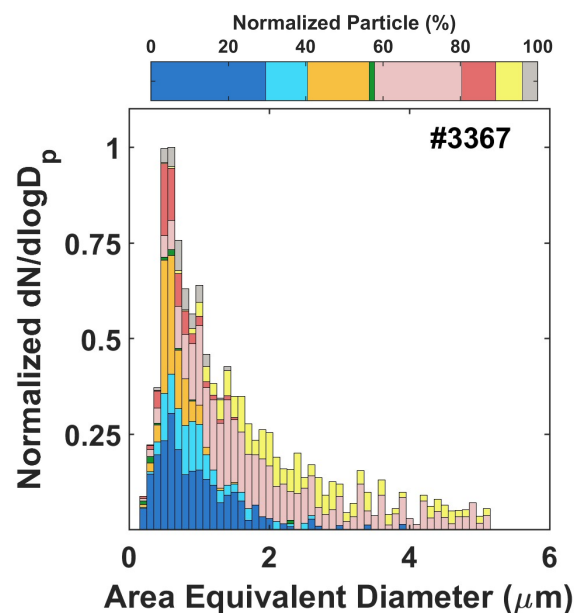




■ Na-rich
 ■ Na-rich sulfate
 ■ Sulfate
 ■ Carbonaceous
 ■ Dust
 ■ Carbonaceous+Dust
 ■ Biological
 ■ Other

06/02 DS

06/02 NS



Biological Particles indicated by arrows

- Presence of primary biological particles
- DS contains higher percentage of Na-rich, Na-rich sulfate and biological particles than NS

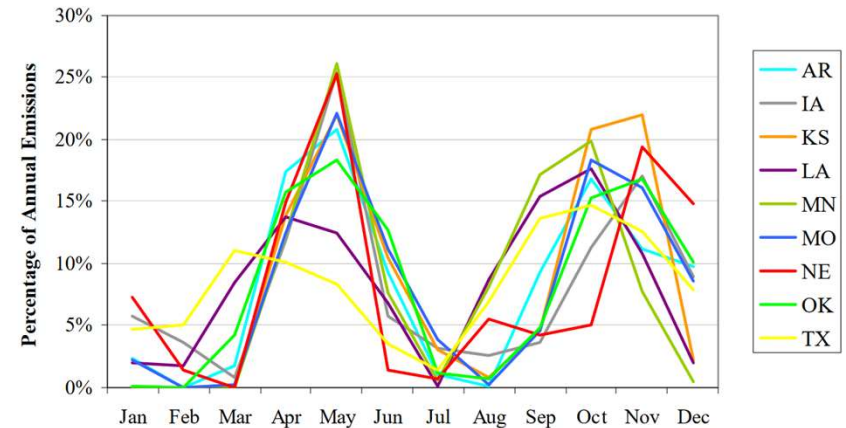
Results courtesy of EMSL PNNL



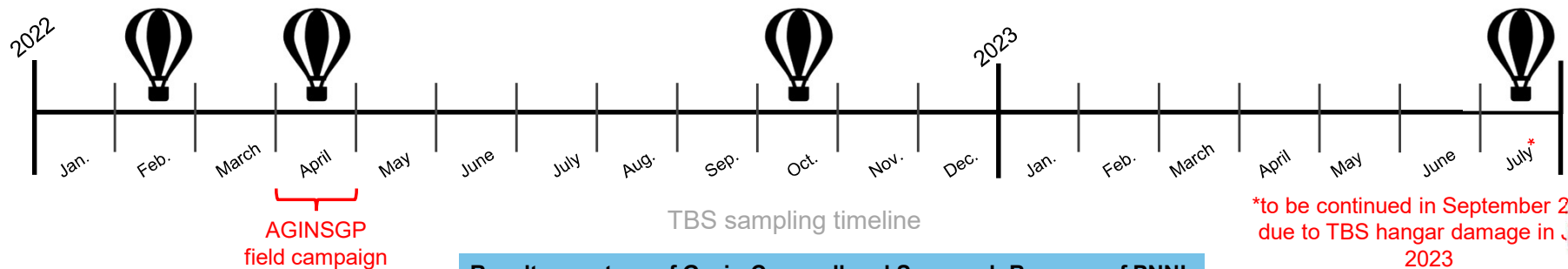


Understanding Contributions of Agricultural Dust to Vertical Profiles of Ice-Nucleating Particles in the Central Great Plains (DustINP); PI: Susannah Burrows, PNNL

- FY2022 FICUS award to use the TBS to measure vertical profiles of aerosol and INPs at the SGP site
 - Agricultural soils are hypothesized to be a prominent source of INPs at SGP
 - Four TBS sampling campaigns were conducted as part of the DustINP ARM TBS Field Campaign at SGP during different times of the year in order to capture different time points within the agricultural emission cycle (right)
 - One of these TBS campaigns overlapped with the surface-based ARM AGINSGP campaign (Agricultural Ice Nuclei at SGP) and also included measurements of INP on the TBS.
 - TBS payload included CPC, POPS, meteorology and wind sensors, STAC (substrate sampling), and IcePuck



Seasonal cycle of agricultural soil emissions in the Great Plains, Penfold et al. 2005.



Results courtesy of Gavin Cornwell and Susannah Burrows of PNNL





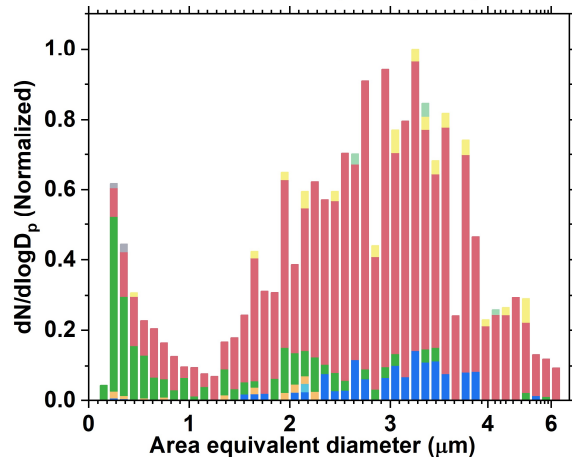
Particle composition can vary substantially between the ground and aloft

Ground sample is clearly dusty, while TBS Flight 2 has little to no dust.

Still more work needs to be done on disentangling the effect of composition on INP activity.

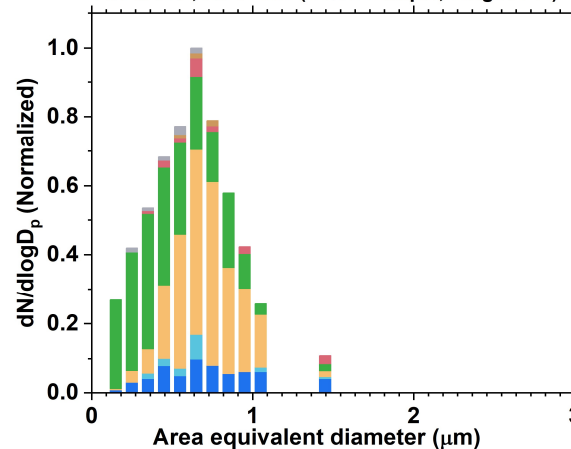
4/11/2022 ground all day

11/04/2022, N.P.= 1130 (Day Sample, Stage A+B)

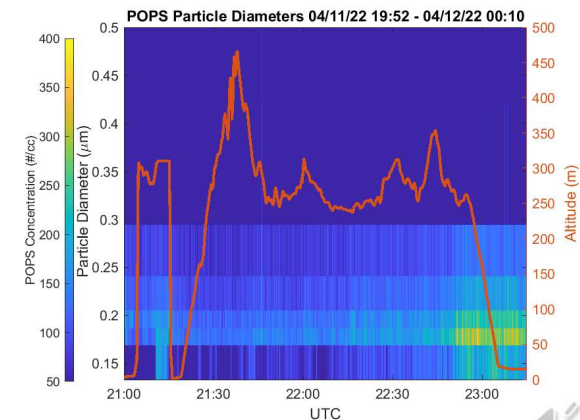
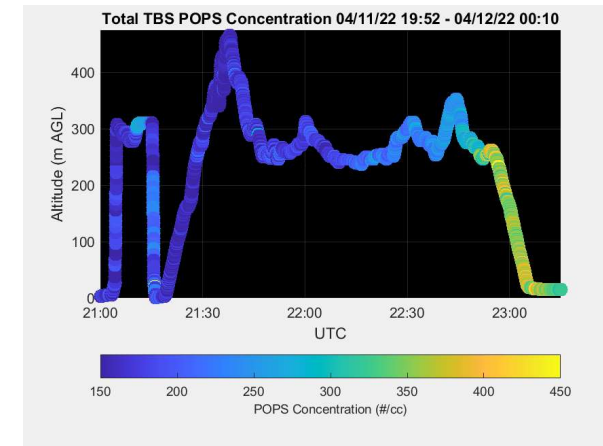


4/11/2022 TBS STAC Flight 2

11/04/2022, N.P.= 559 (STAC Sample, Stage A+B)

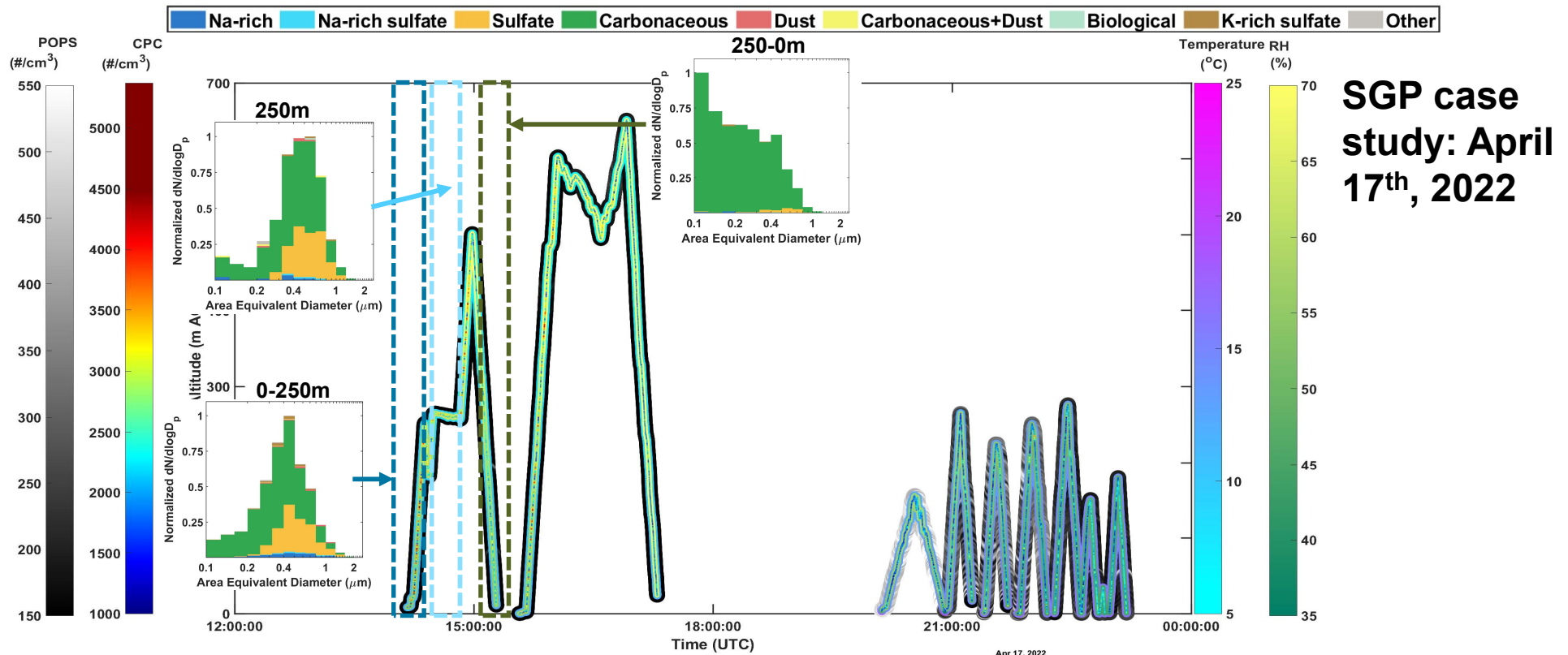


- Na-rich
- Biological
- Na-rich Sulfate
- Si-rich Sulfate
- Sulfate
- K-rich Sulfate
- Carbonaceous
- Other
- Dust



Results courtesy of Gavin Cornwell, Susannah Burrows, and Nurun Nahar Lata of PNNL





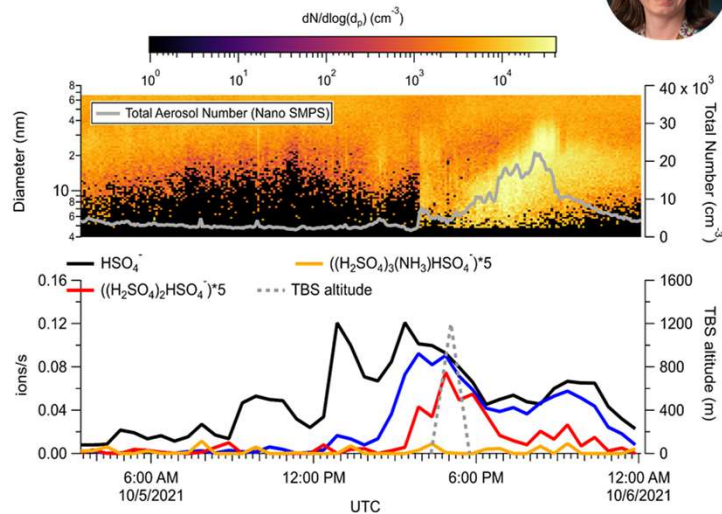
SGP case study: April 17th, 2022

- The size-resolved chemical composition showed a significant difference for ascending (0-250m) and descending flight samples (250m-0m).
- Ascending sample is dominated by carbonaceous and sulfate and descending sample contains very high carbonaceous particles



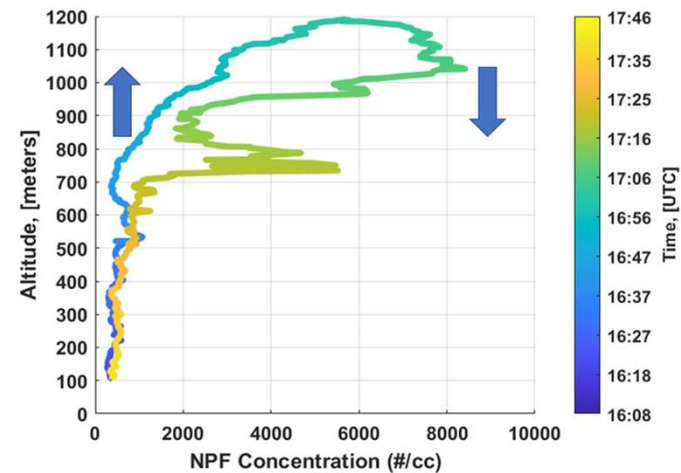
- Current models poorly represent both the **magnitude** and the **vertical initiation** of boundary layer new particle formation. To address these gaps, a combined TBS-surface measurement campaign was organized at the ARM SGP to:

- Identify any “missing” aerosol precursors responsible for observed NPF (PI: Browne)



- Higher order sulfuric acid ion clusters (n = 3) were not observed, suggesting **insufficient precursors to initiate surface NPF**.

- Identify the vertical locations where observed NPF initiates (co-I: Kuang)



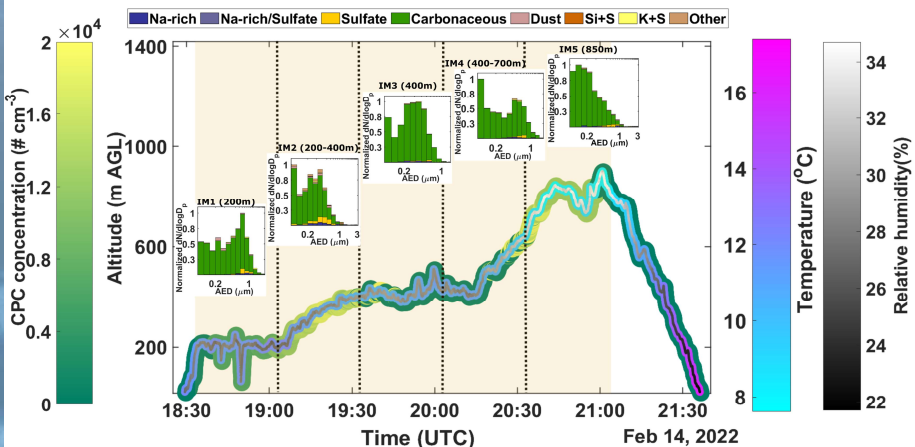
- TBS-based 1 nm CPC (right) provided vertically-resolved aerosol concentrations indicating that **NPF initiates aloft (> ~1200 m)** followed by downward transport to the surface where particle growth continues.

Results courtesy of Eleanor Browne of UC Boulder and Chongai Kuang of BNL

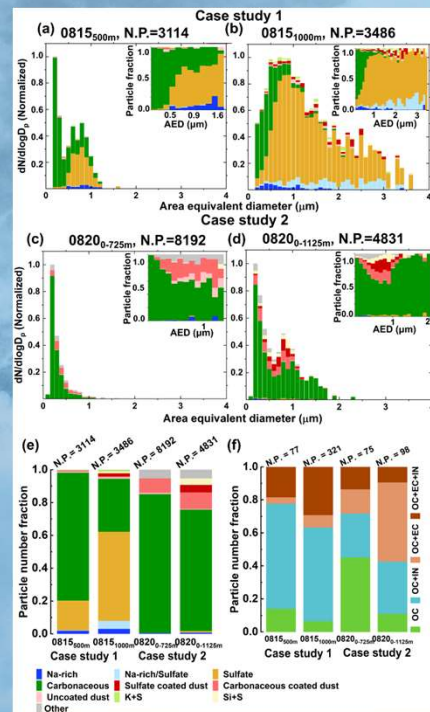


ARM

Size and Time-Resolved Automated Aerosol Sampling; PI: Swarup China, PNNL EMSL



- Vertical profile of atmospheric interactions and processes
- Size-resolved and time-resolved chemistry



Lata et al. EST 2023
doi/10.1021/acs.est.2c09498

Environmental
Science
Atmospheres

- STAC has been deployed at different sites
- Case study shows size-resolved composition at the SGP site

Results courtesy of EMSL PNNL

Cheng et al., Environ. Sci.: Atmos., 2022
DOI: 10.1039/D2EA00097K



ARM

Seasonal vertical aerosol profiling for aerosol-cloud-precipitation interactions to advance mountainous hydrological process science; PI: Allison Aiken, LANL, Co-I: Daniel Feldman, LBNL, Co-I: Paul DeMott, Colorado State University



Feldman, Aiken and Dexheimer at the TBS during SAIL. Photo by N. Bilow

FY2023 FICUS award to use the TBS to conduct seasonal vertical aerosol profiling

FOUR TBS DEPLOYMENTS IN 2023

- Winter Storm – January
- Spring Melt – April and May
- Summer Monsoon - June



TBS at SAIL in June. Photo by Aiken.

FY23 FICUS Awardee



Allison Aiken
Los Alamos National Laboratory

Seasonal Vertical Aerosol Profiling for Aerosol-cloud-precipitation interactions to Advance Mountainous Hydrological Process Science

Aerosols are critical for understanding the water cycle of mountainous regions, but a complete understanding cannot be provided without vertically resolved observations. The project aims to provide a greater understanding of aerosols and associated meteorological conditions for complex mountainous terrain in the East River Watershed of the Upper Colorado River.

FICUS | EMSL | ARM | U.S. DEPARTMENT OF ENERGY

Results courtesy of Allison Aiken of LANL, Dan Feldman of LBNL, and Paul DeMott of Colorado State University



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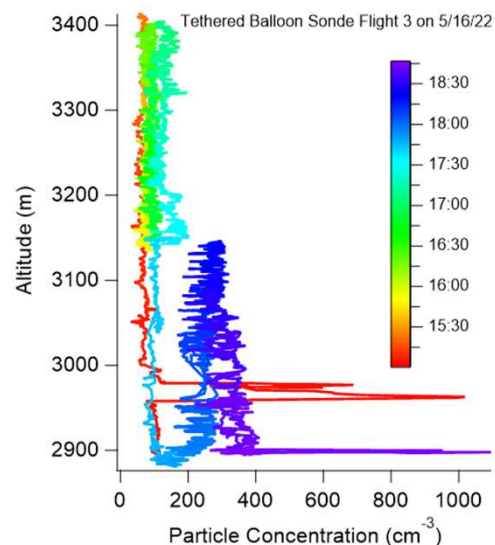
SAIL Aerosol Vertical Profiles (SAIL-AVP)

AEROSOL FLIGHTS: (~1-4 PER DAY)

Filter collection for metal analysis (LBNL)
IcePuck (Ice Nuclei)

Instrument	Property Measured	Type
Printed Optical Particle Spectrometer (POPS) (6 units)	Aerosol size distribution from 140 nm to 3 μm	Baseline
Condensation Particle Counter (CPC) Model 3007 (4 units)	Total aerosol concentration from 0.01 μm to 1 μm	Baseline
Size- and Time-Resolved Aerosol Collector (STAC)	Size- and time-resolved chemical composition from 0.1 μm to 5.0 μm	Baseline
Cascade impactors (6 units)	Size-resolved chemical composition at four cut-off sizes (0.25, 0.5, 1.0, 2.5 μm)	Available upon request
MicroAeth AE-51	Black carbon concentration measured at 880 nm	Available upon request

Example Aerosol Payload for the Tethered Balloon System (TBS).



Aerosol plume measured in real-time by the POPS. Figure from Feldman et al., BAMS, 2023.



TBS at SAIL, June 2023.
Photo: Brent Peterson/AntiGravity Films



Non-size-selected filter sample for offline chemical analysis. Photo: Vandergrift/EMSL.



Results courtesy of Allison Aiken of LANL, Dan Feldman of LBNL, and Paul DeMott of Colorado State University

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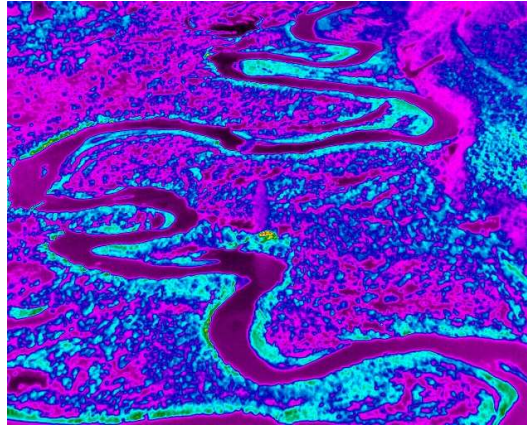
SAIL Aerosol Vertical Profiles (SAIL –AVP)

IMAGING FLIGHTS: APPROX. 1-2 PER DAY WITH IMAGES AT DIFFERENT ALTITUDES, E.G. 100 M AND 200 M

Visible and IR Cameras (tbscam)

POPS for aerosol particle number and size distributions

Meteorology sensor



Visible and IR Images from May 2023.



TBS at SAIL, May 2023. Photo: Brent Peterson/AntiGravity Films



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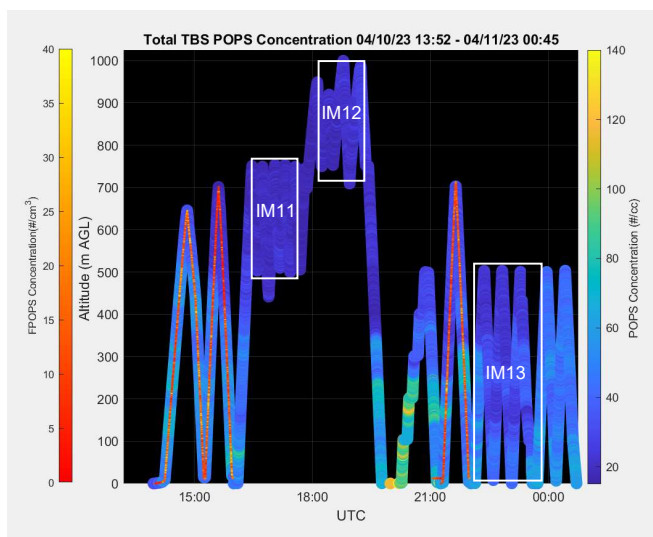
SAIL Aerosol Vertical Profiles (SAIL-AVP)



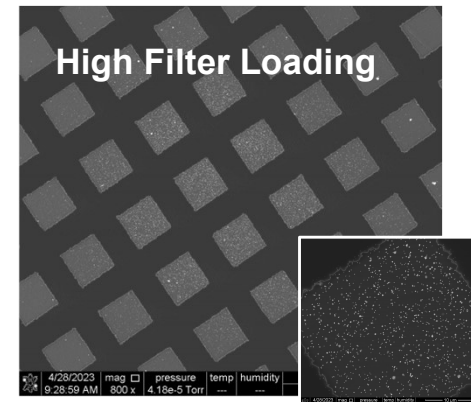
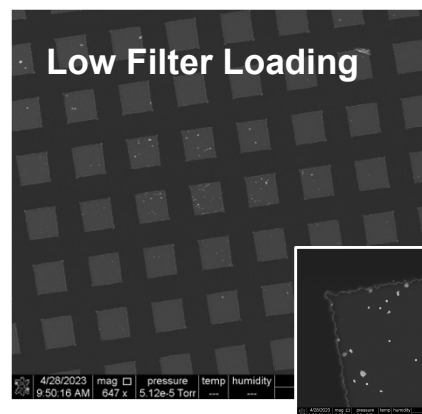
DATA AVAILABLE ON ARM DATA DISCOVERY AND PRELIMINARY EMSL FILTER ANALYSIS

Winter samples had low particle loadings and will have to be combined for a bulk analysis
Spring and Summer samples had better particle loadings due to higher concentrations, increased flow and longer sampling periods

*See Poster 14, during Poster Session 2 (Tues Aug. 8 at 9:15am) by Aiken et al. for more info.



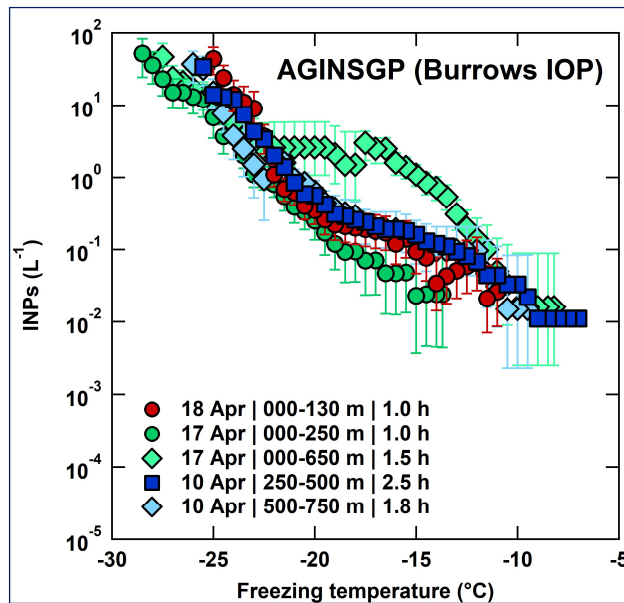
POPS aerosol number concentration data collected during one flight with three filter collection periods – data available on ARM Data Discovery.



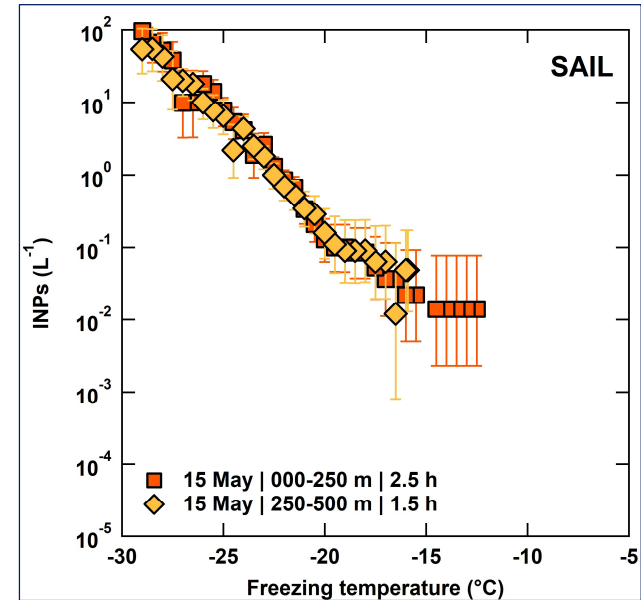
Size-selected filter loading analysis by EMSL from April 10, 2023 TBS Flight during F2 between 700 – 1000 meters above ground level.



INP from TBS at SGP April 2022



INP from TBS at SAIL May 2022



- No additional TBS INP samples have yet been processed since October 2022
- Additional SAIL TBS INP samples from July '22 and four 2023 deployments are planned to be processed under CSU's Russell Perkins' *Comprehensive Characterization of the Seasonal Cycles of INP for Studies of Precipitation Drivers in SAIL* new ASR project



ARM

FY24 TBS Campaigns

- PI Coty Jen, Carnegie Mellon University:
Boundary Layer Gradients in New Particle Formation
- SA-CPC, April 2024 at SGP
- PI Haofei Zhang, University of California Riverside:
Characterization of Organosulfates and Organonitrates in Vertically-Resolved Aerosols over the Southern Great Plains
- STAC samples for nano-DESI, February, July, October at SGP
- PI Peter Schwindt, Sandia National Laboratories:
Dual Comb Spectroscopy (DCS) to TBS
- **GHG lidar**, September and October 2024 at SGP
- Vertical Tower-Based Distributed Temperature Sensing
- March – October 2024 at BNF



TBS aloft at SGP on 5/29/23. Courtesy of AntiGravity Films.





Potential FY25 TBS Operating Locations

- ARM currently anticipates that BNF will be included as a potential TBS operating location in FY24 TBS proposal calls for flights in FY25.
- ARM TBS will work in FY24 to secure flight approvals and an operating location for FY25 flights at the ARM Urban Integrated Field Laboratory (UIFL) Coast-Urban-Rural Gradient Atmospheric Experiment (CoURAGE) deployment to Baltimore, MD.
- ARM TBS and ENA staff are currently seeking flight approvals from Portuguese authorities and an operating location for TBS at ENA.
- ARM TBS and NSA staff are in discussions with the U.S. Navy to secure a land lease agreement for TBS flights at NSA. Initial FAA approvals have been received for daytime TBS flights to 915 m AGL.

Thank you!

Questions?

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Andy Glen, aglen@sandia.gov (Sandia ARM Lead)
Casey Longbottom, cmlongb@sandia.gov (ARM TBS Lead
Mechanical Engineer)

