DOE/SC-ARM-23-049

SAIL Aerosol Vertical Profiles (SAIL-AVP) Field Campaign Report

AC Aiken
P DeMott
J Smith
J Christensen
W Dong
S China
G Vandergrift
D Feldman
J Creamean
J Fan
N Bouskill
D Dexheimer
Z Cheng

December 2023

DISCLAIMER

DOE/SC-ARM-23-049

SAIL Aerosol Vertical Profiles (SAIL-AVP) Field Campaign Report

AC Aiken, Los Alamos National Laboratory
D Feldman, Lawrence Berkeley National Laboratory (LBNL)
P DeMott, Colorado State University (CSU)
Principal Investigators

J Creamean, CSU
J Smith, University of California, Irvine
J Fan, Argonne National Laboratory
J Christensen, LBNL
N Bouskill, LBNL
W Dong, LBNL
D Dexheimer, Sandia National Laboratory
S China, Pacific Northwest National Laboratory (PNNL)
Z Cheng, PNNL
G Vandergrift, PNNL
Co-Investigators

December 2023

How to cite this document:

Aiken, AC, D Feldman, P DeMott, J Creamean, J Smith, J Fan, J Christensen, N Bouskill, W Dong, D Dexheimer, S China, Z Cheng, and G Vandergrift. 2023. SAIL Aerosol Vertical Profiles (SAIL-AVP) Field Campaign Report. U.S. Department of Energy, Atmospheric Radiation Measurement user facility, Richland, Washington. DOE/SC-ARM-23-049.

Work supported by the U.S. Department of Energy,
Office of Science, Office of Biological and Environmental Research

Acronyms and Abbreviations

3D	three-dimensional
ACSM	aerosol chemical speciation monitor
AGL	above ground level
AMF	ARM Mobile Facility
ARM	Atmospheric Radiation Measurement
ASR	Atmospheric System Research
BC	black carbon
CCN	cloud condensation nuclei
CPC	condensation particle counter
CSU	Colorado State University
CSU INS	CSU Ice Nucleation Spectrometer
DOE	U.S. Department of Energy
EMSL	Environmental Molecular Sciences Laboratory
FPOPS	fluorescent printed optical particle spectrometer
GPS	Global Positioning System
INP	ice nucleating particles
LBNL	Lawrence Berkeley National Laboratory
MDT	Mountain Daylight Time
NPF	new particle formation
PNNL	Pacific Northwest National Laboratory
POPS	printed optical particle spectrometer
SAIL	Surface Atmosphere Integrated Field Laboratory
SAIL AVP	SAIL Aerosol Vertical Profiles
SFA	Science Focus Area
SP2	single-particle soot photometer
STAC	size- and time-resolved aerosol collector
TBAC	time-resolved bulk aerosol collector
TBS	tethered balloon system
UCRB	Upper Colorado River Basin
UHSAS	ultra-high-sensitivity aerosol spectrometer
UTC	Coordinated Universal Time

Contents

Figures

Tables

1.0 Summary

1.1 Science Goals

Aerosols are central to understanding the water cycle within mountainous regions, but a complete understanding of this role cannot be provided without vertically resolved observations, particularly for aerosol-cloud interactions, since we simultaneously need to know aerosol information and meteorology near cloud bases. The goal of SAIL Aerosol Vertical Profiles (SAIL-AVP) was to perform tethered balloon system (TBS) measurements during different seasons to elucidate process-level understanding of the aerosols and associated meteorological conditions within complex mountainous terrain. Measurements were conducted during the deployment of the U.S. Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) user facility's second Mobile Facility (AMF2) as part of the Surface Atmosphere Integrated Field Laboratory (SAIL) campaign in the East River Watershed of the Upper Colorado River Basin (UCRB) in southwestern Colorado. In mid-latitude continental interior mountain ranges, and especially at SAIL, aerosol vertical profiles and their relationships with meteorology are, almost without exception, inferred from a combination of ground-based and remote-sensing data. These flights provided many more dimensions to aerosol-cloud interactions that are unavailable to those inferential approaches: the TBS collected in situ information in the vertical, optical, chemical, and biological dimensions for aerosol-cloud interactions. Furthermore, the collocation of these flights with longstanding collaborative resources in the region, including the ongoing surface and subsurface hydrologic observations from the DOE's Watershed Function Science Focus Area (SFA), produced a unique set of atmospheric observations that are complemented by existing land-surface and subsurface (e.g., groundwater) observations.

1.2 TBS Flights

SAIL-AVP extended the core scientific capabilities of the AMF2 Aerosol Observing System (AOS) by deploying the TBS to the SAIL campaign in Crested Butte, Colorado four times during 2023 (see Figure 1). A total of 75 flights were conducted over the course of 23 days and 95 flight hours. Flights included vertical profiling up to ~1,000 m above ground level (AGL) as well as lofting flights depending on the payload and science goals for each flight. Measurements and data were collected during the winter (post-storm), spring (two deployments during snowmelt), and summer (monsoon).

Figure 1. Images from each deployment in sequential order. Winter, spring 1, spring 2, and summer show the different seasons and surface conditions during the four TBS deployments of SAIL-AVP in 2023.

The TBS flights conducted in January, April, May, and June 2023 performed vertically resolved measurements of aerosol concentration, size distribution, and chemical properties in tandem with meteorology and cloud conditions to understand what aerosol processes dominate during different atmospheric conditions and seasonal events. These measurements provided insights into which types of particles were contributing to cloud condensation nuclei (CCN) and ice nucleating particles (INP), and which impact clouds, snow and precipitation, new particle formation (NPF), and aerosol growth events. These data were primarily collected with filters. Imaging flights (visible and infrared) were performed to relate aerosols in the column to the surface cover and vegetation state during each deployment. SAIL-AVP deployments during different seasons enabled the probing of different atmospheric conditions and aerosol-cloud-precipitation interactions to understand the seasonality of their impact to mountain hydrology, which is the dominant mode of variability of these interactions.

1.3 Aerosol Filters

Preliminary chemical analysis of the bulk and size-selected aerosol particle samples collected on the filters that flew on the TBS as part of these deployments has been conducted by DOE's Environmental Molecular Sciences Laboratory (EMSL; Cheng et al. 2022, China et al. 2021) at Pacific Northwest National Laboratory. The filter samples from the first deployment in the winter had very low particle loadings on the bulk and size-selected particle collectors. The second deployment was very challenging due to local environmental conditions, including high winds and large amounts of snow, so only a few filters were collected. The filter analysis from the third deployment was delayed since we were waiting to sample higher loadings expected in the spring. That analysis is forthcoming. Samples were collected, and EMSL determined the particle loadings to be better for analysis, but they were still low. The summer deployment was the most successful in terms of total flights (28) and samples collected. In addition to the ARM/EMSL filters, filter samples were collected using a miniaturized prototype sampler called the IcePuck (Handix Scientific, Inc.). IcePuck samples were collected for offline immersion-mode INP concentration analysis using the Colorado State University Ice Nucleation Spectrometer (CSU INS). In 2023, a total of 32 samples were collected during 21 flights. All INP samples have been transported to CSU and are preserved frozen until requested for processing of INP data.

1.4 Data Processing and Availability

The ARM real-time data from the TBS, including meteorology at the ground and on the TBS, and aerosol number concentrations and size distributions are currently available via open access on ARM Data Discovery. Analysis requiring offline processing, such as chemical analysis by EMSL and INP by CSU, are not posted yet, but will be posted to ARM Data Discovery with no delay nor any embargo period once that processing is complete.

2.0 Operations

2.1 Measurements

General information about the TBS and typical payloads can be found online on the ARM TBS instrument page and in the TBS instrument handbook (Dexheimer 2018). The instruments used in this deployment are summarized in Table 1. There is also a merged data product available called “tbsmerged” that includes most/all online data.

Table 1. Instruments deployed for SAIL-AVP on the TBS, including the data name in the ARM Data Center (if available) and properties measured.

Instrument	Data Name	Property Measured
Cameras, visible and infrared	tbscam	Visible and 30 Hz surface temperature imaging of 1.5 µm to 5.1 µm spectral band
Cascade impactors		Size-resolved aerosol chemical composition from 0.25 µm to 2.5 µm
Condensation particle counter (CPC)	tbscpc	Total aerosol number concentration from 0.01 to 1µm
IcePuck	tbsinp	Time-resolved bulk aerosol immersion-mode INP concentrations
iMet	tbsimet	Pressure, temperature, relative humidity, 3D GPS
MicroAeth AE-51		Black carbon concentration measured at 880 nm
Printed optical particle spectrometer (POPS)	tbspops	Aerosol size distribution from 140 nm to 3 µm
Size- and time-resolved aerosol collector (STAC)		Size- and time-resolved individual particle morphology and chemical composition from 0.07 µm to 2.3 µm
Time-resolved bulk aerosol collector (TBAC)		Time-resolved high-resolution mass spectrometry analysis to probe molecular information

2.2 Deployments

2.2.1 Post-Winter Storm (January 21-24)

The first deployment had a delayed start due to a winter storm and was forced to conclude early due to low visibility and cold temperatures. Four flight days from January 21 to 24 collected ten flights of data. No precipitation was recorded by the ARM AOS (Uin et al. 2019, Uin and Smith 2021, Theisen et al. 2023) during the sampling period, and the organic aerosol mass sampled by the aerosol chemical speciation monitor (ACSM; Watson 2017) was below 0.3 µg/m^3. EMSL conducted a preliminary analysis of the samples and determined that the loadings were very low. Multiple samples will be combined for analysis by EMSL to establish an estimate of the average seasonal background of aerosol composition after a winter storm.

- January 21 – 2 flights
- January 22 – 3 flights, all below 500 m AGL
- January 23 – 3 flights, moderate winds
- January 24 – 2 morning flights before high winds

2.2.2 Pre-Snowmelt (April 6-11)

The second deployment also had a delayed start due to snowstorms. The conditions were unseasonably cold and the dates sampled were prior to the beginning of snowmelt. Six days of flights with a total of 22 flights were collected. Preliminary analysis by EMSL concluded that the concentrations were still very low during this collection period. The AOS data showed that a large supermicron event occurred on April 4, a few days prior to the first TBS flight. Like the first deployment, there was also no precipitation recorded by the AOS during sampling. Organics remained low, < 0.4 $\mu g/m^3$, with the highest concentrations recorded on April 8 and 9. A black carbon (BC) event at the AOS was also recorded in the morning of April 6 by the single-particle soot photometer (SP2; Sedlacek 2017).

- April 6 – 4 flights, up to 1150 meters AGL
- April 7 – 3 flights, cold, low concentrations
- April 8 – 3 flights, warmer, higher total concentrations
- April 9 – 3 flights, warmest
- April 10 – 6 flights, long and high altitude
- April 11 – 3 flights, AM flights, high winds

2.2.3 Snowmelt Start (May 9-13)

The third deployment also had a delayed start due to lack of snowmelt. The TBS flew for five days and was able to collect data during a total of 15 flights. AOS organics were < 1.2 $\mu g/m^3$ and the SP2 recorded a BC event on May 12.

- May 9 – 3 morning flights, still snow on the ground
- May 10 – 2 flights, high loadings at the surface due to winds
- May 11 – 1 flight, snow and rain reduced operations
- May 12 – 4 flights, high winds
- May 13 – 5 flights before storms

2.2.4 Summer Monsoon (June 8-15)

There was no AOS ultra-high-sensitivity aerosol spectrometer (UHSAS) data available during this deployment, which impacted TBS operations since that data is usually used to inform flight plans. Due to the storms that would develop midday, the TBS team developed a customized flight strategy to begin flights at 6 am MDT, break during peak mixing and storm formation midday, and resume flights from late afternoon until 8 pm MDT, unless midday turbulence was not severe or storms did not form.

- June 8 – 2 AM flights
- June 9 – 5 flights
- June 10 – 5 flights, winds limited altitude to 100 m AGL
- June 11 – 3 flights up to 1 km AGL

- June 12 – 2 flights up to 1 km
- June 13 – 2 flights
- June 14 – 3 flights, highest concentrations
- June 15 – 6 flights

3.0 Preliminary Results

3.1 Aerosol Concentration and Size

Number concentrations and size distributions from all TBS flights are available in the ARM Data Center. Figures 2 and 3 show examples of the online ARM TBS data from the second deployment period in April 2023 at SAIL. Data were collected up to 1000 meters AGL. Flights two and five were lofting flights that collected filter samples. Total number concentrations were the lowest during this day for those flights that were collected between 500 and 1000 meters AGL. Despite lower concentrations, the TBAC and STAC loadings were considered overall to be good by EMSL for chemical analysis due to the extended sampling time for those lofting flights.

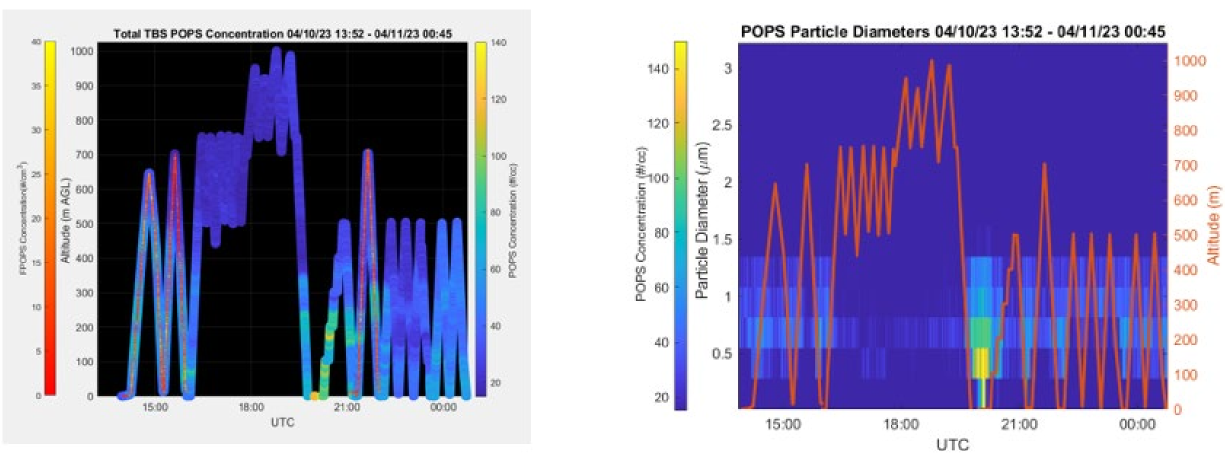

Figure 2. (a) TBS POPS number concentrations (#/cc) and (b) mean particle diameter (µm) shown at the altitude (m) at which it was collected during six flights on April 10, 2023. Fluorescent POPS (FPOPS) data is shown, but not discussed in this report as it was deployed as a part of a separate campaign.

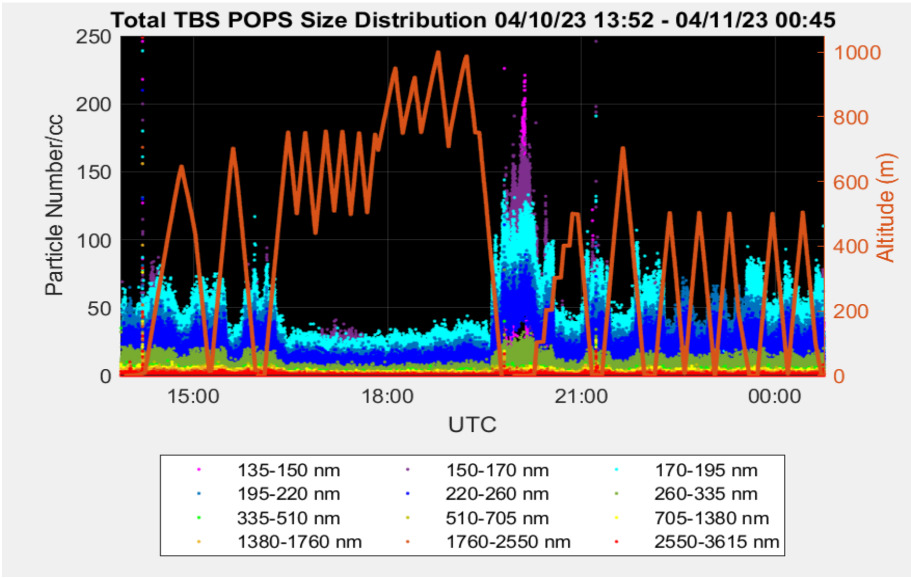

Figure 3. TBS POPS size distributions (#/cc) depicted on the left axis versus the time in UTC of data collection over the course of six flights. Altitude (m) is plotted on the right axis versus time.

3.2 Aerosol Chemical Analysis

Analysis of size-resolved and bulk chemical composition is being conducted by EMSL. Figure 4 shows an example of the analysis from the same day as above. Preliminary analysis shows the dominance of carbonaceous aerosol sampled at three different altitudes that day. Sulfate and sodium-rich particles were also detected for particles smaller than 0.5 µm in diameter.

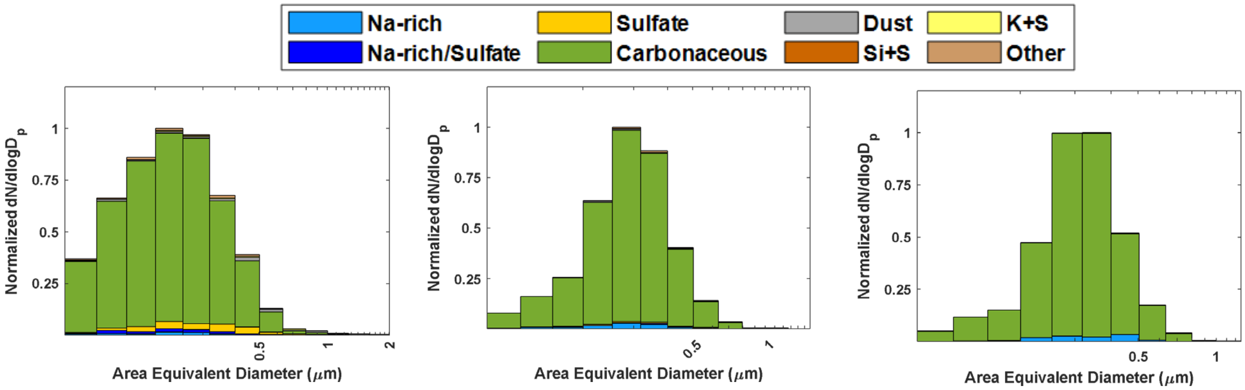

Figure 4. Size-dependent chemical analysis from filters collected at three different altitudes shown for particles smaller than 2 µm in diameter sampled sequentially during the SAIL-AVP TBS flights on April 10, 2023: (a) 500-750 m AGL, (b) 700-1000 m AGL, (c) 0-550 m AGL.

Bulk molecular chemical information is also currently being analyzed at EMSL. Figure 5 shows two samples analyzed during the fourth TBS deployment in the summer comparing samples collected during the day versus at night. Significant signal indicates the presence of both organics and organosulfates. Elemental ratios and functional groups will also be analyzed.

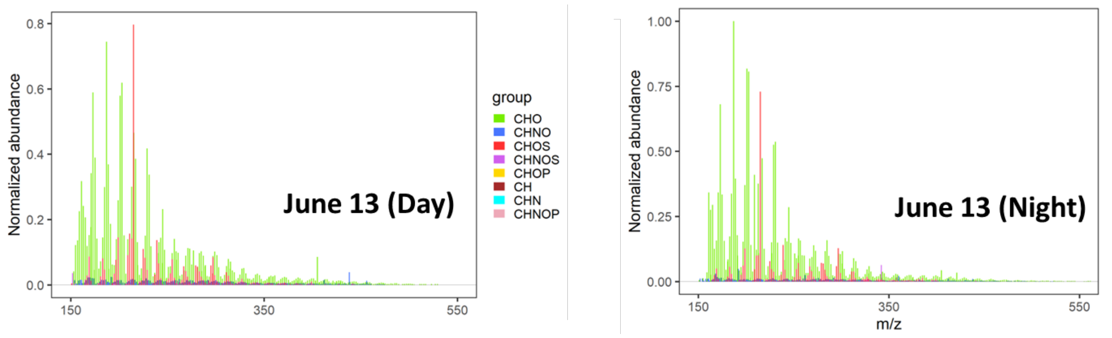

Figure 5. Bulk chemical analysis using mass spectrometry from filters collected during the SAIL-AVP shown as a function of signal versus mass-to-charge ratio (m/z) and colored by groups based on elemental composition for TBS flights conducted on June 13, 2023 during the (a) day and (b) night.

3.3 Preliminary Findings and Future Work

The collection of aerosol profiles at SAIL enabled direct characterization of aerosol and meteorology interactions and aerosol deposition events during SAIL. The cold-season flights demonstrated that the SAIL study area is remarkably pristine in terms of atmospheric aerosols. Both anthropogenic and biological aerosols contributed negligibly to total aerosol concentrations. Occasional plumes of dust and biomass burning also impacted the UCRB. The TBS data indicated the time- and space-scales at which these plumes distribute throughout the boundary layer of the SAIL study area. The warm-season data indicated that the atmosphere is much less pristine and is impacted by mechanically generated aerosols (e.g., dust), biomass burning aerosols, and biogenic aerosols (including new particle formation and growth from precursor gasses as well as direct emission of primary biological particles such as bacteria, pollen, and fungi). The TBS data highlight the relative contributions of these different types of aerosols in space and time and show that their different sources all contribute to atmospheric aerosol processes in the UCRB.

Further analysis will focus on direct and indirect impacts of the regimes associated with the aerosols measured with the SAIL-AVP TBS flights, and the impacts of these measured aerosols on clouds, frozen surface albedo, and land-surface processes. Studies will be pursued that explore what process representations climate models, which seek accurate representations of aerosol-cloud interactions and atmospheric aerosol processes in complex terrain, ultimately need to include to avoid biases.

4.0 Publications and References

4.1 Presentations

1. Aiken, AC, KB Benedict A Shawon, K Gorkowski, J Viegas, J Bilberry, and D Feldman. 2022. Surface Atmosphere Integrated Field Laboratory (SAIL) aerosol regimes and processes, including supermicron and bioaerosol events measured during the SAIL Supermicron Bioaerosol (SSB) campaign. Presented at the ARM/Atmospheric System Research (ASR) Principal Investigators Meeting, Washington D.C.

2. Feldman, D, AC Aiken, WR Boos, R Carroll, V Chandrasekar, SM Collis, J Creamean, G de Boer, J Deems, PJ DeMott, J Fan, AN Flores, M Grover, D Gochis, AL Hodshire, R Jackson, EJ Levin, JR O'Brien, M Raleigh, A Rhoades, W Rudisill, ZS Sherman, S Skiles, J Smith, A Varble, and KH Williams. 2022. A year in the Colorado Rockies -- Perspectives on science opportunities from the first half of SAIL. Presented at the ARM/ASR Principal Investigators Meeting, Washington D.C.
3. Aiken, AC, KB Benedict, A Shawon, J Viegas, J Bilberry, and D Feldman. 2023. Seasonal Aerosol Regimes and Processes Observed in Mountainous Terrain at Surface Atmosphere Integrated Field Laboratory (SAIL). Presented at the ARM/ASR Principal Investigators Meeting, Washington D.C.
4. DeMott, PJ, RJ Perkins, J Creamean, TC Hill, S Kreidenweis, AC Aiken, D Dexheimer, D Feldman, N Lata, and S China. 2023. Aerosol Influences on Ice Nucleating Particles Interpreted through INP, Online and Single Particle Aerosol Characterization Measurements in SAIL. Presented at the ARM/ASR Principal Investigators Meeting, Washington D.C.
5. Feldman, D, AC Aiken, V Chandrasekar, SM Collis, J Creamean, G de Boer, J Deems, PJ DeMott, J Fan, AN Flores, M Grover, TC Hill, AL Hodshire, EJ Hulm, C Hume, R Jackson, F Junyent, AD Kennedy, M Kumjian, EJ Levin, J Lundquist, JR O'Brien, A Rhoades, W Rudisill, ZS Sherman, S Skiles, J Smith, R Sullivan, A Theisen, M Tuftedal, A Varble, AC Wiedlea, S Wielandt, KH Williams, and Z Xu. 2023. Summary of and Selected Highlights from the Surface Atmosphere Integrated Field Laboratory (SAIL) Field Campaign. Presented at the ARM/ASR Principal Investigators Meeting, Washington D.C.
6. Aiken, AC, et al. 2023. "Supermicron and Bioaerosol Events and Impacts." Presented at the SPLASH/SAIL/SOS (S3) Combined Workshop. Boulder, Colorado.
7. Smith and Knapp. 2023. "Investigating aerosol formation and growth during SAIL." Presented at the SPLASH/SAIL/SOS (S3) Combined Workshop. Boulder, Colorado.
8. Aiken, AC, et al. 2023. "Aerosol Science for Climate, Human Health, and Global Security." Invited colloquium at the Department of Earth & Planetary Sciences (Geological, Environmental, and Atmospheric Sciences), University of New Mexico. Albuquerque, New Mexico.
9. Aiken, AC, PJ DeMott, J Fan, S Skiles, J Smith, KB Benedict, A Shawon, D Dexheimer, S China, F Mei, M Zawadowicz, SAIL Aerosol Observing System mentors, and ARM Site Operations staff. 2023. "Aerosol Measurements for Integrated Mountainous Hydroclimate Processes in the Upper Colorado River Basin." Invited platform at the American Geophysical Union Fall Meeting. San Francisco, California.
10. Isakson, L, R Jundt, M Ballon, P Sorensen, AC Aiken, and AR Nelson. 2023. "Accelerate Your Research by Leveraging the Power of Multiple Scientific User Facilities Through One Competitive Proposal: Learn About the Facilities Integrating Collaborations for User Science (FICUS) Program." Town hall presented at the American Geophysical Union Fall Meeting. San Francisco, California.

4.2 Publications

Feldman, DR, AC Aiken, WR Boos, RWH Carroll, V Chandrasekar, S Collis, JM Creamean, G de Boer, J Deems, PJ DeMott, J Fan, AN Flores, D Gochis, M Grover, TCJ Hill, A Hodshire, E Hulm, CC Hume, R Jackson, F Junyent, A Kennedy, M Kumjian, EJT Levin, JD Lundquist, J O'Brien, MS Raleigh, J Reithel, A Rhoades, K Rittger, W Rudisill, Z Sherman, E Siirila-Woodburn, SM Skiles, JN Smith,

RC Sullivan, A Theisen, M Tuftedal, AC Varble, A Wiedlea, S Wielandt, K Williams, and Z Xu. 2023. “The Surface Atmosphere Integrated Field Laboratory (SAIL) Campaign.” *Bulletin of the American Meteorological Society* 104(12): E2192–E2222, https://doi.org/10.1175/BAMS-D-22-0049.1

Aiken, AC, DR Feldman, PJ DeMott, RJ Perkins, S Kreidenweis, N Bouskill, J Christensen, JM Creamean, W Dong, J Fan, J Smith, D Dexheimer, S China, A Shawon, and F Mei. 2024. “Seasonal vertical aerosol profiling for aerosol-cloud-precipitation interactions to advance mountainous hydrological process science.” In preparation.

4.3 Collaborations

- Connections to large-scale meteorology – Adeyemi Adebiyi – University of California, Merced
- Ice nucleating particles – PJ DeMott/RJ Perkins/S Kreidenweis – CSU
- Metals – J Christensen – LBNL
- New particle formation – JN Smith – University of California, Irvine
- Nitrates – N Bouskill – LBNL
- Supermicron and Bioaerosol – AC Aiken/KB Benedict/A Shawon – LANL

4.4 References

Cheng, Z, A Liyu, D Dexheimer, NN Lata, G Kulkarni, CM Longbottom, F Mei, and S China. 2022. “An automated size and time-resolved aerosol collector platform integrated with environmental sensors to study the vertical profile of aerosols.” *Environmental Science: Atmospheres* 2: 1263–1276, https://doi.org/10.1039/D2EA00097K

China, S, F Mei, D Dexheimer, Z Cheng, NN Lata, G Vandergrift, and AM Shawon. 2021. Size and Time-Resolved Automated Aerosol Sampling Field Campaign Report. ARM user facility. DOE/SC-ARM-21-017. https://doi.org/10.2172/1828151

Creamean, JM, TC Hill, and CC Hume. 2022. Ice Nucleation Spectrometer (INS) Instrument Handbook. ARM user facility. DOE/SC-ARM-TR-278. https://doi.org/10.2172/1846263

Dexheimer, D. 2018. Tethered Balloon System (TBS) Instrument Handbook. ARM Climate Research Facility. DOE/SC-ARM-TR-206. https://doi.org/10.2172/1415858

Dexheimer, D, M Airey, E Roesler, C Longbottom, K Nicoll, S Kneifel, F Mei, R Harrison, G Marlton, and P Williams. 2019. "Evaluation of ARM tethered-balloon system instrumentation for supercooled liquid water and distributed temperature sensing in mixed-phase Arctic clouds." *Atmospheric Measurement Techniques* 12(12): 6845–6864, https://doi.org/10.5194/amt-12-6845-2019

Sedlacek, AJ. 2017. Single-Particle Soot Photometer (SP2) Instrument Handbook. ARM Climate Research Facility. DOE/SC-ARM-TR-169. https://doi.org/10.2172/1344179

Theisen, A, O Mayol-Bracero, J Uin, S Smith, J Shilling, C Kuang, M Zawadowicz, A Singh, R Trojanowski, J Creamean, A Sedlacek, C Hayes, D Campos DeOliveira, and M Allain. 2023. ARM FY2024 Aerosol Operations Plan. ARM user facility. DOE/SC-ARM-TR-289. https://doi.org/10.2172/2008425

Uin, J, AC Aiken, MK Dubey, C Kuang, M Pekour, C Salwen, AJ Sedlacek, G Senum, S Smith, J Wang, TB Watson, and SR Springston. 2019. "Atmospheric Radiation Measurement (ARM) Aerosol Observing Systems (AOS) for Surface-Based In Situ Atmospheric Aerosol and Trace Gas Measurements." *Journal of Atmospheric and Oceanic Technology* 36(12): 2429–2447, https://doi.org/10.1175/JTECH-D-19-0077.1

Uin, J, and S Smith. 2021. Southern Great Plains (SGP) Aerosol Observing System (AOS) Instrument Handbook. ARM user facility. DOE/SC-ARM-TR-267. https://doi.org/10.2172/1756406

Watson, TB. 2017. Aerosol Chemical Speciation Monitor (ACSM) Instrument Handbook. ARM Climate Research Facility. DOE/SC-ARM-TR-196. https://doi.org/10.2172/1375336

5.0 Lessons Learned

5.1 Cold-Season Weather

Aerosol loadings were low in the winter, making offline chemical analysis difficult/non-ideal due to low concentrations on the filters. The deployments were also a significant challenge to collect the data by the TBS operations team. We were thankful that two weeks were planned for each deployment since this allowed us to collect data even during the most challenging conditions. For example, in January, the TBS team had to dig out three feet of snow to start collections after a storm as well as conclude the deployment early due to low visibility and cold temperatures.

5.2 Warm-Season Weather

Snow cover did not abate until the June TBS deployment, prolonging low aerosol loadings until then. Thunderstorms occurred during four TBS flight days in June, which required the TBS operations team to develop a new strategy for the daily flight schedules. Wind speeds and turbulence aloft generally increased as thunderstorms developed, which also presented a challenge for the TBS team.

ARM

www.arm.gov

U.S. DEPARTMENT OF ENERGY

Office of Science