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ARM FY2024 Aerosol Operations Plan

A Theisen
J Uin
J Shilling
M Zawadowicz
R Trojanowski
A Sedlacek
D Campos DeOliveira
O Mayol-Bracero
S Smith
C Kuang
A Singh
J Creamean
C Hayes
M Allain

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ARM

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A Theisen, Argonne National Laboratory
O Mayol-Bracero, Brookhaven National Laboratory (BNL)
J Uin, BNL
S Smith, BNL
J Shilling, Pacific Northwest National Laboratory
C Kuang, BNL
M Zawadowicz, BNL
A Singh, BNL
R Trojanowski, BNL
J Creamean, Colorado State University
A Sedlacek, BNL
C Hayes, BNL
D Campos DeOliveira, BNL
M Allain, BNL

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Acronyms and Abbreviations

ACSM	aerosol chemical speciation monitor
ACSM-TOF	aerosol chemical speciation monitor – time of flight
ACTRIS	Aerosol, Clouds and Trace Gases Research Infrastructure
AETH	aethalometer
AGINSGP	Agricultural Ice Nuclei at SGP
AMF	ARM Mobile Facility
AMSG	Aerosol Measurement and Science Group
AOD	aerosol optical depth
AODBE	Aerosol Optical Depth Best Estimate VAP
AOS	Aerosol Observing System
AOSMET	Aerosol Observing System meteorological instruments
APS	aerodynamic particle sizer
ARM	Atmospheric Radiation Measurement
AS	atomizer system
AWARE	ARM West Antarctic Radiation Experiment
BNF	Bankhead National Forest
CACTI	Cloud, Aerosol, and Complex Terrain Interactions
CAMS	Center for Aerosol Measurement Science
CAPE-K	Cape Kennaook/Grim, Tasmania
CAPS	cavity attenuated phase shift monitor
CAPS-PMEX	cavity attenuated phase shift extinction monitor
CCN	cloud condensation nuclei
CCNC	cloud condensation nuclei counter
CLAP	continuous light absorption photometer
CM	calibration material
CPC	condensation particle counter
CPCF	condensation particle counter, fine
CPCUF	condensation particle counter, ultrafine
EBAS	a database hosting observation data of atmospheric chemical composition and physical properties developed and operated by the Norwegian Institute for Air Research (NILU).
ENA	Eastern North Atlantic
EPCAPE	Eastern Pacific Cloud Aerosol Precipitation Experiment
FM	flow meter
FY	fiscal year
GHG	greenhouse gases monitor
GUC	Gunnison (SAIL)
HOU	Houston (TRACER)
HTDMA	humidified tandem differential mobility analyzer

IMPROVE	Interagency Monitoring of Protected Visual Environments
INP	ice nucleating particle, filters for ice nucleation particles
INS	ice nucleating spectrometer
IOP	intensive operational period
MAOS	Mobile Aerosol Observing System
MCPC	Multiple Channel Per Carrier
MFC	mass flow controllers
MOSAiC	Multidisciplinary Drifting Observatory for the Study of Arctic Climate
NANASMPS	nano scanning mobility particle sizer
NEPHDRY	nephelometer, ambient
NEPHWET	nephelometer, RH scanned
NOAA	National Oceanic and Atmospheric Administration
NOX	nitrogen oxide monitor
NSA	North Slope of Alaska
OLI	Oliktok Point
OPC	optical particle counter
OZONE	ozone monitor
PSL	polystyrene latex
PTI	photothermal interferometer
PTR-MS	proton transfer reaction-mass spectrometer
QA	quality assurance
QC	quality control
RH	relative humidity
RLPROF-FEX	Raman Lidar Profiles – Feature detection and Extinction VAP
SAIL	Surface Atmosphere Integrated Field Laboratory
SGP	Southern Great Plains
SMPS	scanning mobility particle sizer
SO2	sulfur dioxide monitor
SP2	single-particle soot photometer
SP2-XR	extended-range SP2
TAP	tricolor absorption photometer
TBS	tethered balloon system
TE	transmission efficiency
TRACER	Tracking Aerosol Convection Interactions Experiment
UHSAS	ultra-high-sensitivity aerosol spectrometer
VAP	value-added product
WCCAP	World Calibration Center for Aerosol Physics\
WMO	World Meteorological Organization
WMO-GAW	WMO-Global Atmospheric Watch Programme

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Tables

1.0 Introduction

The Atmospheric Radiation Measurement user facility (ARM) deploys a suite of aerosol and trace gas (further mention of aerosols will assume inclusion of trace gases) instrumentation at each of ARM's observatories. ARM currently deploys five Aerosol Observing Systems (AOS; Uin et al. 2019), one each at:

- Southern Great Plains (SGP)
- Eastern North Atlantic (ENA)
- ARM Mobile Facilities (AMF1, 2, and 3).

Aerosol measurements at ARM's North Slope of Alaska (NSA) observatory have historically been made by the National Oceanic and Atmospheric Administration (NOAA) and provided to ARM through a collaboration.

As ARM's support for aerosol instrumentation increases, it is important for ARM to communicate plans and priorities for aerosol measurements to the community to maximize the benefit and planning around scientific activities and to advance confidence in ARM's aerosol measurements.

ARM will develop a yearly aerosol operations plan for the upcoming fiscal year (October 1-September 30) starting with FY24. This plan will be open and available through the ARM aerosol instrument webpages and will include:

- Review of the previous activities since the last plan (in this case, 2018)
- Planned activities and their priorities for the upcoming FY
- Calibration timing and efforts
- Planned activities for data products and value-added products (VAP).

Questions about the plan should be sent to Olga Mayol-Bracero through the mentor contact page: https://arm.gov/connect-with-arm/organization/instrument-mentors/list#aos.

2.0 AOS Instrumentation

Each AOS has a common set of standard instruments with additional instruments deployed as needed to ensure the best measurements at each site. The measurements include number concentration, size distribution, chemical composition, radiative and optical properties, hygroscopicity, trace gases, and supporting meteorological conditions. Table 1 lists instrumentation deployed at each ARM site and other instrumentation available for field campaigns such as during intensive operational periods (IOPs).

Table 1. Matrix of aerosol instruments and the observatories where they are deployed.

Instrument	AMF1	AMF2	AMF3	SGP	ENA	NSA	IOP
Aerosol chemical speciation monitor-quadrupole (ACSM)							
Aerosol chemical speciation monitor-time of flight (ACSM-TOF)							
Aethalometer (AETH)						NOAA	
Aerodynamic particle sizer (APS)							
Cavity attenuated phase shift monitor (CAPS)							
Carbon monoxide/nitrous oxide/water vapor (CO)							
Continuous light absorption photometer (CLAP)						NOAA	
Cloud condensation nuclei (CCN)							
Condensation particle counter (CPC, CPCF)						NOAA	
Ultrafine condensation particle counter (CPCUF, CPCU)							
Humidified tandem differential mobility analyzer (HTDMA)							
Impactor (1-10 µm)						NOAA	
Nano scanning mobility particle sizer (NANOSMPS)							
Nephelometer, ambient (NEPHDRY)						NOAA	
Nephelometer, RH scanned (NEPHWET)							
Humidigraph							
Ozone (OZONE)							
Scanning mobility particle sizer (SMPS)							
Sulfur dioxide (SO2)							
Single-particle soot photometer (SP2)	IOP	IOP	XR			XR	X
Ultra-high-sensitivity aerosol spectrometer (UHSAS)							
Meteorological information (AOSMET)							
Filters for ice nucleating particles (INS/INP)		IOP					
Proton transfer reaction-mass spectrometer (PTR-MS)							X
Nitrogen oxide 3-channel [NO, NO2, NOy] (NOX)							X
Greenhouse gases [CO_2, CH_4] (GHG)							X
Planned additions in FY24							
Planned removals							

2.1 Instrument Tiers

ARM generally has operated a high-quality research-grade AOS system but as noted below in FY24 Engineering and Development, ARM will invest in other tiers of aerosol measurements including aerosol nodes as defined below. ARM has also defined which instruments constitute the standard suite of AOS instrumentation. Instrumentation outside this baseline could be operated during IOPs or field campaigns as requested.

2.1.1 Aerosol Nodes

ARM is defining aerosol nodes to cover a range of possible aerosol systems for deployment, from lower-cost standalone systems to research-grade instruments deployed in a small shelter. The measurements deployed will depend on the scientific priorities of the field campaigns but may include, but are not limited to, size distributions, concentrations, and/or trace gases. As noted in the Engineering Development section, ARM is currently investing in two aerosol nodes for the extended AMF3 deployment to the Bankhead National Forest (BNF) in northwest Alabama and is also exploring options for aerosol nodes for the upcoming urban AMF deployment. Neither set of aerosol nodes have yet been fully specified; however, we anticipate that AMF3 systems will have more advanced capabilities than urban systems.

2.1.2 Standard AOS Instruments

An ARM standard AOS system has high-quality, research-grade instrumentation. These are highly complex systems with a variety of instrumentation and sampling protocols. For ARM purposes, a standard AOS includes the following instruments, currently deployed at every AOS.

Table 2. Standard AOS instruments.

Aerodynamic particle sizer (APS)	Ozone (O3)
Cloud condensation nuclei counter (CCN)	Particle soot absorption photometer (PSAP)
Condensation particle counter (CPC/CPCF)	Scanning mobility particle sizer (SMPS)
Impactor	Ultra-high-sensitivity aerosol spectrometer (UHSAS)
Nephelometer (NEPH)	AOS meteorological system (AOSMET)

2.1.3 Additional AOS Instruments

This instrumentation may be deployed full-time at certain sites or just during IOPs. It is not the same across all AOSs and could be deployed standalone in some cases. This set of instruments generally includes the following:

Table 3. Additional AOS instruments.

Aerosol chemical speciation monitor (ACSM/ACSM-TOF)	Humidified tandem differential mobility analyzer (HTDMA)
Aethalometer (AETH)	Nano scanning mobility particle sizer (NANOSMPS)
Carbon monoxide monitor (CO)	Proton transfer reaction-mass spectrometer (PTR-MS)
Ultrafine condensation particle counter (CPCU/CPCUF)	Sulfur dioxide monitor (SO2)
Cavity attenuated phase shift monitor (CAPS)	Single-particle soot photometer (SP2)
Filters for ice nucleation particles (INS/INP)	

3.0 Outcomes from the 2018 Aerosol Plan

The Aerosol Measurement and Science Group (AMSG) held a workshop in early 2017 (McComiskey and Sisterson, 2018) to understand the impediments to using ARM data for aerosol science. From this workshop came an ARM Aerosol Measurement Plan (Mather et al. 2018) that detailed a series of recommendations for ARM (Table 2).

Out of the 25 tasks defined, 11 have been completed by ARM (green shading in Table 2). Seven of these tasks are currently in progress (tan shading in Table 2). The remaining seven have not been formally addressed. For example, on improving the documentation of measurements and datastreams, there have been efforts to add processing information to the instrument handbooks for one or two instruments and discussions about developing a technical report on AOS data processing, but ARM will develop a formal plan to address this in the future.

A short overview of the completed tasks from this plan can be found in Appendix A with overviews of the in-progress tasks in Appendix B.

Table 4. 2018 ARM Aerosol Measurement Plan-recommended tasks (Mather et al. 2018). Green-shaded tasks are completed and tan-shaded are in progress.

#	Task	Theme	Priority	Readiness	Year Planned
1	Improve and simplify access to aerosol data	Documentation	1	2	2018
2	Improve documentation of measurements and datastreams	Documentation	1	2	2018
3	Complete SGP AOS by adding Ozone	Deployment	1	1	2018
4	Analyze ENA satellite observations (Supplemental Site)	Deployment	1	2	2018
5	Develop measurement plan for NSA	Deployment	2	3	2019
6	Implement an inlet drying system (initially at SGP)	Configuration	1	2	2018
7	Inlet characterization	Configuration	2	2	2019

#	Task	Theme	Priority	Readiness	Year Planned
8	Convert Mobile AOS (MAOS-A) to AMF1 AOS	Configuration	2	1	2018
9	Complete harmonization of core data products	Data Products	1	2	2018
10	Identify candidate data products for other communities	Data Products	2	3	2019
11	Develop prioritization for ultrafine CPCs	Number Density	3	2	2019
12	Implement second set of size distribution instruments	Size Distribution	2	1	2019
13	Comparable size distribution output across instruments	Size Distribution	1	2	2018
14	Establish CCN scan strategy	Hygroscopicity	3	3	2019
15	Characterize humidigraph	Hygroscopicity	2	2	2018
16	Reduce number of HTDMAs in field	Hygroscopicity	1	1	2018
17	Develop strategy for hygroscopic measurements	Hygroscopicity	1	3	2018
18	Determine PSAP/tricolor absorption photometer (TAP) filter migration path	Optical Properties	1	2	2018
19	Upgrade an aethalometer to 2-spot configuration	Optical Properties	2	1	2018
20	Implement improved ACSM quality controls	Composition	1	1	2018
21	Implement ingest for the ACSM-TOF	Composition	1	2	2018
22	Develop plan to support detailed composition measurements	Composition	3	3	2019
23	Implement filter sampling via the Interagency Monitoring of Protected Visual Environments (IMPROVE) network	Composition	3	2	2019
24	Upgrade an ARM HSRL to support aerosol retrievals	Profiles	2	2	2019
25	Support lidar/radiometer retrieval development	Profiles	3	2	2019

4.0 ARM AOS Instrument Operations

4.1 FY24 Operations

4.1.1 Aerosol Observing System

ARM will continue operating AOSs at SGP, ENA, AMF1 (Eastern Pacific Cloud Aerosol Precipitation Experiment [EPCAPE]), and AMF3 (BNF) in FY24. Additional instrumentation will be added to the NOAA NSA facility in FY24 (see Table 1 for the specific instruments). During the Cape Kennaook/Grim, Tasmania campaign (CAPE-K), only a small subset of instrumentation (APS, SP2, and UHSAS) will be deployed at the AMF2 as the site is collocated with the Cape Grim Baseline Air Pollution Station. Efforts are underway to make data from the station available to users and for use in VAPs. As ARM continues to

expand and enhance capabilities, it must scale back in other areas. Changes for FY24 impacted aerosol operations include:

- ACSM
  - ENA ACSM will be removed from service and kept as a spare
  - AMF2 ACSM-TOF will be sent to be installed at NSA
- HTDMA
  - ARM will operate a maximum of two HTDMAs at a single time. In FY24, ARM will operate the SGP and AMF1 (EPCAPE) HTDMA systems. After AMF1 is taken offline at the end of the campaign, the HTDMA at AMF3 will be brought online. The ENA HTDMA will be refurbished and will be available if needed for IOP or other purposes. A plan will be developed for the offline HTDMAs whether they are kept at the site or if they are shipped to the mentor.
  - The HTDMA units not actively deployed may be used for laboratory tests to better characterize instrument performance and to refine HTDMA data products. Examples include:
    - Characterizing instrument performance at different ambient conditions
    - Extending the HTDMA measurement range to larger particle sizes
    - Improving data inversion by using an external Multiple Channel Per Carrier (MCPC).

    The goal of this work is to better quantify measurement uncertainty, refine the existing ARM HTDMA data products (such as the sub-saturated kappa), and develop new value-added data products to facilitate wider use of ARM HTDMA data. A plan for the operation of the HTDMAs in the field and in the laboratory will be developed during the coming year.
- Humidigraph
  - The humidigraphs are aging in ARM and many are at the point of needing replacement. Instead of replacing these systems, ARM will retire all humidigraphs from operations and the subsequent RH-scanned nephelometers.

4.1.2 Ice Nucleating Particles

ARM has established routine ice nucleating particle (INP) filter collection and offline measurements at select sites since 2020. The filters are processed using an ice nucleating spectrometer (INS) generally referred to as INP. Collections of duplicate filters for 24 hours occurred approximately every six days at Oliktok Point (OLI) (M1) and SGP (C1). IOP collections have and/or currently include Agricultural Ice Nuclei at SGP (AGINSGP) (SGP C1), Surface Atmosphere Integrated Field Laboratory (SAIL) (Gunnison [GUC] M1 and S2), Tracking Aerosol Convection Interactions Experiment (TRACER) IOP (Houston [HOU] M1 and S3), and EPCAPE (EPC M1). INP filter samples were also collected on the tethered balloon system (TBS) during AGINSGP and SAIL. Data from OLI, part of SGP, and part of SAIL are available on Data Discovery. Due to the spin-up time required to establish this program, and the pandemic, there is a backlog of samples from most sites. The plan for FY24 is to continue filter collections for EPCAPE and SGP and start filter collections for CAPE-K (Apr 2024), NSA (Sep 2024), and BNF (Feb 2024). Extra effort will be put forth towards sample processing in FY24 to catch up on the backlog of filters by FY25, so that incoming samples starting in FY25 can be processed almost immediately following shipment of samples to Colorado State University.

4.2 Calibration

4.2.1 Calibration Schedule

Generally, the mentors calibrate the aerosol instruments at the beginning and end of mobile facility deployments with calibrations planned in between depending on the length of the deployment and scientific drivers for those campaigns. To align with needs expressed from the community for more routine calibration to better support field campaigns, IOPs, and long-term measurements in general, a new calibration plan for AOS instruments is being developed. The calibration plan is subject to change if other priorities and complications arise. The aerosol team will work with ARM communications on a communication plan to best convey changes to the community. The initial calibration plan for FY24 is shown in Table 5 with specific instrument-level calibration needs in Table 6. The aerosol mentor team will also work with site operators to define calibration procedures and transfer ownership of some calibration activities to site operations to improve the timeliness of calibrations and reduce the travel burden on the mentor team.

4.2.2 Intensive Operational Periods

As noted in Table 5, ARM will define two periods at SGP that are ideal for IOP operations in FY24. Initially, these will be back-to-back periods starting after the calibration trip in March 2024, through August, with the expectation that there will be another period for calibrations in June. ARM will prioritize efforts to ensure that all instruments are operational, calibrated, and producing high-quality data during this period. This will include shifting known activities (repairs, upgrades, etc.) that would take an instrument offline to either before or after this period and providing more frequent reviews of the data from the Data Quality Office and mentor. These periods do not exclude any other time of the year for IOPs but will be a period in which ARM makes a concerted effort to provide high-quality data with high uptime.

Table 5. Planned calibration activities for each of the ARM observatories. Yellow indicates periods that would be ideal for IOPs at SGP.

Site	Sep 2023	Oct 2023	Nov 2023	Dec 2023	Jan 2024	Feb 2024	Mar 2024	Apr 2024	May 2024	Jun 2024	Jul 2024	Aug 2024	Sep 2024	Oct 2024	Nov 2024	Dec 2024
AMF1 (EPC)																
AMF2 (CAPE-K)*																
AMF3 (BNF)																
ENA																
SGP							X			X						
NSA																
Calibration Trip																
X - Every effort will be made to ensure all instruments are operating at a high quality																
Ideal periods for IOPs																

Table 6. Calibration frequency and needs for each instrument type.

Personnel	Instrument	Calibration Frequency	Equipment Needs
Mentor/Operators	ACSM	4x/year	CS, AS, FM
Operators	AETH, flows	1x/year	FM
Mentor/Operators	APS	4x/year	FM
Operators	CAPS	2x/year	AS
Mentor	CCN	2x/year	CS, AS
Operators	CO, MFC	1x/year	FM
Mentor/Operators	CPCf, CPCuf, SMPS	4x/year	CS
Mentor	HTDMA	2x/year	CS, AS
Mentor	INS/INP, MFC	1/year	FM
Operators	NEPH	2x/year	AS
Operators	OPC	4x/year	FM
Operators	OZONE, MFC	1x/year	FM
Operators	PSAP, Flow, MFC	1x/year	FM
Operators	SO2, MFC	1x/year	FM
Mentor	SP2	2x/year	CS, AS
Mentor (Operator for calibration check)	UHSAS	2x/year	CS, AS

Mass flow controllers (MFC)
Cal SMPS (CS)
Atomizer system (AS)
Flow meters (FM)
Calibration material (CM) PSL, ammonium sulfate, nitrate, Fullerene soot

4.2.3 Improving Calibration Processes

ARM will procure instrumentation for the establishment of a gold-standard reference for size distribution (SMPS) and number concentration measurements (CPC). This equipment will be installed and tested at the Center for Aerosol Measurement Science (CAMS) at Brookhaven National Laboratory (BNL). These standards will then be compared against World Calibration Center for Aerosol Physics (WCCAP) standards every other year.

In parallel, processes will be developed in FY24 for calibration workflow and timing for each instrument. We expect that these calibration activities will result in downtime of the instruments, and they will be planned accordingly as part of the future aerosol operations plan for transparency. These activities are expected to occur over FY24 and FY25 and possibly into FY26. Calibrations of ARM instrumentation (CPC, SMPS, APS, UHSAS, OPC, CCN, ACSM) will start in FY25 with closure and intercomparison efforts in FY26/FY27.

4.3 FY24 Engineering and Development

In addition to routine AOS operations, the mentor team is focused on improving and expanding ARM measurements to better serve the research community. These efforts may revolve around improved understanding of the measurements, new instrumentation, new instrument development, or other needs as they arise. It is important that ARM prioritize these efforts and communicate those priorities to the community. Table 7 shows an overview of activities with further information below for Priority 1 activities.

Table 7. FY24 planned aerosol engineering and development activities.

Task	Priority	Planned End Date
Aerosol node development	1	March 2025
Aerosol flux measurement development	1	Sep 2025
Center for Aerosol Measurement Science (CAMS)	1	N/A
NSA additional instrument deployment	1	Dec 2023
Absorption measurement intercomparison and calibration experiment for advancing ARM's absorbing aerosol measurements	1	Dec 2025
New instrumentation for AMF3 (SP2-XR, SO2, APS)	1	SO2 (Jan 2024)
Training of AMF site operators on calibrations and instrument maintenance at BNL	1	December 2024
Develop and implement a plan for distributed aerosol measurements for urban AMF deployments	1	Sep 2024
Develop a strategy for hygroscopicity measurements	1	Dec 2023
Correction factors for the new PSAP filter media	2	Dec 2024
Gas analyzer Intercomparison	2	Dec 2024
Refurbishing the ENA HTDMA	2	Sep 2023
Testing a new field-deployable calibration system	2	Dec 2024
Replacement of the aging NEPH systems	3	July 2025
Absorption, scattering, and extinction closure study	3	Sep 2023
Develop a data flagging approach for identifying MOSAiC AOS contamination events	3	Nov 2023

Items are listed as "On Hold" due to possible future funding constraints.

4.3.1 Aerosol Node Development

As part of the third ARM Mobile Facility (AMF3) deployment to BNF, there is a need to measure the spatial distribution of aerosol properties. ARM is investing in the development of two aerosol nodes that will initially measure aerosol size distribution and number concentration but may be expanded to include additional measurements such as optical properties, CCN, INP, trace gases, and potentially more.

4.3.2 Aerosol Flux Measurement Development

ARM is deploying a single-particle flux system on the 40-meter tower at AMF3 to determine the viability of measuring aerosol fluxes. If the tests prove successful, additional heights will be deployed in subsequent years. Efforts for this will start in Q3 of FY24.

4.3.3 Center for Aerosol Measurement Science (CAMS)

As noted in the calibration section, ARM will be improving existing calibration processes. New calibration equipment will be procured for this effort and a detailed calibration plan for ARM aerosol instruments (particle number concentration and size) will be developed.

4.3.4 NSA Additional Instrument Deployment

In partnership with NOAA, ARM will deploy additional instrumentation to fill gaps in the existing observations. This will include an ACSM, APS, SP2-XR, and INP. The timeline for deployment of the ACSM, APS, and SP2-XR is currently under development but is anticipated in the first half of FY24. INP measurements will start in September 2024.

4.3.5 Absorption Measurement Intercomparison and Calibration Experiment for Advancing ARM's Absorbing Aerosol Measurements

A replacement for the PSAP is needed since it has been discontinued. Although potential replacements are available, side-by-side operation is insufficient to quantitatively assess their performance due to the lack of an accepted standard for aerosol absorption. Indeed, each of the available instruments provide "calibrated" values, but a factor of 2 disagreement between instruments of different types (for example, PSAP compared to AE33) is not uncommon. To provide ARM with the guidance needed for selecting a successor to the PSAP and to substantively improve the measurement fidelity of filter-based measurements, this project will use in situ instruments that measure aerosol absorption (e.g., CAPS-SSA, PTI) as a reference against which to compare filter-based measurements (e.g., PSAP, aethalometer).

4.3.6 New Instrumentation for AMF3

In addition to the aerosol node and aerosol flux measurement development and the gas analyzer intercomparison, ARM is adding additional instrumentation to the AMF3 AOS. This includes an APS, SO2, and extended-range SP2 (SP2-XR). The SO2 and APS are standard ARM instruments, but the SP2-XR will be a new addition that will require ARM to develop new processes (ingest, data quality, calibration, etc.).

4.3.7 Training Site Operations for Calibrations

To reduce travel costs while also maintaining reliable calibrations, the aerosol mentor team will train site operators on how to perform necessary calibrations and maintenance, starting with the upcoming CAPE-K deployment (APS, SP2, UHSAS), with a plan to expand this to other sites and instruments. This training will take place at BNL over the course of 1-2 weeks when the AMF2 AOS is there.

5.0 ARM AOS Data Products

5.1 FY23 Accomplishments and Ongoing Activities

Aerosol Optical Depth (AOD) and AOD Best Estimate (AODBE): ARM recently upgraded the MFRSR to include a new 1625-nm channel. This channel has significant interference from gas-phase species. A procedure for subtracting these interferences was developed in FY23 and implementation of this procedure was completed. We expect HOU AOD data including these corrections will be released by the end of FY23. We modified the AODBE 5-channel VAP to process data for multiple sites and updated the associated data object design and processed definitions. Currently we are processing AODBE data for the ENA site and expect this data to be released by the end of FY23.

CCN Kappa: Kappa is a parameterized representation of an aerosol particle's hygroscopicity widely used in models to calculate CCN concentrations and cloud properties. In the last two years, we have developed the CCN-SMPS kappa VAP and processed data for many campaigns/sites. In FY23, we developed a VAP that uses CCN and UHSAS data to calculate kappa. We also continue to maintain the SMPS-CCN kappa VAP and process data for new sites and AMF deployments.

CCN Profile: In previous years, we began implementing a VAP that estimates the CCN vertical profile using lidar data. The original version of the VAP used a datastream from the NOAA f(RH) instrument that is no longer available. As a workaround, we generated a new datastream from the Raman lidar that describes the expected change in aerosol size with altitude to estimate hygroscopic growth. In FY23 we implemented this and evaluated CCN profile data using the revised input datastream. Once this was implemented, we were able to process data from 2016 to 2033 at the SGP site. We also worked to improve the QA/QC implemented in the VAP.

Merged Size Distributions: We recently developed a VAP that merges data from the SMPS and APS instruments into a single size distribution. In FY 23, we moved the SMPS-APS merged size product into production and generated data for sites with both instruments. We also developed a machine learning algorithm that performs QA/QC on the merged SMPS-APS data set and released this data product to evaluation in late FY23/early FY24. Finally, we developed a VAP that merges SMPS and UHSAS size distributions and released this data for evaluation.

Data Sharing and Engagement: A long-term goal of ARM is to strengthen relationships with the international aerosol measurement community (WMO-Global Atmospheric Watch Programme [WMO-GAW], Aerosol, Clouds and Trace Gases Research Infrastructure [ACTRIS], etc.). ARM already has some engagement with ACTRIS and EBAS (an international database hosting observation data of atmospheric chemical composition and physical properties) regarding sharing ARM data in their databases. More efforts are needed to align calibration procedures, data processing, and data sharing with these organizations.

5.2 FY24 Planned Activities

Detailed plans for specific data product development efforts in FY24 are as follows.

CCN Profile: In FY24, we plan to run the CCN Profile VAP at more sites, including ENA. We will also continue evaluating the accuracy of the VAP by comparison to in situ measurements made on both manned and unmanned aircraft. Finally, we will begin to develop a machine learning model to evaluate the data via QA/QC.

HTDMA kappa: Calculation of kappa using cloud condensation nuclei counter (CCNC) and size distribution data involves several assumptions and is sensitive to errors in the sizing measurements. We planned to develop a VAP that calculates kappa under subsaturated conditions using data from ARM's HTDMA instruments. This plan will be modified based on any modifications to the HTDMA deployment plan. The new VAP should be less sensitive to errors in the instrument sizing and will provide a measure of kappa under subsaturated conditions.

Merged Size Distribution Machine Learning: In FY24, we will develop a machine learning QA/QC test for the SMPS/UHSAS merged size distribution. This will require manually labeling a relatively large data set, investigating the best model to perform the QA/QC test, and implementing the model to provide an automated QA/QC.

AOD and AODBE: ARM deploys several instruments capable of reporting AOD and related products. We have been working on extending these products to additional sites that require more manual labor in evaluating the Langley measurements and will continue to do so in FY24, including processing AOD data for new campaigns such as the ARM West Antarctic Radiation Experiment (AWARE). The AODBE VAP was released for the SGP site for five channels of MFRSR data. In FY24, we will complete implementation of the gas-phase subtraction at 1625 nm and release AOD data for all seven channels of the MFRSR. SGP and TRACER will be evaluated first, followed by ENA.

6.0 References

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Appendix A

2018 Aerosol Measurement Plan Completed Tasks

- Complete SGP AOS by adding Ozone

  An ozone monitor was added to the SGP E13 AOS system on March 21, 2019

- Analyze ENA satellite observations

  Data from the ENA satellite site was analyzed and a technical report submitted in 2019 (Aiken et al. 2019) with additional analysis presented in Gallo et al. 2020.

- Develop a measurement plan for NSA

  A plan has been developed and is being implemented. ARM plans to deploy an ACSM, APS, SP2, and filters for INS at the NOAA facility alongside NOAA instrumentation.

- Inlet characterization

  The 2021 transmission efficiency (TE) experiment of the AOS inlet stack concluded that the TE50 at the lower limit and upper particle size limit were 0.016 and 6.2 μm.

- Convert MAOS-A to AMF1 AOS

  The MAOS-A system was reconfigured and integrated into the first ARM Mobile Facility (AMF1) as part of the Cloud, Aerosol, and Complex Terrain Interactions (CACTI) campaign in May 2018.

- Complete harmonization of core data products

As part of this process, all AOS data was moved away from a mentor-edited workflow to a standardized and mostly automated workflow. In general, most instruments are processed to a base a-level datastream with minimal corrections. The data are then processed to b-level where added corrections, quality control, and calibrations are incorporated.

- Determine PSAP/TAP filter migration path

  ARM has removed the TAP from service and has continued to look for a replacement to the PSAP. Based on analysis from the ARM aerosol mentor team, the PSAP filters were migrated from E70 filters to Emfab filters on the following dates

  – SGP 03/01/20
  – OLI 03/03/20
  – ENA 04/01/20

  - AMF2 (SAIL) 09/01/21
  - AMF1 (TRACER) 10/01/21

- Upgrade an aethalometer to 2-spot configuration

  The AE-31 aethalometer was upgraded to a two-spot AE-33 in 2019. The system is currently deployed with the AMF1 AOS.

- Implement improved ACSM quality controls

  The ACSM processing was updated to automate the b-level data production assuming a collection efficiency of unity (CE=1). This b-level data set is being combined with a mentor-processed data set (assuming CE=1) to include additional correction and quality control as examined by the mentor. Additionally, a c-level data product was created to calculate the composition dependent collection efficiency described by Middlebrook et al. 2012. This task was completed in March 2022.

- Implement ingest for the ACSM-TOF

  The ACSM-TOF processing follows a similar process as the quad ACSM noted above. This processing was completed in January 2023.

- Implement filter sampling via the IMPROVE network

  An IMPROVE network system was installed at the SGP site in October 2019 and the data are available as an external data set:
  https://adc.arm.gov/discovery/#/results/instrument_class_code::impaer

Appendix B

2018 Aerosol Measurement Plan In-Progress Tasks

- Implement an inlet drying system (initially at SGP)

  Inlet drying systems have been installed in the SGP and AMF1 AOS systems. The AOS at AMF3 and AMF2 are planned for implementation next.

- Identify candidate data products for other communities

  ARM has discussed getting data in the GAW database and efforts are ongoing. Additionally, ARM has held first meetings with ACTRIS geared towards common practices, data products, and more.

- Implement second set of size distribution instruments

  An SMPS was installed in the ENA AOS in November 2022. An additional SMPS was procured for installation in the AMF3 when it comes online in mid-to-late 2023. ARM is also in the process of procuring new APSs for NSA, ENA, and AMF3.

- Comparable size distribution output across instruments

  The aerosol translator is leading an effort to create a merged size distribution VAP using a machine learning method. This is under testing and evaluation.

- Upgrade an ARM HSRL to support aerosol retrievals

  ARM has upgraded the first HSRL system, originally from NSA, and is in the process of upgrading its second HSRL. ARM is also procuring a new advanced lidar for NSA and the other systems used for scientific priorities at SGP and the mobile facilities.

- Support lidar/radiometer retrieval development

  A translator is currently preparing the Raman Lidar Profiles – Feature detection and Extinction (RLPROF-FEX) VAP at SGP and improving the HSRL data to support multi-wavelength lidar retrievals of aerosols.

- Reduce number of HTDMAs in field

  ARM is in the process of reducing the number of operating HTDMAs to two at a maximum. For FY24, this will include SGP and AMF1 (EPCAPE). Once EPCAPE is complete, the HTDMA at AMF3 (BNF) will be brought online.

Appendix C

Download Metrics 1/1/2018-7/7/2023

Does not include aircraft data.

Table 8. Instrument download metrics, 2018-2023.

Instrument	Non-Infrastructure Downloads	Non-Infrastructure Users	Publications
CCN*	1072	333	15
CPC	772	259	20
SMPS*	771	230	23
AOSMET	514	205	4
UHSAS	519	190	7
NEPH	487	163	13
PSAP	398	135	9
AOS	395	180	30
ACSM*	363	134	8
CO	316	93	2
HTDMA	264	83	4
OZONE	177	71	4
SP2*	172	83	12
AETH	123	67	4
APS*	107	46	6
SO2	79	39	1
GHG	64	16	2
CAPS-PMEX	58	20	2
OPC	43	12	2
NOX	42	25	0
CLAP	39	19	1

*Numbers include VAPs, if available, which may pull in data from multiple products.

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