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ARM FY2026 Aerosol Operations Plan

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ARM

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Acronyms and Abbreviations

3D	three-dimensional
AAE	Absorption Ångström Exponent
ACSM	aerosol chemical speciation monitor
ACSMCDCE	ACSM, Corrected for Composition-Dependent Collection Efficiency Value-Added Product
ACSM-TOF	aerosol chemical speciation monitor, time of flight
ACTRIS	Aerosol, Clouds and Trace Gases Research Infrastructure
AETH	aethalometer
AFS	Aerosol Flux Measurement System
AMF	ARM Mobile Facility
AMICE-2	Absorption Measurements InterComparison Experiment 2
AMSG	Aerosol Measurement Science Group
AOD	aerosol optical depth
AODBE	AOD Best Estimate Value-Added Product
AOP	aerosol operations plan, annual operations plans
AOS	Aerosol Observing System
AOSMET	Aerosol Observing System meteorological instruments
APS	aerodynamic particle sizer
ARM	Atmospheric Radiation Measurement
BNF	Bankhead National Forest
BNL	Brookhaven National Laboratory
CAMS	Center for Aerosol Measurement Science
CAPE-k	Cape kennaook/Grim, Tasmania
CAPS	cavity attenuated phase shift extinction monitor
CARGO-ACT	Cooperation and AgReements enhancing Global interOperability for Aerosol, Cloud, and Trace gas research infrastructures
CCN	cloud condensation nuclei
CCNC	cloud condensation nuclei counter
CHARMS	Cryogenic, High-Accuracy Refraction Measuring System
CLAP	continuous light absorption photometer
CoURAGE	Coast-Urban-Rural Atmospheric Gradient Experiment
CPC	condensation particle counter
CPCF	condensation particle counter, fine
CPCU	condensation particle counter, ultrafine
CPMA	centrifugal particle mass analyzer
CRG	ARM site code for CoURAGE campaign

DAQ	data acquisition system
DOD	Data Object Description
DOE	U.S. Department of Energy
DQ	data quality
DUSTIEAIM	Desert-Urban System Integrated Atmospheric Monsoon
ENA	Eastern North Atlantic
EPC	ARM site code for EPCAPE campaign
EPCAPE	Eastern Pacific Cloud Aerosol Precipitation Experiment
FAIR	Findability, Accessibility, Interoperability, and Reusability
FY	fiscal year
GAW	Global Atmosphere Watch
HOU	ARM site code for TRACER campaign
HTDMA	humidified tandem differential mobility analyzer
INP	ice nucleating particle, filters for ice nucleation particles
IOP	intensive operational period
KCG	ARM site code for kennaook/Cape Grim, Tasmania campaign
LED	light-emitting diode
MOSAiC	Multidisciplinary drifting Observatory for the Study of Arctic Climate
NANOSMPS	nano scanning mobility particle sizer
NASA	National Aeronautics and Space Administration
NEPHDRY	nephelometer, ambient
NOAA	National Oceanic and Atmospheric Administration
NO_X	nitrogen oxide monitor
NSA	North Slope of Alaska
NUC	Next Unit of Computing
OPC	optical particle counter
OZONE	ozone monitor
POPS	portable optical particle spectrometer
PSAP	particle soot absorption photometer
PTRH	pressure, temperature, and relative humidity
QA	quality assurance
QC	quality control
RL	Raman lidar
SGP	Southern Great Plains
SMPS	scanning mobility particle sizer
SO2	sulfur dioxide monitor
SP2	single-particle soot photometer
SP2-XR	extended-range SP2

TIARA	Tikhonov Advanced Regularization Algorithm
TRACER	Tracking Aerosol Convection Interactions Experiment
TROPOS	Leibniz Institute for Tropospheric Research
UCR	University of California, Riverside
UHSAS	ultra-high-sensitivity aerosol spectrometer
VAP	value-added product
WCCAP	World Calibration Center for Aerosol Physics
WMO	World Meteorological Organization

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1.0 Introduction

The U.S. Department of Energy's Atmospheric Radiation Measurement User Facility (ARM) deploys at each of ARM's observatories a suite of aerosol and trace gas (further mention of aerosols will assume inclusion of trace gases) instrumentation that constitute the Aerosol Observing System (AOS; Uin et al. 2019). ARM currently deploys five AOSs, one each at:

- Southern Great Plains (SGP) – aerosol measurements started in 1996
- Eastern North Atlantic (ENA) – aerosol measurements started in 2014
- ARM Mobile Facilities (AMF1, 2, and 3).

To improve aerosol measurements at its North Slope of Alaska (NSA) facility (a 6th ARM observatory), in FY2025, ARM began complementing data historically provided by the National Oceanic and Atmospheric Administration (NOAA) with additional instrumentation that monitors aerosol chemical composition and particle size (i.e., aerosol chemical speciation monitor [ACSM], extended-range single-particle soot photometer [SP2-XR], and aerodynamic particle sizer [APS]).

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 develops a yearly aerosol operations plan (AOP) for every fiscal year (October 1-September 30). This started in fiscal year (FY) 2024 (Theisen et al. 2024, Mayol-Bracero et al. 2025). Due to uncertainties in the FY26 budget, this plan was developed under a business-as-usual approach and will be updated as circumstances evolve. It will be made available through the ARM aerosol instrument web pages and will include:

- Review of the previous activities since the last plan
- Planned activities and their priorities for the upcoming fiscal year (FY)
- Planned activities for data products and value-added products (VAPs).

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 aerosol particle number concentration, size distribution, chemical composition, radiative and optical properties, hygroscopicity, concentration of 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[1]	AMF2[2]	AMF3	SGP	ENA	NSA	IOP
Aerosol chemical speciation monitor-quadrupole (ACSM)							
Aerosol chemical speciation monitor-time of flight (TOF-ACSM)							
Aethalometer (AETH)						NOAA	
Aerodynamic particle sizer (APS)							
Cavity attenuated phase shift monitor (CAPS)							
Carbon monoxide/nitrous oxide/water vapor (CO)		Y					
Continuous light absorption photometer (CLAP)						NOAA	
Cloud condensation nuclei (CCN)		Y					
Condensation particle counter (CPC, CPCF)		Y				NOAA	
Ultrafine condensation particle counter (CPCUF, CPCU)		Y					
Humidified tandem differential mobility analyzer (HTDMA)							
Impactor (1-10 µm)		Y				NOAA	
Nano scanning mobility particle sizer (NANOSMPS)							
Nephelometer, ambient (NEPHDRY)		Y				NOAA	
Ozone (OZONE)		Y					
Scanning mobility particle sizer (SMPS)		Y					
Sulfur dioxide (SO2)							
Single-particle soot photometer (SP2)	IOP		XR			XR	X
Ultra-high-sensitivity aerosol spectrometer (UHSAS)							
Meteorological information (AOSMET)		Y					
Filters for ice nucleating particles (INS/INP)						X	X
Nitrogen oxide 3-channel [NO, NO_2, NOy] (NO_X)[5]							X
Y = part of the system							
Additions in FY25							
Removed from operations							

[1] The AMF1 will be deployed at Phoenix, Arizona as part of the Desert-Urban System Integrated Atmospheric Monsoon (DUSTIEAIM) project (June 1, 2026-Sept 30, 2027).

[2] The AMF2 AOS, except for the APS, SP2, and UHSAS, was not deployed in the AMF2 deployment at CAPE-k (KCG, Cloud, Aerosol, and Precipitation Experiment at kennaook/Cape Grim, April 15, 2024-Nov15, 2025) due to the overlap with the existing measurements at the Cape Grim, Tasmania aerosol stations. Plans for the next AMF2 deployment are still pending.

[3] CAPS instruments were retired.

[4] ARM operated a single HTDMA at AMF1 (CoURAGE, CRG - Coast-Urban-Rural Atmospheric Gradient Experiment); following its completion on November 30, 2025, all HTDMA instruments have been retired.

[5] ARM contracted out the operations of a NO_X system for the CoURAGE campaign. ARM will review the trace gas measurement strategy in FY26.

2.1 Instrument Tiers

ARM operates high-quality, research-grade AOS and, since 2024, has also been investing in other tiers of aerosol measurements. These are organized into three categories: **Standard AOS, Additional AOS Instruments, and Aerosol Nodes**. A summary of the instruments within each tier is provided in **Table 2**.

- **Standard AOS** – Complex, research-grade systems with a broad range of instruments and sampling protocols, currently deployed at all AOS sites.
- **Additional AOS Instruments** – A set of instruments that may be deployed either full-time at certain sites or temporarily during intensive operational periods (IOPs) and field campaigns (Table 2). These are not standardized across all AOS sites and may sometimes be operated standalone.
- **Aerosol Nodes** – Since 2024, ARM started the design of the aerosol nodes to provide flexible measurement capabilities ranging from low-cost standalone systems to small-shelter research-grade deployments. Two types are being developed:
  - **Mini-AOS** – with broader measurement capabilities such as particle size distributions and, as the system matures, additional optical measurements. Two mini-AOS units are planned for deployment at the AMF3 site in the Bankhead National Forest (BNF): one is currently being tested and will transition to deployment, while the second is under development.
  - **Micro-AOS –** smaller portable systems using Handix portable optical particle spectrometer (POPS) instruments. A network of three units was deployed during the AMF1 urban CoURAGE campaign in Maryland (Dec 2024-Nov 2025). A single POPS system will be deployed for DUSTIEAIM. The remaining units are under consideration for some testing alongside an AOS at an existing site to better characterize the instruments.

Table 2. Standard and additional AOS instruments.

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)
Additional AOS instruments	
Aerosol chemical speciation monitor (ACSM/TOF-ACSM)	Nano scanning mobility particle sizer (NANOSMPS)
Aethalometer (AETH)	Sulfur dioxide monitor (SO2)
Carbon monoxide monitor (CO)	Single-particle soot photometer (SP2, SP2-XR)
Ultrafine condensation particle counter (CPCU/CPCUF)	Filters for ice nucleation particles (INS/INP)

3.0 AOS Team

Instrument Mentors – Responsible for operating instruments, engineering activities, overseeing calibrations and maintenance, and ensuring data quality through QA/QC in coordination with the ARM Data Quality Office. They also develop documentation, train site operators, and refine operational protocols as needed for deployments. **Lead Mentor (LM), Associate Mentor (AM)**

- Olga L. Mayol-Bracero – AOS LM, AM: Infrastructure, nephelometer
- Scott Smith – AOS AM, LM: Infrastructure
- Janek Uin – LM: HTDMA UHSAS, nephelometer AM: CCN, Infrastructure
- Ogo Enekwizu – LM: CCN
- Ashish Singh – LM: CPCu, CPCf, SMPS, n-SMPS, APS
- Delano C. de Oliveira – LM: Calibration system, AM: SMPS, n-SMPS, CPCs, APS, Infrastructure
- Tamanna Subba – AM: SMPS, n-SMPS, CPCs, APS
- Art Sedlacek – LM: SP2, SP2-XR, Aethalometer, PSAP, trace gases
- Maria Zawadowicz – LM: ACSM
- Mirtha Allain – AM: ACSM
- Chris Hayes – programming, data systems, AM: trace gases
- Jessie Creamean – LM: INP
- Connor Flynn – AM: PSAP
- Sarah Petters – LM: distributed aerosol (POPS – portable optical particle spectrometer) sensors at CoURAGE campaign
- Markus Petters – LM: distributed aerosol (POPS) sensors at CoURAGE campaign
- Fernando Morais –AM: Infrastructure, calibrations
- Andrew McMahon - programming, engineering, electronics
- Gabriel Vignato - infrastructure

Site Operators – Oversee the AOS day-to-day operations in coordination with the instrument mentors.

- AOS AMF1, AMF2, and ENA - LANL (Lead techs: Mark Manriquez, Samuel González, Ana Bloom, Frank Zurek, Tom Day, Bruno Cunha, Tercio Silva)
- AOS AMF3 and SGP – ANL (Lead techs: Ken Teske, Farrel Clark)
- NSA – in collaboration with NOAA (Bryan Thomas, Ross Burgener)

Ingest Development – Develop and maintain the ARM data ingest system that processes the raw data into uniformly formatted, accessible data for archiving and distribution.

- Brian Ermold, Gabriel Gibler, Yan Shi

Translators – Produce value-added data products (VAPs) and tools to broaden the use of AOS data.

- John Shilling – aerosol translator
- Gourihar Kulkarni, Evgueni Kassianov, Duli Chand – VAP science mentors
- Brian Ermold, Gabe Gibler, Max Levin, Chitra Sivaraman, Josh Howie – VAP developers

4.0 FY25 Outcomes

The FY25 outcomes are organized into three parts—Operations, Calibration Activities, and Engineering and Development. These build on the tasks outlined in the FY2024 Aerosol Operations Plan (AOP; Theisen et al. 2024) and the 2018 Aerosol Measurement Plan (Mather et al. 2018), many of which ARM

has been advancing in recent years (see FY25 AOP Table 4, Mayol-Bracero et al. 2025). A summary of completed and in-progress tasks is provided in **Appendix A**, with additional outcomes highlighted in Table 3.

4.1 Operations

Table 3. Summary of FY25 AOS operations.

Site	Summary of Operations
Southern Great Plains (SGP)	• All AOS instruments operated successfully, with minimal downtime and consistently high data quality. • SGP underwent a World Meteorological Organization (WMO) Global Atmosphere Watch (GAW) audit—an important step to ensure data quality, consistency, and global comparability—resulting in recommendations to be provided in a forthcoming report.
North Slope of Alaska (NSA)	• ARM achieved a major milestone at NSA by deploying three aerosol instruments (ACSM, SP2-XR, and APS) at NOAA's Barrow Observatory, launching long-sought measurements of aerosol chemical composition and size distribution, and by adding INP filter collections.
Eastern North Atlantic (ENA)	• All AOS instruments operated successfully, with minimal downtime and consistently high data quality. • The AOS was upgraded by moving from physical computers to virtual machines and consolidating serial instruments onto a centralized Moxa server. This upgrade enhances reliability, ensures consistency with other AOS deployments, and provides greater flexibility for future operations. Upgraded NUCs (Next Unit of Computing) remain onsite to serve as backups.
AMF1 – CoURAGE (CRG)	• The AOS was deployed in a rural ancillary site northwest of Baltimore, Maryland, operating reliably, producing high-quality data with minimal interruptions. • Three portable optical particle spectrometer (POPS, AOS-Mini) systems were deployed at three ground sites, successfully operating for a majority of the campaign with limited downtime and high data quality.
AMF2 – CAPE-k (KCG)	• ARM enhanced aerosol observations by deploying APS, SP2, UHSAS and INP filter collection, while opting not to install a full AOS since the campaign leveraged the existing Cape Grim Baseline Station. Instruments have been operating reliable, producing high-quality data with minimal interruptions. The APS experienced occasional failures, during which it was substituted with either the OPC or a guest APS. • ARM is processing data from the baseline station into a-level products for O3, CPC, CPCU, CCN100, and ACSM-TOF. The quality of the data is not ensured by ARM and users are encouraged to download final data sets from Cape Grim.

Site	Summary of Operations
AMF3 – Bankhead National Forest (BNF)	• AMF3 officially started operations October 1, 2024. The AOS has been operating successfully, with minimal downtime and consistently high data quality. • A system of pressure, temperature, and relative humidity (PTRH) sensors, similar to the one in AMF1 AOS, was implemented for all AOS sample lines to enable better monitoring of sampling conditions and to catch measurement issues faster.
Other	• ARM has retired all HTDMA systems from operations except one. The AMF1 unit remained in use through the end of CoURAGE (November 30, 2025), after which it was retired. • ARM retired all cavity attenuated phase shift extinction monitors (CAPS) at the end of FY25 (see Table 1). Efforts are ongoing to determine feasibility for aerial facility deployments or for improvements to make the CAPS more robust for operating at BNF.

4.2 Calibration Activities

Calibration Schedule. In FY25 AOP, the aerosol mentor team has established a structured calibration schedule for AOS instruments, focusing on calibrations at the start and end of mobile facility deployments, with additional calibrations during campaigns as needed. The plan accounts for the calibration frequency and requirements for each instrument type.

Gold-reference instruments for SMPS and CPC calibrations. Significant progress has been made toward establishing ARM calibration infrastructure at the Center for Aerosol Measurement Science (CAMS) at BNL. Laboratory space has been prepared, and infrastructure (sampling system, data connections) are being installed. Procurement and installation of gold-standard reference instruments for SMPS and CPC calibrations are in progress. Several key instruments, including CPCs, electrometer, and auxiliary devices have already been procured, acceptance-tested, inspected for safety, installed, and verified for power and communication functionality. In addition, the CPC reference standards were verified and calibrated by the WCCAP, as required by the vendor (TSI). Looking ahead, SMPS calibrations are scheduled to begin in FY26 with the SGP instruments. Additional details and the timeline are provided in Section 5.2, Table 6.

CARGO-ACT. ARM's role in CARGO-ACT focused on harmonizing calibration procedures, establishing common approaches to uncertainty and operations, and aligning ARM's calibration procedures with international standards. Refer to the FY25 AOP for more details on the CARGO-ACT project. Several CARGO-ACT aerosol key reports involving ARM AOS were submitted in FY2025, including recommendations for harmonized calibration and operation procedures, a framework for estimating measurement uncertainty, and extensive documentation of existing calibration, operation, and processing protocols across the U.S. and Europe. In addition, a strategic plan for harmonizing ARM with ACTRIS's WCCAP is underway. Importantly, in July 2025, the WMO GAW audit of the SGP AOS, led by Leibniz Institute for Tropospheric Research/World Calibration Center for Aerosol Physics (TROPOS/WCCAP), evaluated compliance with global standards, provided recommendations for improving measurements, and reinforced the international credibility of ARM data—ensuring accuracy, consistency, and comparability of aerosol observations across networks. Following the audit, SGP will be well positioned to pursue designation as a WMO GAW Regional Station.

4.3 Engineering and Development

To highlight our progress, Table 8 from the FY25 AOP (here Table 4) has been included. A short overview of activities is provided below.

Table 4. Progress on FY25 planned aerosol engineering and development activities.

Task	Priority	Progress/Planned End Date
Aerosol node development	1	In progress/Dec 2026
Aerosol flux measurement development	1	In progress/Dec 2027
Center for Aerosol Measurement Science (CAMS)	1	In progress/Dec 2026
Setting up SMPS and CPC gold-standard calibration capabilities for ARM AOS instruments	1	In progress/Dec 2026
Absorption Measurement Intercomparison and Calibration Experiment for advancing ARM's absorbing aerosol measurements	1	In progress/March 2026
Develop and implement a plan for distributed aerosol measurements for urban AMF deployments	1	Completed
Contracted deployment of a NOx system with the ARM AOS for CoURAGE	1	March 2026
Gas Analyzer Intercomparison	1	Completed
Correction factors for the new PSAP filter media	2	Sep 2026
Refurbishing the ENA HTDMA	2	Completed
Testing a new field-deployable calibration system	2	Completed
Replacement of the aging NEPH systems	2	In progress/Sep 2026
Develop a data-flagging approach for identifying MOSAiC AOS contamination events	2	Completed
Evaluating UHSAS and OPC measurements	2	Completed
Deployment of an OPC inside the CRG AOS container	2	Completed
ACSM Calibration Uncertainty Study	2	Completed
Drying the AOS impactor and APS sample flows	2	Completed
Retire humidified tandem mobility analyzer (HTDMA)	3	April 2026
Modernization of the AOS instrument management software	3	On hold
Gradually remove the real-time flow sensor from the existing standalone CPCs (CPCF, CPCuf) in SGP and ENA in FY24	4	Completed

Aerosol node development. Mini-AOS 1 is under development at BNL. System integration has been largely completed, including enclosure, sample conditioning, particle loss checks, diagnostics software, and ARM remote connect, with data ingest still in progress. Testing is underway to establish calibration procedures, compare with AOS systems, and assess lower-cost instruments, moving the node toward field readiness for BNF deployment in FY26.

Aerosol flux measurement development. ARM is testing a single-particle flux system on the 40-m tower at BNF to evaluate aerosol flux measurements. The FY25 milestone of surveying and selecting instruments was completed, while procurement of instruments and accessories (OPC, data logger, enclosure) is currently in progress.

Center for Aerosol Measurement Science. See updates under Section 4.2 Calibration Activities. This project will be closed once the procurement of gold-reference instrumentation is complete. All other calibration activities will continue under the "**Setting up SMPS and CPC gold-standard calibration capabilities for ARM AOS instruments**" activity (see below).

Setting up SMPS and CPC gold-standard calibration capabilities for ARM AOS instruments. See updates under Section 4.2 Calibration Activities.

Absorption Measurement Intercomparison and Calibration Experiment for advancing ARM's absorbing aerosol measurements (AMICE-2). The AMICE-2 measurements at BNL have concluded FY25 deliverables. Performance metrics for instruments included in AMICE-2 will be provided. Recommendations were submitted the 2nd quarter of FY26.

Develop and implement a plan for distributed aerosol measurements for urban AMF deployments. Three systems were successfully deployed at ground sites for the CoURAGE campaign in and around Baltimore, Maryland. From November 2024 through November 2025, all units operated reliably with high-quality data and no outages, supported by the availability of a spare POPS for rapid replacement if needed. A single system will be deployed at the main site for DUSTIEAIM.

Contracted deployment of a NOx system with the ARM AOS for CoURAGE. A CAPS-based NOx system operated at CoURAGE from December 20, 2024 through November 2025, performing well with high data availability. Data are expected to be made available by the end of May 2026.

Gas analyzer intercomparison. The MIRO Gas analyzer (MGA-10) was tested as a potential replacement for ARM trace gas instruments, and it is not a viable option for ARM deployments.

Correction factors for the new PSAP filter media. Correction factors for PSAPs new Emfab filter material is currently on hold; see Section 5.3 (Engineering and Development) for further details.

Refurbishing the ENA HTDMA. For FY26, ARM operated a single HTDMA at AMF1 (CoURAGE). After the completion of CRG (30 November 2025), ARM retired all HTDMA instruments. Two systems were kept in case ARM revisits this measurement in the future.

Testing a new field-deployable calibration system. A prototype of a compact and low-cost calibration system (akin to TSI SMPS) was tested for potential use within ARM as a transfer standard. The evaluation showed that the system worked well in general, but for the specific requirements for ARM use, more development would have been needed, and we decided not to pursue this option.

Replacement of the aging NEPH systems. ARM has decided to transition using the Aurora LED-based nephelometers. Five units have been procured and are being evaluated at BNL. Two more units will potentially be procured to cover all the ARM sites. The order of priority for upgrades: BNF, SGP, AMF1, ENA, AMF2.

Develop a data-flagging approach for identifying MOSAiC AOS contamination events. AOS data from the MOSAiC expedition was affected by local emissions from the ship. To identify the periods with local contamination, several filtering methods were proposed and tested. The outcome of this project provides users of the data with information and tools for processing the data before further analysis. Code to implement the filtering is also available as a result of this work. (github: https://github.com/ARM-Development/MOSAiC-Aerosol-Flagging). Collaborators are prepping for paper submission.

Evaluating UHSAS and OPC measurements. The study determined that there are always measurement artifacts associated with all optical particle sizing instruments and that the operating parameters of a specific device have a strong influence on how strongly these artifacts manifest in the data. As such, there is no intrinsically better optical sizing instrument that would be free of these effects. The key findings have been published as an ARM report and a more thorough analysis has been published in a peer-reviewed journal. (Lewis et al. 2026).

Deployment of an OPC inside the CRG AOS container. An OPC was deployed inside the CRG AOS container to assess dust intrusion risks ahead of DUSTIEAIM (Desert-Urban SysTem IntegratEd AtmospherIc Monsoon), the next field deployment for the AMF1 AOS starting in April 2026. Data analysis showed that dust enters the AOS even without operator traffic, with intrusion strongly influenced by wind direction, particularly when winds approach at a slight angle to the door.

ACSM Calibration Uncertainty Study. The project successfully conducted the first laboratory intercomparison of all five ARM ACSMs at BNL, achieving baseline centrifugal particle mass analyzer (CPMA)-based calibrations, maintenance, and improved protocols that advance consistency and standardization across the ARM ACSM network. Refer to the ARM report for more details.

Drying the AOS impactor and APS sample flows. We implemented and tested a drying system for the AOS impactor line and the APS at the SGP, AMF1, and AMF3 sites to address measurement ambiguities caused by humidity. A new project will be created to manage the broader impacts of adding this system to the SGP APS.

Retire humidified tandem mobility analyzer (HTDMA). Refer to the text above under "Refurbishing ENA HTDMA".

Modernization of the AOS instrument management software. Due to higher-priority activities, this project was put on hold but will be re-evaluated when effort is available to continue.

Gradually remove the real-time flow sensor from the existing standalone CPCs (CPCF, CPCuf) in SGP and ENA in FY24. The real-time flow sensor modification in standalone CPCs at SGP and ENA was removed. This required reverting the LabVIEW VI to the standard data acquisition system (DAQ) configuration and adjusting the CPC ingest to align with an existing Data Object Description (DOD). With this change, ARM CPCFs now share the same DOD/ingest across all sites, ensuring that any future updates are uniformly implemented system wide.

4.4 Data Products

Aerosol Optical Depth (AOD) and AOD Best Estimate (AODBE). In FY25 ARM processed and released 7-channel AOD data for EPC and ENA. For AODBE, ARM processed and released 5-channel data for two NSA sites (C1 and C2) and for HOU.

CCN Kappa. The SMPS kappa VAP is now running as a baseline VAP and is produced for every site that has both a cloud condensation nuclei counter (CCNC) and an SMPS. In FY25 ARM released data for BNF, CoURAGE, and ENA.

CCN Profile. ARM evaluated the quality of the altitude-dependent CCN concentrations retrieved by the CCN profile VAP. Based on this analysis, a machine learning (ML) model to perform automated QA/QC analysis on the VAP retrieval was developed. A publication outlining this methodology has been drafted, and we are currently integrating it into the VAP code.

Merged Size Distribution and Merged Size Distribution Machine Learning. The Merged Size Distribution Machine Learning VAP uses a machine learning algorithm to evaluate the QA/QC on the merged SMPS-APS data set. In FY25 ARM transitioned the Merged Size Distribution VAP to a baseline VAP, so it is now produced for all sites with both an SMPS and APS in near-real time. The accuracy of the ML VAP was evaluated against hand-labeled data, which helped improve the QA/QC accuracy. As a result, a new, machine-learning-evaluated Merged Size Distribution data set was released for the EPC campaign.

Merged Aerosol. In response to requests from ARM users and advisory groups, a new VAP was developed. This tool bundles data from multiple aerosol instruments into a single file with a unified timestamp. The VAP simplifies the user experience and reduces the effort required for scientists analyzing multi-instrument data. In FY25, an initial version of the VAP was developed, and data was released for the SGP, HOU, and EPC sites for user evaluation.

Additional VAPs. The ACSM, corrected for composition-dependent collection efficiency (ACSMCDCE) VAP, corrects the ACSM data for non-unity particle sampling. This VAP is now operational and running in real time. Data are available for all sites with an ACSM. The AOP VAP combines PSAP and nephelometer data to provide corrected in situ aerosol optical properties. The AOP VAP also runs in real time and is available for all sites with a PSAP and nephelometer. Development of the HTDMA kappa VAP was suspended because of the decision to retire HTDMA instruments.

5.0 FY26 Plans

5.1 Operations

ARM will continue operating AOSs at the following locations in FY26: SGP, ENA, AMF1 (transitioning after CoURAGE to DUSTIEAIM in the beginning of June 2026), and AMF3 (BNF). In addition, ARM will operate supplemental instrumentation at the NOAA NSA facility (see Table 1 for the list of specific instruments). During the Cape kennaook/Grim, Tasmania campaign (CAPE-k) that ended in October 2025, only a small subset of instrumentation (APS, SP2, and UHSAS) was deployed at the AMF2 because the site was collocated with the Cape Grim Baseline Air Pollution Station. CAPE-k ARM aerosol

data are available to users. Plans for the AMF2 are currently to be determined; future deployments will be announced through a U.S. Department of Energy (DOE) call for proposals as priorities warrant.

After the completion of CoURAGE, ARM retired HTDMA instruments. Two were mothballed for potential future use.

ARM continues to produce hygroscopicity (kappa) and growth factor data products from HTDMA and CCN-SMPS instruments (with future direction pending HTDMA retirement), while also conducting routine ice nucleating particle (INP) filter collections and analyses across multiple sites and campaigns, with data made publicly available after processing. Details on the hygroscopicity are documented in the FY25 AOP.

5.2 Calibration Activities

Calibration schedule. For FY26, calibration periods have been scheduled for AMF1 CoURAGE (ending Nov 30, 2025), BNF, DUSTIEAIM, ENA, SGP, and NSA (Table 5). Table 5 also outlines ideal windows for IOPs. During these ideal or already planned IOPs, ARM will prioritize keeping instruments fully operational, calibrated, and generating high-quality data, while deferring repairs or upgrades to other times. 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. FY26 planned calibration activities for each of the ARM observatories.

ARM CPC and SMPS instruments will continue to undergo regular calibrations according to the schedule outlined in Table 5. As ARM's centralized calibration laboratory at CAMS becomes operational, calibrations will increasingly be performed there using the gold-standard reference instruments. The long-term goal is for all ARM CPC and SMPS instruments to be calibrated annually, either directly at the calibration laboratory or against a transfer standard. However, this will not yet be fully implemented in FY26; only the sites specifically noted in Table 5 (SGP and BNF) will be included at this stage. The calibration schedule also retains flexibility to accommodate unforeseen instrument issues (both deployed and calibration units) as well as potential shipping delays.

Gold-reference instruments for SMPS and CPC calibrations. Calibration of ARM's CPCs and SMPSs will begin in FY26 with the SGP instruments. The calibration plan, including September activities, is outlined in Table 6. The timeline shifted by about six months relative to the FY25 AOP due to procurement delays. Reference instruments will be compared bi-annually against WCCAP standards. Over time, we aim to expand these efforts to include additional aerosol properties such as composition, optical characteristics, and hygroscopicity. These calibration activities will involve some instrument downtime, which will be planned and documented in the Annual Operations Plans (AOPs) for transparency.

Table 6. Gold-standard calibration activities for Q1 FY26.

Tasks	Deliverables	Planned End Date
Procurement and installation of reference instrument for SMPS calibrations	Instrument has been installed at BNL and tested for proper operation. Staff has been trained on its operation. Certificate of performance from WCCAP for reference instrument.	Completed
Preparation of lab for CPC calibrations	Calibration lab is set up and ready to receive reference instrument for CPC calibrations.	April 2026
Procurement and installation of reference instrument for CPCs calibrations	Instrument has been installed at BNL and tested for proper operation. Staff has been trained on its operation. Certificate of performance from WCCAP for reference instrument.	April 2026
First calibrations of ARM CPC instruments using gold standards (starting with SGP), data analysis	ARM CPCs from SGP have a certificate of performance.	June 2026
Calibrating transfer standard at the calibration lab to be used in field calibrations	Transfer standard calibrated and ready for use.	June 2026
First calibrations of ARM SMPS instruments using reference instrumentation (starting with SGP), data analysis	ARM SMPSs from SGP have a certificate of performance.	July 2026
Documenting and sharing the results and lessons learned from the first ARM calibrations	Calibration results, procedures, and lessons learned disseminated to relevant parties.	September 2026
Routine calibrations of ARM instruments	All ARM CPC and SMPS instruments are regularly calibrated at the calibration lab or using a transfer standard.	FY27 and beyond

The plan above outlines the launch of regular ARM instrument calibrations at the ARM calibration laboratory in FY26, with future activities anticipated to proceed on a routine, scheduled basis.

CARGO-ACT. CARGO-ACT will conduct dedicated campaigns to compare data production and compatibility across partner networks, including cross-network quality control, traceability, and calibration. The project will also begin drafting a roadmap for harmonizing vocabularies, host a workshop on FAIR (Findability, Accessibility, Interoperability, and Reusability) resources, and develop a plan to strengthen engagement with global bodies to maximize impact.

5.3 Engineering and Development

Besides routine AOS operations, the mentor team is focused on improving and expanding ARM measurements to better serve the research community. These efforts include 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. FY26 planned aerosol engineering and development activities.

Task	Priority	Planned End Date
Aerosol node development	1	Dec 2026
Aerosol flux measurement development	1	Dec 2027
Center for Aerosol Measurement Science (CAMS)	1	Dec 2027
Setting up SMPS and CPC gold-standard calibration capabilities for ARM AOS instruments	1	Dec 2026
Absorption Measurement Intercomparison and Calibration Experiment for advancing ARM's absorbing aerosol measurements (AMICE2)	1	March 2026
Correction factors for the new PSAP filter media	3	Sep 2026
Contracted deployment of a NOx system with the ARM AOS for CoURAGE	1	March 2026
Developing a sample line zeroing system for AOS	1	May 2026
AOS activities between field campaigns (starting with DUSTIEAIM)	1	Dec 2026
Replacement of the aging NEPH systems	2	Sep 2027
Retire humidified tandem mobility analyzer (HTDMA)	3	April 2026
Modernization of the AOS instrument management software	3	On hold

Aerosol node development. In FY26, aerosol node development will focus on advancing the mini-AOS systems. For mini-AOS 1, installation and calibration at BNF main site have been completed, with data ingest operational and data quality (DQ) visualization underway. Ongoing efforts include comparison against the full AOS, handbook development, and use of an existing preventive maintenance framework. Following an April calibration trip, the system will be transitioned to a supplementary site for extended operation. In parallel, mini-AOS 2 development is progressing, with key procurements (including the mSEMS) underway, and upcoming instrument prioritization and design review to finalize the build.

Aerosol Flux Measurement System (AFS) development. In FY26, aerosol flux measurement efforts will focus on advancing the AFS bench model development. Procurement of key components, including the 3D wind sensor and data logger, has been initiated, and an OPC model has been identified. Ongoing discussions with the vendor will define the optimal DAQ configuration for flux measurements, alongside continued development and testing of the data acquisition system to assess sampling frequency, time-lag, and synchronization performance.

Center for Aerosol Measurement Science (CAMS), Setting up SMPS and CPC gold-standard calibration capabilities for ARM AOS instruments, and CARGO-ACT. The FY26 plans for these three activities are outlined in Section 5.2 Calibrations.

Absorption Measurements Intercomparison Experiment 2 (AMICE-2). Final recommendations for aerosol absorption measurements—based on AMICE-2 instrument performance—have been delivered via a technical slide deck (in preparation for a peer-reviewed publication). The recommendations call for a detailed characterization and calibration of CAPS-ssa, followed by its deployment as the primary absorption measurement, complemented by AE33 instruments to provide absorption wavelength dependence (Absorption Ångström Exponent [AAE]). (The initial phase of the AMICE project was presented during the FY25 AOP.)

Correction factors for the new PSAP filter media. Correction factors for the new PSAP filter media were developed during AMICE-2. The implementation of these corrections is currently under discussion. They will be implemented in the AOP value-added product and potentially in the b1-level datastream. Please check the documentation carefully to understand the corrections applied for each product.

Distributed aerosol measurement for urban deployments. ARM completed the deployment of three ground-based POPS for the CoURAGE campaign in Baltimore, Maryland at the end of November 2025. A system is currently planned to be deployed for DUSTIEAIM with the additional systems used as spares with the possibility of deploying at BNF to characterize the systems alongside the AOS.

CoURAGE NOx measurements. Deployment was completed. Data will be provided by the end of May. These systems are not planned for any additional deployments in FY26 at the moment. Future plans for NO_X measurements will be discussed by ARM management.

Developing a sample line zeroing system for AOS. ARM is developing a sample line zeroing system—the Clean Air System (CAS) for the AOS to perform automated zero checks of AOS instruments and sample lines. CAS will also be evaluated for protecting instruments from high-aerosol-loading events. The CAS, adapted from the purge air system for instrument protection from ship emissions used during the MOSAiC expedition, will be integrated directly into the sampling system to allow more frequent zero tests without modifications or disruptions to the sample lines. New control software will be developed to operate the system automatically, remotely, or locally, with status data saved as part of the AOS datastream. After initial testing at SGP, four additional systems will be built and deployed across the remaining AOS units.

AOS activities between field campaigns. ARM will support the monitoring and coordination of AOS tasks beginning with the DUSTEIAIM campaign, with the process then applied to subsequent field campaigns. Activities will follow an internal template that serves as a guideline, with the understanding that additional tasks may be required.

5.4 Data Products

Detailed plans for specific data product development efforts in FY26 are as follows:

AOD and AODBE. Processing of Aerosol Optical Depth (AOD) data will continue for new campaigns such as BNF, now including the 1625-nm channel. The AODBE VAP will also incorporate this new channel, with data processed for EPCAPE and TRACER campaigns, ensuring enhanced coverage and accuracy.

CCN Profile. The CCN Profile VAP will be updated to use HSRL data when Raman lidar data are not available at a site. A machine learning routine developed by data analysts will be integrated to improve QA/QC, and the VAP's performance will be re-evaluated against in situ measurements.

Merged Size Distribution Machine Learning. The ML algorithm for merged size distributions will be assessed for performance at new sites and campaigns with SMPS and APS instruments. QA/QC evaluations will be applied to the data, and updated data sets—including those from the HOU and BNF sites—will be released.

Merged Aerosol. User feedback will be incorporated to refine the Merged Aerosol VAP, extending its application to additional sites including BNF. A technical report documenting the methodology and updates will be prepared to support transparency and reproducibility.

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Appendix A

Historical Aerosol Operations Plan Completed and In-Progress Tasks

A.1 Completed Tasks

Improve and simplify access to aerosol data

We have made substantial improvements in aerosol data access and are also continually improving on the basis of user feedback. Key improvements:

- New Data Discovery interface
- Additional metadata to improve the search capabilities
- Spatial, temporal, and keyword search capabilities
- Dedicated home page search by Category for "Aerosols"
- Improved data details page with contact information, citations, data quality timeline, primary measurements, and data plots
- Added recommendations for aerosol datastreams.

Improve documentation of measurements and datastreams

Metadata auditing for the aerosol datastreams is complete. The ARM Data Center metadata team improved the metadata keywords and classifications.

The VAP web pages have been updated to provide improved short summary descriptions of VAPs including caveats that describe when the VAP is applicable and when caution should be used. The reference list has been updated and made easier to use to identify VAP point of contacts.

CARGO-ACT work package 2 will also contribute to improve documentation regarding aerosol measurements (in situ and remote sensing).

Identify candidate data products with other communities

This task has been successfully addressed through ARM's active engagement with international data-sharing initiatives. ARM has been working toward making its data available through the Global Atmosphere Watch (GAW) database and, in parallel, has partnered with ACTRIS to align on common

practices and data products. These collaborations led to the launch of the three-year CARGO-ACT project (Cooperation and AgReements enhancing Global interOperability for Aerosol, Cloud and Trace gas research infrastructures), which aims to harmonize aerosol data across ARM, ACTRIS, NOAA, and NASA, thereby increasing usability for the global research community, including modelers and satellite data users.

As part of this interoperability effort, the ARM Data Center provided CARGO-ACT with a list of candidate data sets and a FAIR implementation plan. Furthermore, ARM has harvested metadata records from ACTRIS and made them discoverable through the ARM Data Discovery tool. Users can now search and explore ACTRIS data sets via ARM's interface, with downloads seamlessly redirected to the ACTRIS portal.

Reduce number of HTDMAs in field

ARM has reduced the number of operating HTDMAs to two at a maximum. For FY25, this will include BNF and AMF1 (CoURAGE). Once CoURAGE is completed, the HTDMA at SGP will be brought online.

Refurbishing of ENA HTDMA

This is not happening, since after the completion of CoURAGE ARM is retiring all HTDMA instruments.

Removal of ACSM at ENA

In FY24, ARM retired from operations the ENA ACSM to add an ACSM to NSA.

Retirement of humidigraphs

To enable new scope, in FY24 ARM retired all humidigraphs and RH-scanned nephelometers from operations.

New instrumentation for AMF3

The AMF3 will be deployed at BNF in Alabama, starting September 2024. In addition to the aerosol node and aerosol flux measurement development, ARM added additional instrumentation to the AMF3 AOS. This includes an APS, sulfur dioxide monitor (SO2), extended-size-range SMPS (size range is extended from 10-500 nm to 10-800 nm), and SP2 (SP2-XR). The SO2 and APS are standard ARM instruments, but the SMPS and the SP2-XR are new additions that require ARM to develop new processes (ingest, data quality, calibration, etc.).

Implement an inlet drying system (initially at SGP)

This task was initially created to track the implementation and testing of a drying system for the AOS impactor line and the APS at the SGP site. The drying system has already been implemented for AMF1 and AMF3 AOS. We have since separated out the SGP APS portion, and a new task will be initiated specifically for drying the SGP APS sample line, as there is a broader scope of impacts to consider. As part of this new task, we will also include the requirement for a review by the broader community, such as the Aerosol Measurement Science Group (AMSG).

Implement new PTRH sensors in AOS02 and AOS03

New PTRH sensors were developed and successfully deployed in AOS01, AOS02, and AOS03. These sensors are in each sample line, as close to the instrument as possible to characterize the conditions of the sample air as it enters the instruments.

NSA additional instrument deployment

In September 2024, ARM started deployment of the following instruments: ACSM, APS, SP2-XR, and filters for INS at the NOAA facility alongside NOAA instrumentation.

Develop prioritization for ultrafine CPCs

We have "increased" the number density of the ultrafine CPC (CPCu or CPCuf) to four ARM sites (AMF1, AMF2, AMF3, SGP).

Implement second set of size distribution instruments

There are SMPSs and APSs in all five ARM deployments. The new SMPS at the AMF3 has a wide-range differential mobility analyzer that allows a measurement range of 10 to 800 nm. There is a sixth APS at NSA since September 2024.

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.

Absorption, scattering, and extinction closure

This was an optical closure analysis involving the Aerodyne CAPS (cavity attenuated phase shift spectroscopy) aerosol extinction monitor and the TSI nephelometer (aerosol scattering). The particle soot absorption photometer (PSAP, aerosol absorption) was to be the third element in this study, but due to the discontinuation of the filter media, it was not included. The study demonstrated that measurements of scattering coefficients and extinction coefficients for purely scattering particles agree to within 5-10 % in controlled laboratory experiments. This accuracy limits the extent to which closure between scattering, absorption, and extinction can be attained for an aerosol that contains absorbing components. The fact that numerous correction schemes have been, and are still being, proposed for filter-based measurements of aerosol light absorption (e.g., PSAP or aethalometer), which can vary considerably among themselves, indicates that this approach is unlikely to yield accurate results under any situation. For this reason, filter-based measurements are really only useful in identifying relative changes in absorption, not the actual absorption coefficients.

Increase PSAP filter change at SGP

On a nightly basis, every weekend, and during extended weekends, the PSAP filters at SGP face an excessive load, resulting in the loss of absorption measurements for several hours to an entire day each weekend, contingent on local conditions. To extend the operational window of the SGP PSAP, we increased the filter change frequency at minimally two changes per day—at the start and end of each shift.

New trace gas analyzer

We tested the MIRO Gas analyzer (MGA-10) as a potential replacement for ARM trace gas instruments and it is not a viable option for ARM field deployments. See Section 4.3.7.

Develop plan to support detailed composition measurements

ARM plans to operate the ACSMs and look at opportunities for expansion as they present themselves and as budgets align.

Develop strategy for hygroscopic measurements

Following the reduction in the HTDMA operations, the freed-up HTDMA units are undergoing performance evaluation before starting the tests on new operational modes. For more details regarding this plan, refer to Section 4.1.2.

Upgrade an ARM HSRL to support aerosol retrievals

ARM upgraded one high-spectral-resolution lidar (HSRL) to add a 532-nm wide-field-of-view channel and 1064-nm narrow-field-of-view channel along with off-nadir scanning. This system is deployed at SGP, alongside the Raman lidar (RL) which will allow for three-wavelength retrievals of aerosols optical and physical properties. ARM is in the process of upgrading its second HSRL to the same configuration for deployment at the AMF3 observatory in Bankhead National Forest where there will also be a RL deployed. ARM is also in the early phases of procuring an aerosol profiling lidar, similar to those deployed for ACTRIS. We plan to incorporate aerosol microphysical retrieval into a VAP. ARM is working with the NASA Langley Research Center to receive their TIARA algorithm (Tikhonov Advanced Regularization Algorithm), which uses HSRL and RL to derive aerosol properties. In the last year, data analyst Peng Wu has developed an aerosol feature mask that identifies aerosol features using HSRL data.

A.2 In-Progress Tasks

Support lidar/radiometer retrieval development

Progress on the aerosol microphysical properties retrieval has advanced after initial delays awaiting NASA's open-source code release. The TIARA software has now been transferred to ARM servers and is being run on SGP Raman lidar and HSRL data from the Cryogenic, High-Accuracy Refraction Measuring System (CHARMS) campaign, with results being validated against NASA outputs for consistency. Work is underway to plan implementation of the software as an ARM VAP, including discussions on transitioning the code from C to Python. Some issues with SGP HSRL data have been identified and are being addressed in collaboration with the University of Wisconsin lidar group.

Appendix B

User Metrics 1/1/2020-12/31/2024

Table 8. Instrument download metrics, 2020-2024.

Instrument	Non-Infrastructure Downloads	Non-Infrastructure Users	Publications
CCN*	1279	356	46
SMPS*	967	291	53
CPC	781	269	58
UHSAS	546	205	29
ACSM*	472	151	40
NEPH	429	151	30
AOSMET	398	157	0
CO	346	81	8
PSAP	312	128	25
HTDMA	252	86	18
OZONE	214	80	9
APS*	187	94	17
SP2*	181	92	34
AOS	150	78	61
SO2	126	49	3
OPC	78	28	5
AETH	71	44	8
CAPS-PMEX	37	20	2
CLAP	35	17	4
NOX	33	15	1

Note: does not include related statistics from aerial deployments.
*Numbers include VAPs, if available, which may pull in data from multiple products.

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