Breakout Session: Aerosol Measurement Uncertainties
Olga Mayol-Bracero (BNL), Rich Moore (NASA)

1:15 – 1:18 – Introductory Remarks
1:18 – 1:30 – Aerosol Measurement Uncertainties: What is ARM AOS Currently Doing? – Olga Mayol-Bracero

1:30 – 2:05 **- Operation**s

- 1:30 – 1:35 - A case for developing particle standards having known size, shape and composition to improve atmospheric measurements and model performance - Nicole Riemer
- 1:35 – 1:40 - Hygroscopicity closure evaluations - Janek Uin
- 1:40 – 1:45 - Assessing the calibration uncertainty and inter-instrument variability of the ACSM - Maria Zawadowicz
- 1:45 – 1:50 - Aerosol water: Target of opportunity and uncertainty for ARM - Allison McComiskey
- 1:50 – 2:00 - Discussion

2:00 – 2:10 - **Developing of Instruments**

- 2:00 – 2:05 – ARM mini-AOS for Distributed Sensing Network - Ashish Singh (**virtual**)
- 2:05 – 2:10 – Discussion

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- 2:10 – 2:15 – How models use (or don't use) measurement uncertainties? Jerome Fast

2:15 – 2:45 – **Open Discussions**

At the end we should come up with:

- List of **strategic opportunities** for ARM in the topics presented
- List of problematic **roadblock(s)**
- Prioritized **list of actionable items** within the framework of a 5-y strategic plan (timescale and required resources)

Aerosol Measurement Uncertainties: What is ARM AOS Currently Doing?

Olga Mayol-Bracero

AMSG Workshop

July 9, 2024

Salt Lake City, Utah

MOSAIC, Photo credit Janek Uin

Outline

- Background
- Calibrations
- Infrastructure
- Data Quality Assurance

Reducing the uncertainty in aerosol-climate forcing is critical for any effort to attribute, mitigate, or predict climate changes (IPCC, 2023; Kahn 2023).

- Magnitudes of aerosol direct and indirect climate forcing, and underlying mechanisms, represent the **largest uncertainties** in models used to characterize the current state and to simulate future climate (IPCC, 2023)

To meet ARM's mission to advance Earth and climate system models, accurate and precise measurements of aerosols and their properties must be made accessible to the modeling community.

How do we reduce uncertainty in ARM's in-situ aerosol measurements?

- Improve accuracy and precision of measurements
  - Measurements of the highest quality with high-end instruments (e.g., no low-cost sensors)
  - Instruments need to be calibrated under lab conditions, with reference instrumentation
  - Variability between reference instruments from different calibration labs should be low
  - Network measurements need to be comparable
  - Well-developed instrument calibration protocols
  - Capacity building (e.g., calibration training and workshops)

Other questions we need to ask

- What measurement uncertainty models can live with?
- Which measurement uncertainties have a higher priority, and which have a lower priority?
- How do we communicate uncertainties to the community?
- How do we communicate this for the user to consume?

Calibrations

ARM has presented needs in the area of instrument calibration and protocols.

U.S. DEPARTMENT OF ENERGY | Office of Science DOE/SC-ARM-21-010

ARM Aerosol Measurement Science Group 2019 Strategic Planning Workshop Report

Importance of well-developed instrument calibration protocols and well-characterized measurements and recognition of these as a limitation to stakeholders.

"since the cost of instruments and facilities needed for instrument calibration is a common theme …[it] suggests the **need for centralized facilities. Is it possible for the DOE community to establish such a facility?"** McComiskey et al. 2021

Whitepaper, motivated by discussions initiated at the 2017 Joint ARM-ASR PI Meeting, edited by J. N. Smith & N. Riemer

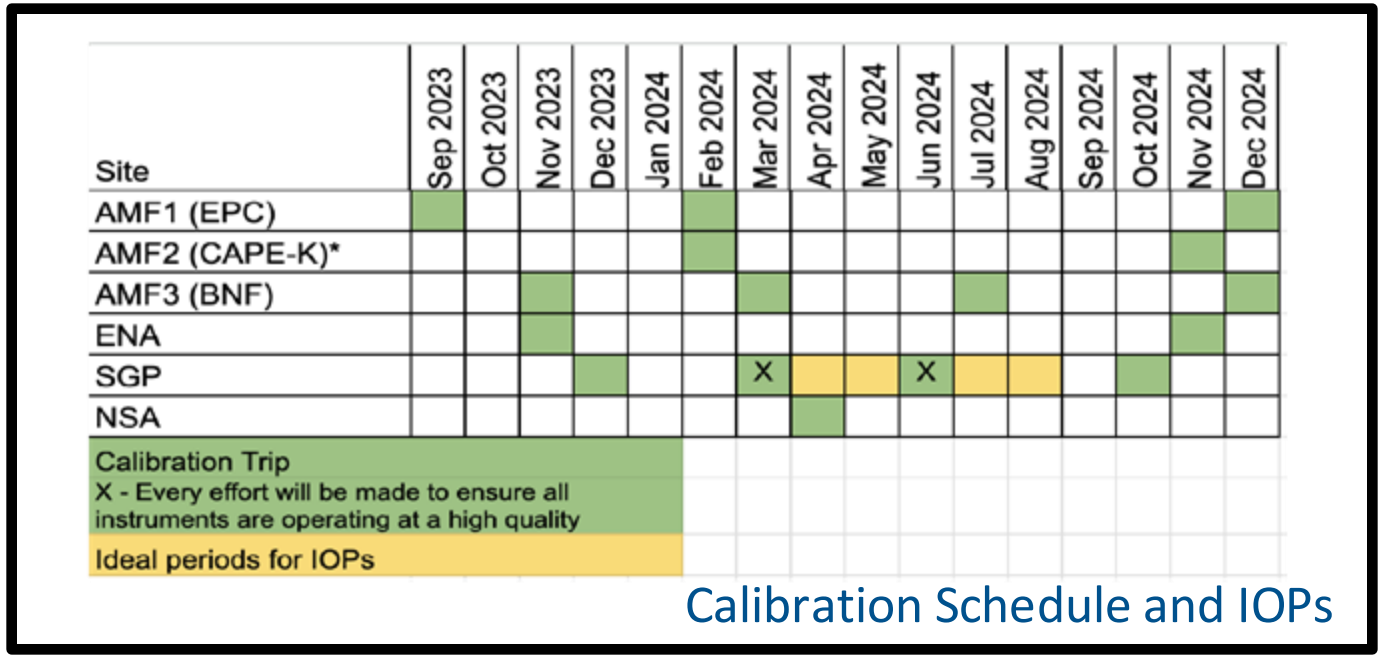
Developing particle standards having known size, shape and composition to improve atmospheric measurements and model performance

"importance of robust instrument calibration in the context of ASR science"

Brookhaven National Laboratory

Improvements in AOS Calibration Processes

- In the last few years, **we tripled the # of calibrations per deployment**.
- ARM IOPs aligned with calibration plan
- Calibrations closely integrated with CAMS calibrations plans
- Staggered to spread the workload and equipment needs
- Flexibility to adjust to ARM's needs



Calibration Schedule and IOPs

Theisen et al. ARM FY2024 Aerosol Operations Plan. 2023. 10.2172/2008425

Improvements in AOS Calibration Processes

Establishment of the **Center for Aerosol Measurement Science (CAMS)**

CAMS GOAL

To become a nationwide aerosol calibration and measurement science center that will provide traceable measurement services to ARM and beyond.

Chemical composition laboratory

Optical properties laboratory

Hygroscopicity laboratory

CAMS Main Laboratory

- Replica of the ARM AOS sampling stack
- Accommodations for guest instruments

Microphysical properties laboratory

https://www.bnl.gov/envsci/cams/

Brookhaven National Laboratory

Improvements in AOS Calibration Processes

CAMS Progress

Task 1: Establishing gold-standard reference instruments

Gold-standard reference instrumentation

- Highest order of reference instrument against which other instruments will be periodically calibrated
- Characterized and calibrated using first-principles techniques, NIST traceable standards (where possible), or accepted practices established by the wider community
- Dedicated to instrument calibration and intercomparison (remains in the laboratory to avoid performance degradation)

Improvements in AOS Calibration Processes

CAMS Progress: Establishing gold-standard reference instruments

- Procurement of gold-standard instruments for particle size and counting - ongoing
- Prepare infrastructure – ongoing
- Install and test instruments – after procurement
- Hire new CAMS staff – new hire starts in August 2024
- Visits to the World Calibration Center for Aerosol Physics (**WCCAP)** (April and May)
- Part of **CARGO-ACT project** (Cooperation and Agreements foR enhancing Global interOperability for Aerosol, Cloud and Trace gas research infrastructures – ACTRiS, ARM, NOAA, NASA)

Improvements in AOS Calibration Processes

http://www.cargo-act.eu/

CAMS and CARGO-ACT

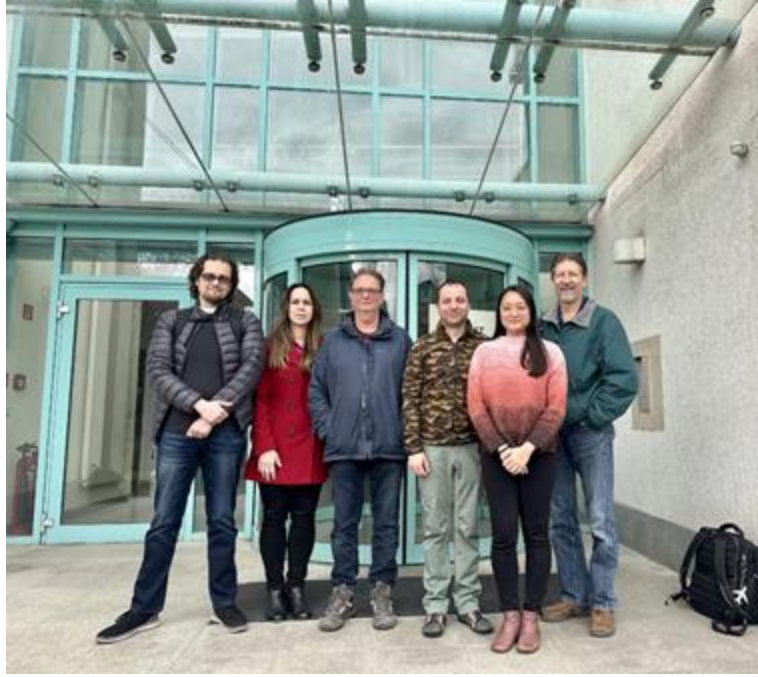
- CARGO-ACT's goal is to deliver a clear roadmap for sustainable global cooperation between key organizations in Europe (ACTRIS) and in the United States (ARM, NOAA, NASA)
  - to provide all users with the **best possible services (data, measurement facilities, reference instruments, reference standards, laboratories)** for accessing and using information for monitoring climate- and air quality-relevant properties of aerosols, clouds, and trace gases
- Project started in March 2024
- CAMS is part of Work Packages 2 and 6 - **first deliverables of WP2 for Aug 2024**
  - WP2 (Specification and documentation of common operation procedures and data quality methodologies)
  - WP3 (Pilot implementations demonstrating service integration)

Improvements in AOS Calibration Processes

Outcomes of WCCAP visits

- Better understanding of instrument and infrastructure needs for CAMS
- Calibration of AOS instruments (2 SMPSs) at WCCAP workshops.
- Activities related to CARGO-ACT – Work Package 2 *"Specification and documentation of common operation procedures and data quality methodologies"*

WCCAP CPC Cal Lab



CPC Cal Workshop

MPSS Cal Workshop

Brookhaven National Laboratory

CARGO-ACT Expected Outcomes Regarding in-situ Aerosol Measurement Uncertainty

- Assessment of traceability, calibration and operating procedures
- Harmonization of quality assurance and uncertainty estimation
  - What are the WCCAP-based measurement uncertainties (MPSS/SMPS and CPC) and where ARM AOS is relative to those?
  - How the calibrations will reduce in-situ aerosol measurement uncertainty and by how much?
  - Development/harmonization of measurement protocols (calibration and operation)

MPSS = Mobility Particle Size Spectrometer

Infrastructure

Lessons Learned from Most Recent AOSs Deployments

SAIL: Surface Atmosphere Integrated Field Laboratory (Sept 2021 – June 2023, Crested Butte, Colorado)

Photo credit Janek Uin

- Low ambient pressure
  - Strained the compressors and vacuum pumps.
  - Pressure drop across the critical orifices caused issues
  - Difficulty maintaining nominal air flows for HTDMA and CPCs
  - Flow calibrations of AOS instruments needed to be redone at that altitude.

Lessons Learned from Most Recent AOSs Deployments

TRACER: TRacking Aerosol Convection interactions ExpeRiment (Oct 2021 – Sept 2022, Houston, Texas)

- Condensation in sampling lines (AOS01)
  - Insulating of the sample lines was not enough
  - Increasing the cabin temperature by 3 degrees C solved the problem.
  - This caused instruments to run hotter than they like.
  - Fans were added to increase cooling
  - Performance of hygroscopicity measurements was affected.

Applications to BNF (changes performed to AOS03)

- Direct conditioned air away from sample lines
- Installed additional Nafion dryers
- Installed of water traps
- Inclusion of sample line sensors (P,T,RH)

AOS03 at BNL

Data Quality Assurance

Data Quality Assurance (DQA)

- **ACSM Calibration Uncertainty Study (Maria's talk)**
  - A laboratory inter-comparison of ARM ACSMs and improvement of calibration protocols.
- **Closure Evaluations (Janek's talk)**
  - Hygroscopicity and Particle Size (TRACER/EPCAPE lessons learned)
- **Data System Improvements (Janek's talk)**
  - Modernization of AOS instrument management software
    - New software would create a centralized system for all instruments in an AOS, improving the ease of implementing real-time instrument comparisons (e.g., direct comparisons and simplified closure calculations derived from raw data)

DQA: Reports

Submitted Reports

- Characterization of the AOS aerosol inlet stack for transmission losses for $D_p > 1$ µm
- Absorption, scattering, and extinction closure
- Evaluating UHSAS and OPC measurements
- AOS nephelometer calibrations during the ARM LASIC campaign
  - Report attached to a DQR

Results of these reports could be available to ARM users upon request. We could require them to be published (as tech reports) if they impact the use of the data (Documentation Breakout session – Adam).

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