

The Atmospheric Radiation Measurement (ARM) User Facility: Overview of Capabilities and Services

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Observations Support Atmospheric Research

MISSION:

Provide the climate research community with strategically located atmospheric observatories to improve the understanding and representation in earth system models of clouds and aerosols and their interactions with the Earth's surface.



The DOE Atmospheric Radiation Measurement (ARM) User Facility

ARM

Measurements of clouds, aerosols, precipitation, radiation, surface properties & the atmospheric state since 1992

Support for process studies & model & satellite development



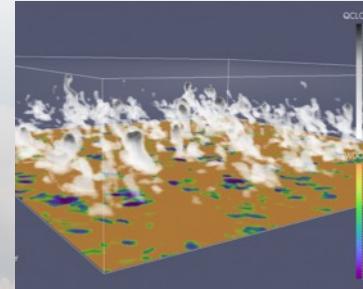
Network of 3 fixed-location & 3 mobile observatories



Piloted & uncrewed aerial measurement platforms



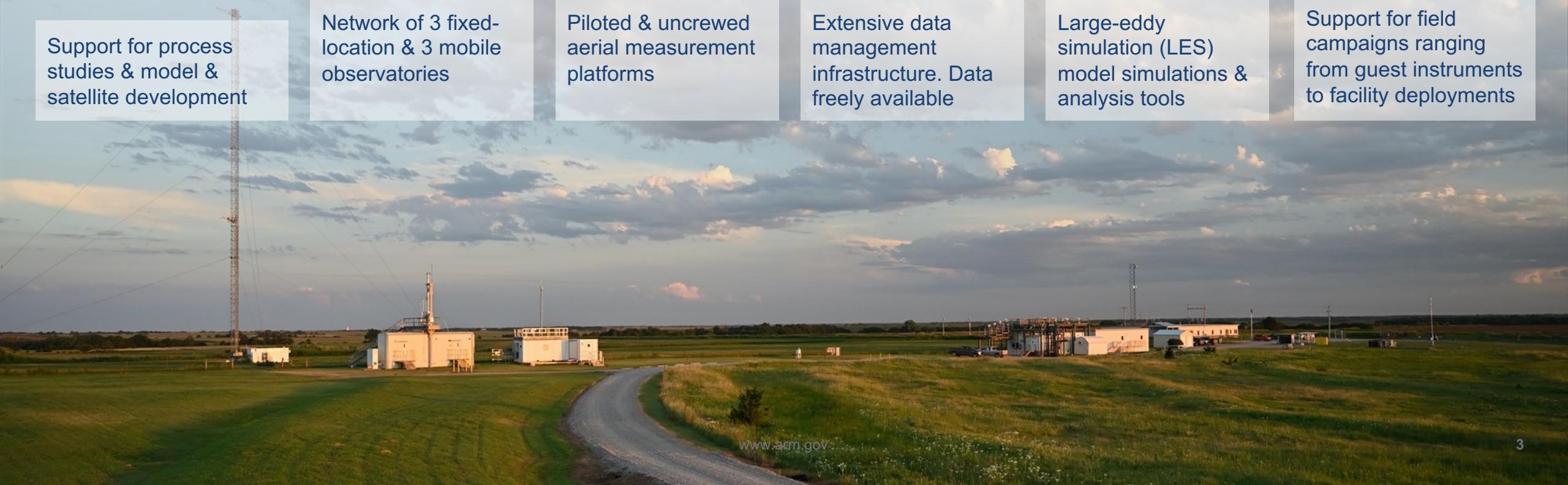
Extensive data management infrastructure. Data freely available



Large-eddy simulation (LES) model simulations & analysis tools



Support for field campaigns ranging from guest instruments to facility deployments



Comprehensive Sets of Measurements Deployed in Diverse Climate Regimes

ARM



Background atmospheric state



Surface energy balance



Aerosol and hydrometeor profiles



Near-surface aerosol properties



Aerial measurements



Aerial facility providing measurements in support of ARM observatories

- ▶ Preparing the Bombardier Challenger 850 regional jet for research flights
 - Adding probe mounts and lab space
 - Measurements of clouds, aerosols, and the atmospheric state
 - Increased payload weight, altitude, and range
- ▶ Modification steps
 - Design work nearly complete and work underway for low-risk modifications
 - Undergoing review of design with FAA, including plans to address updated regulations
 - Remaining modifications will be implemented following FAA approval



- ▶ ArcticShark Uncrewed Aerial System undergoing flight tests
- ▶ Collaborating with Mississippi State on payload and operations
- ▶ New aerial facility hangar at the Port of Pasco

Tethered balloon operations providing in situ profiles and opportunity for collaboration with EMSL

- ▶ Operating since 2015
- ▶ Two-week missions
- ▶ Payload includes ARM and guest instruments
- ▶ Flights in 2020/21 at Oliktok Point, Alaska, and the Southern Great Plains
- ▶ Planning flights in Houston the Southern Great Plains, and Colorado in 2022

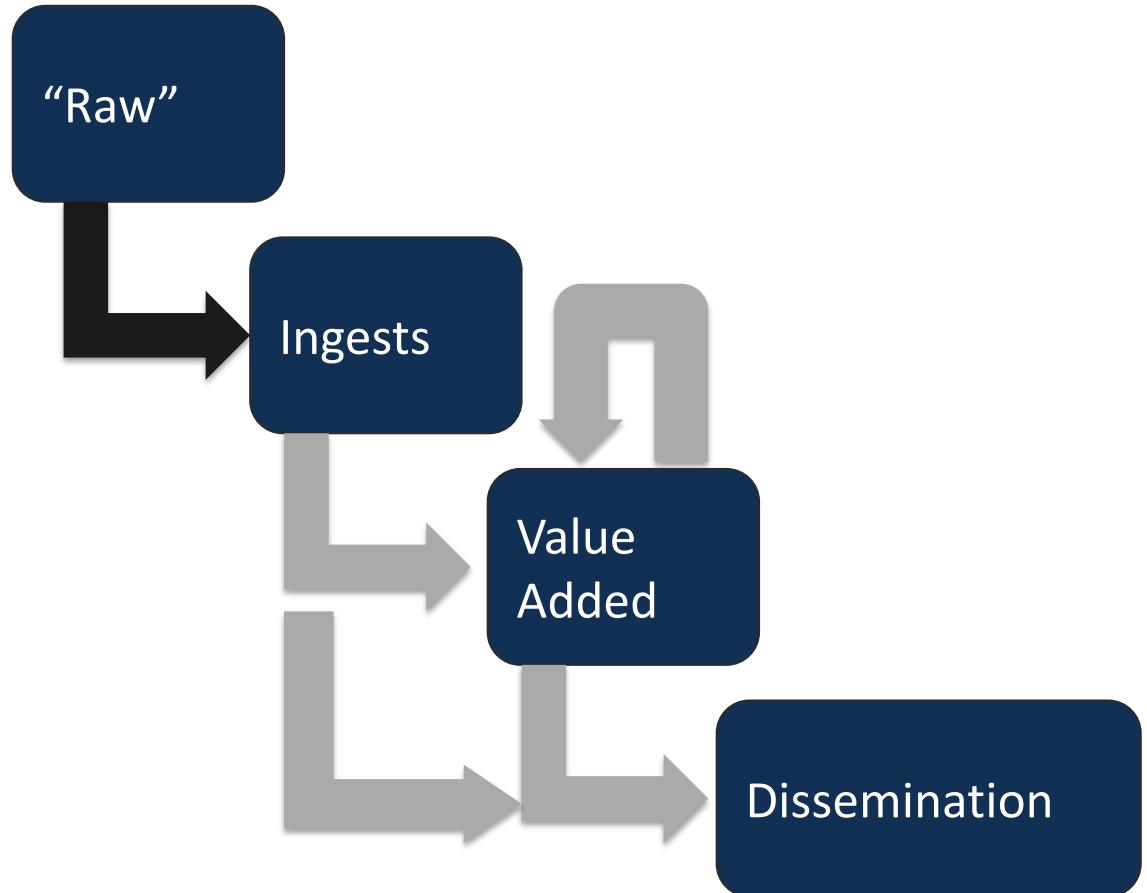


Tethered balloon flight with the EMSL STAC at the ARM Southern Great Plains, February 2021

- ▶ In November 2020, began flying the EMSL particle sampler, STAC, to collect size-resolved aerosol filter samples
- ▶ STAC samples are the target of a 2021 ARM/EMSL joint call for proposals
- ▶ STAC flights are planned to be a recurring collaborative activity

Provides High-Quality Data to Users

- ▶ Operates about 400 instruments across 6 sites and another 60 as part of the aerial facility
- ▶ Delivers over 2,500 datastreams to meet the needs of the science community
- ▶ Data processed to standard format and assigned metadata to aid discovery
- ▶ Approximately 60 active "Value Added Products" that provide
 - Derived parameters
 - Enhanced quality checks
 - Merged products (e.g. for model applications)
- ▶ Online tools support data discovery, ordering, and processing

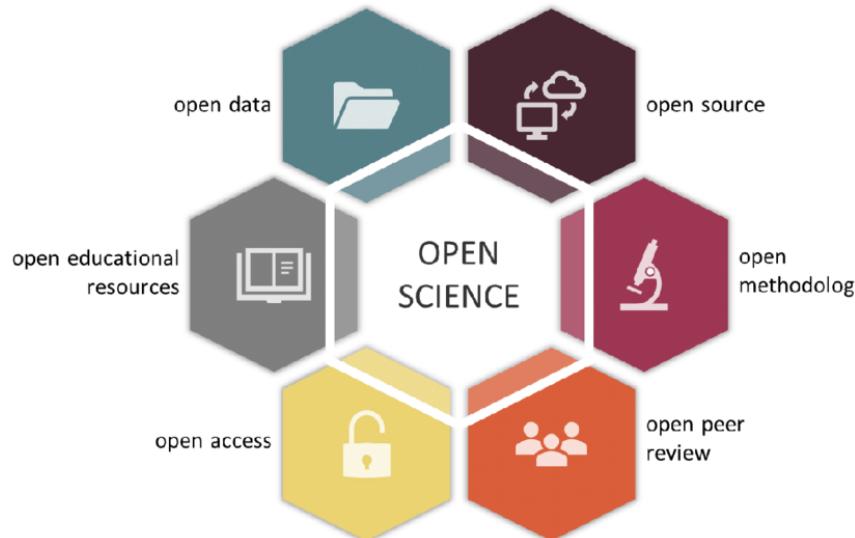


ARM Data Discovery Interface

- ▶ Intelligent search based on user's comfort area with advanced metadata and cutting-edge technologies
- ▶ Recommended data streams and data tagging
- ▶ Newly developed spatiotemporal viewer ("Location Search") for ARM field campaign data
- ▶ Ability to drill down for detailed information
- ▶ Tutorial videos @ <https://www.arm.gov/data/>

The screenshot displays the ARM Data Discovery Interface. At the top, there is a navigation bar with links for HOME, DATA SEARCH, SUPPORT, ACCOUNT, and CART. The main search interface shows search results for "Cloud Properties" and "Field Campaign: Tracking Aerosol Convection Interactions Experiment (TRACER)". On the left, a sidebar provides filtering options for Categories (Cloud Properties, macrophysical, microphysical), Measurements, Sites, Field Campaigns (selected: TRACER), Data Type, and Datastreams. The central area features a "Guided Search" section, a "Using the Map & Timeline" section, and a "VIEWING ALL LOCATIONS" section. The "VIEWING ALL LOCATIONS" section includes a timeline for the ARM Cloud Radiation Facility (ARMCECLRAD) from November 1993 to April 1994, showing data quality levels (ROUTINE, INCORRECT, SUSPECT, MISSING, NOTE, LIMITED ACCESS). It also includes a map showing a location in Arroyo Mágico, Argentina, with a red marker indicating the site. Below the map, there is a "Data Epochs" section for Cumulus Humilis, Congestus, or Stratocumulus Deep Convection Surface Rainfall, with details about the facility, location, and data source.

Open Science in ARM



Gallagher, Rachael et al. (2019). The Open Traits Network: Using Open Science principles to accelerate trait-based science across the Tree of Life. 10.32942/osf.io/kac45.

- ▶ In addition to ARM data being FAIR (Findable Accessible Interpretable and Reusable) ARM supports open science through:
 - Leadership for the Python ARM Radar Toolkit, Py-ART, a community based toolkit for working with gated data sets such as scanning radars.
 - Leadership of the Atmospheric Community Toolkit, ACT, an open source Python toolkit for working with atmospheric time-series datasets of varying dimensions.
 - Support for open educational materials such as cookbooks and workshops such as this! ARM has been increasing integrating with community of practice led groups such as Pythia and Pangeo.

ARM Community HPC Computing Resources

- ▶ Applications of ARM cluster
 - Operational processing (e.g. radar, complex VAPs)
 - HPC ecosystem for LASSO
 - Support user projects involving data-intensive analysis of ARM data
- ▶ New Cumulus cluster is currently under development
 - Phase I will have 7000 compute cores (July 21)
 - Phase II will have total of 16, 000 cores (Q1 FY22)
 - Will support LASSO and other science use cases
 - GPUs for ML/AI based data analytics



<https://arm.gov/capabilities/computing-resources>

Field Campaigns: Investigator-driven Deployments of ARM or Guest Instruments

ARM

ARM field campaigns range in cost and complexity from the deployment of a single guest instrument to the deployment of the ARM Aerial Facility or an ARM Mobile Facility

All field campaigns (also referred to as Intensive Operation Periods) are driven by ARM user proposals

Proposals are reviewed using a graded approach:

- Campaigns involving the aerial or mobile facilities or exceeding \$300K are reviewed annually by an independent review board.
- Smaller campaigns are reviewed internally on a quarterly basis



Mobile facility deployments extend the ability for ARM to sample a wide range of environments

ARM



- ▶ **MOSAiC:** Multidisciplinary Drifting Observatory for the Study of Arctic Climate
 - Central Arctic
 - October 2019–October 2020
 - More than 500 scientists from 20 nations
 - Coincident with cold-air outbreak campaign, COMBLE, in northern Norway
- ▶ **TRACER:** TRacking Aerosol Convection interactions ExpeRiment
 - Houston, Texas; focus on deep convection and aerosols
 - October 2021–September 2022
 - Multiple partners: NASA, NSF, NCAR, Univ. of Houston, Baylor, Texas A&M, and others
- ▶ **SAIL:** Surface Atmosphere Integrated Field Laboratory
 - Crested Butte, Colorado; mountain hydrometeorology
 - September 2021–June 2023
 - Leveraging ongoing work in the East River Watershed; coincident NOAA campaign

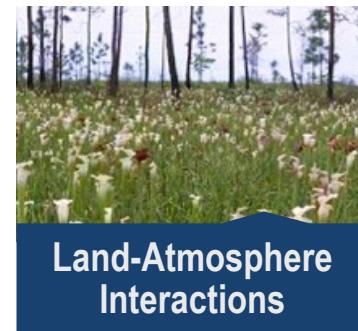
Two upcoming mobile facility deployments will enable research in very different environments

ARM



EPCAPE: Eastern Pacific Cloud Aerosol Precipitation Experiment

- ▶ La Jolla, CA; aerosol impacts on marine stratocumulus
- ▶ February 2023–January 2024



Land-Atmosphere
Interactions

Extended deployment to the southeast United States

- ▶ Northwestern Alabama; deep convection, aerosol processes, and land-atmosphere interactions
- ▶ Five-year deployment beginning in 2023



Aerosol Processes



Deep Convection

Engaging with Users Through Facility Processes, Meetings, and Web Tools

ARM engages with science users through multiple avenues including:

- The ARM Website (<https://www.arm.gov>)
- Newsletters and social media
- Constituent Groups such as the User Executive Committee, the cloud/precipitation and aerosol measurement and science groups and the ASR working groups
- Targeted Workshops and webinars
- Science meetings such as the annual ASR/ARM meeting through breakout sessions and working group chairs

The screenshot shows the official website of the Atmospheric Radiation Measurement (ARM) facility. At the top, there's a navigation bar with links for DATA, CAPABILITIES, RESEARCH, NEWS & EVENTS, and ABOUT. A search bar is also present. A banner at the top right mentions a COVID-19 update. Below the banner, there's a main headline: "The world's premier ground-based observations facility advancing atmospheric and climate research". There are several sidebar boxes with headlines like "DOES POLLUTION MAKE THUNDERSTORMS MORE SEVERE?", "UNDERSTANDING THE FUTURE OF WATER", and "ARM'S DECADAL VISION, PART 1". To the right, there's a large image of a city skyline. Below the banner, there's a section titled "ATMOSPHERIC OBSERVATORIES" with icons for SGP, NSA, ENA, AAF, and AMF, each accompanied by a small photo. Further down, there's a news item about a deadline extended for a virtual short course, and a "WELCOME TO ARM" section with a video link. At the bottom, there's a footer with links for CONNECT WITH ARM, POLICIES, HELP, RESOURCES, and WORKING WITH ARM, along with logos for various partner organizations.

2020 Decadal Vision



MEASUREMENTS

Supporting research of complex science issues through advanced measurements and flexible deployment strategies



DATA SERVICES

Providing powerful and adaptable computing resources to meet data analysis challenges



DATA ANALYTICS

Providing rigorous constraints on atmospheric processes with highly characterized measurements and multivariable analytics



OBSERVATIONS TO MODELS

Supporting frameworks and cross-discipline collaboration to enable strong links between ARM measurements and large-scale models

Questions?

- ▶ <https://www.arm.gov>
- ▶ "Ask Us"

My contact:

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ATMOSPHERIC RADIATION MEASUREMENT USER FACILITY				
CONNECT WITH ARM CREATE ACCOUNT ORGANIZATION 	POLICIES DATA POLICIES CAMPAIGN GUIDELINES LINKING POLICIES PRIVACY & SECURITY NOTICE DIVERSITY, EQUITY, & INCLUSION VULNERABILITY DISCLOSURE PROGRAM	HELP ASK US (circled) ASK A UEC MEMBER DATA QUESTIONS FAQS ACCOUNT MANAGEMENT	RESOURCES MEDIA OUTREACH ACRONYMS GLOSSARY	WORKING WITH ARM USE ARM FACILITIES ACKNOWLEDGE ARM SUBMIT A PROPOSAL FIND EMPLOYMENT VIEW ARM PRIORITIES

Reviewed September 2021

U.S. DEPARTMENT OF
ENERGY