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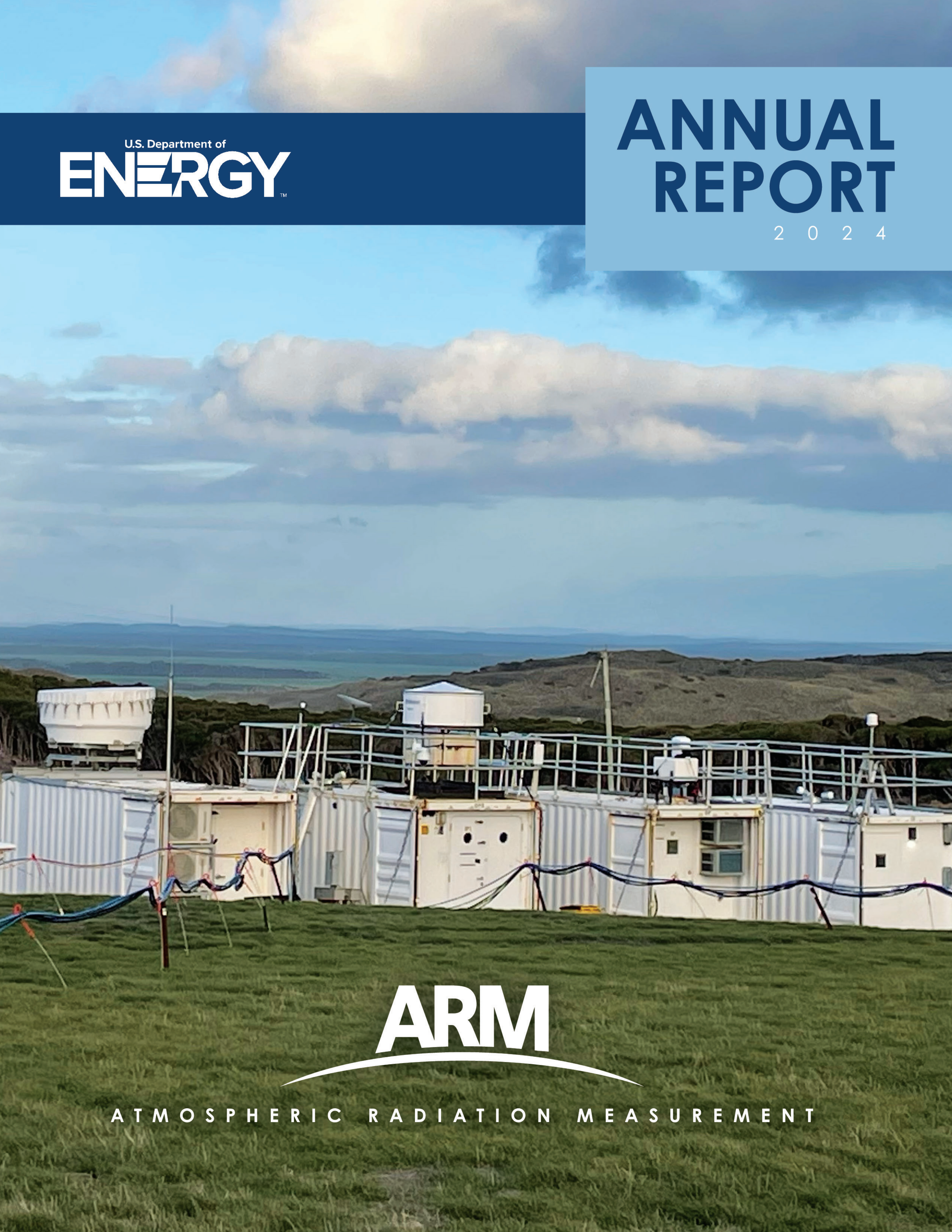


ARM

ATMOSPHERIC RADIATION MEASUREMENT

FROM THE DIRECTOR

A Year of Reflection and Progress for ARM

Fiscal year 2024 (FY2024) was exciting and also quite busy for the Atmospheric Radiation Measurement (ARM) user facility. As mobile deployments began and ended, and data collection continued at our three fixed-location atmospheric observatories, we also spent significant time in FY2024 preparing for ARM's next Triennial Review. The review, which will take place in front of an external panel selected by the U.S. Department of Energy (DOE), is now scheduled for January 2025. Preparing for the review has helped us reflect on ARM's accomplishments since the last review in 2020 and take stock of what is coming.

For at least the next five years, ARM will operate the Bankhead National Forest (BNF) atmospheric observatory in northern Alabama. It was a long road to reach this point, with many challenges along the way, but staff worked hard to have the main and supplemental sites ready to collect official data by the end of FY2024. The Southeastern United States is a high-priority region of interest for DOE, so we are happy that the BNF is finally open so scientists can start tapping into its potential to study aerosols, convective clouds, and land-atmosphere interactions.

On the covers:

Front – ARM instruments, including radars and lidars, are operating in northwestern Tasmania for the Cloud And Precipitation Experiment at kennaook (CAPE-k) from April 2024 to September 2025.

Inside – Visitors to ARM's Eastern North Atlantic atmospheric observatory in September 2024 watch a weather balloon sail into the sky. The group included the president of the Regional Government of the Azores, the U.S. consul in the Azores, and the mayor of Santa Cruz da Graciosa.

In February 2024, the yearlong Eastern Pacific Cloud Aerosol Precipitation Experiment (EPCAPE) completed operations in La Jolla, California. In this report, you will read about the data analysis that has occurred since the campaign ended.

Another coastal campaign began in April in northwestern Tasmania. The Cloud And Precipitation Experiment at kennaook (CAPE-k) is collecting data through September 2025 to fill in knowledge of little-observed atmospheric processes in the Southern Ocean.

Preparation ramped up over FY2024 for the Coast-Urban-Rural Atmospheric Gradient Experiment (CoURAGE) in the Baltimore, Maryland, area. CoURAGE data will complement measurements from a DOE Urban Integrated Field Laboratory that is studying how climate change is affecting Baltimore in coordination with local partners. We look forward to the insights that these data will provide.

In addition to work on the ground, ARM continued to refine and expand its aerial capabilities.

Our tethered balloon system team conducted flights in Oklahoma throughout FY2024, including work supported through the Facilities Integrating Collaborations for User Science (FICUS) program. FICUS-supported scientists can access ARM resources and those of another DOE Office of Science user facility, the Environmental Molecular Sciences Laboratory (EMSL).

Meanwhile, operations of ARM's ArcticShark uncrewed aerial system advanced beyond science and engineering flights. The first user-led ArcticShark campaign, selected from a fall 2023 proposal call, took place in May in Oklahoma to help scientists learn more about new particle formation and turbulence in the boundary layer. Later in FY2024, the ArcticShark flew over and around the BNF in preparation for future flights in the area.

This report also features research related to past campaigns. One of those campaigns, the 2019–2020 Multidisciplinary Drifting Observatory for the Study of Arctic Climate (MOSAiC) expedition, had generated almost 80 ARM-supported journal articles by the close of FY2024. That count will only continue to grow.

ARM always strives to meet the evolving needs of the scientific community—a key driver of its ongoing Decadal Vision—but one thing that stays constant is scientists' desire to easily access and use high-quality data that are relevant to their research. ARM staff worked to improve existing data analysis and discovery tools and incorporate new features into the ARM Data Workbench, which helps users interact with ARM data.

In addition to producing value-added data products for EPCAPE, CAPE-k, and the 2021–2023 Surface Atmosphere Integrated Field Laboratory (SAIL) campaign in Colorado, ARM staff expanded ARM products to new sites while developing new versions of established products.

In November 2023, staff and users met to discuss the future of ARM's high-resolution modeling activity. The Large-Eddy Simulation (LES) ARM Symbiotic Simulation and Observation (LASSO) team is now working on simulations for its third scenario, focused on shallow marine clouds over ARM's Eastern North Atlantic atmospheric observatory.

To broaden our reach and increase the impact of ARM data, we are looking toward the future of data sharing and compatibility in our current work with an ARM-like European network called the Aerosol, Clouds and Trace Gases Research Infrastructure (ACTRIS). We want to make ARM and ACTRIS data more similar so they are easier for scientists to use. ARM and ACTRIS are also helping to validate data from a European-Japanese satellite that launched in May 2024. We are eager to see where this partnership takes ARM, ACTRIS, and atmospheric science as a whole.

ARM has also been focused on developing the workforce of the future and introducing new generations to ARM data. In May 2024 in Cleveland, Ohio, we hosted our first summer school in five years, teaching students how to use open-source tools to work with ARM observations and high-resolution model output. Building on the success and lessons learned in Cleveland, we are planning to host and support more summer schools in the new year.

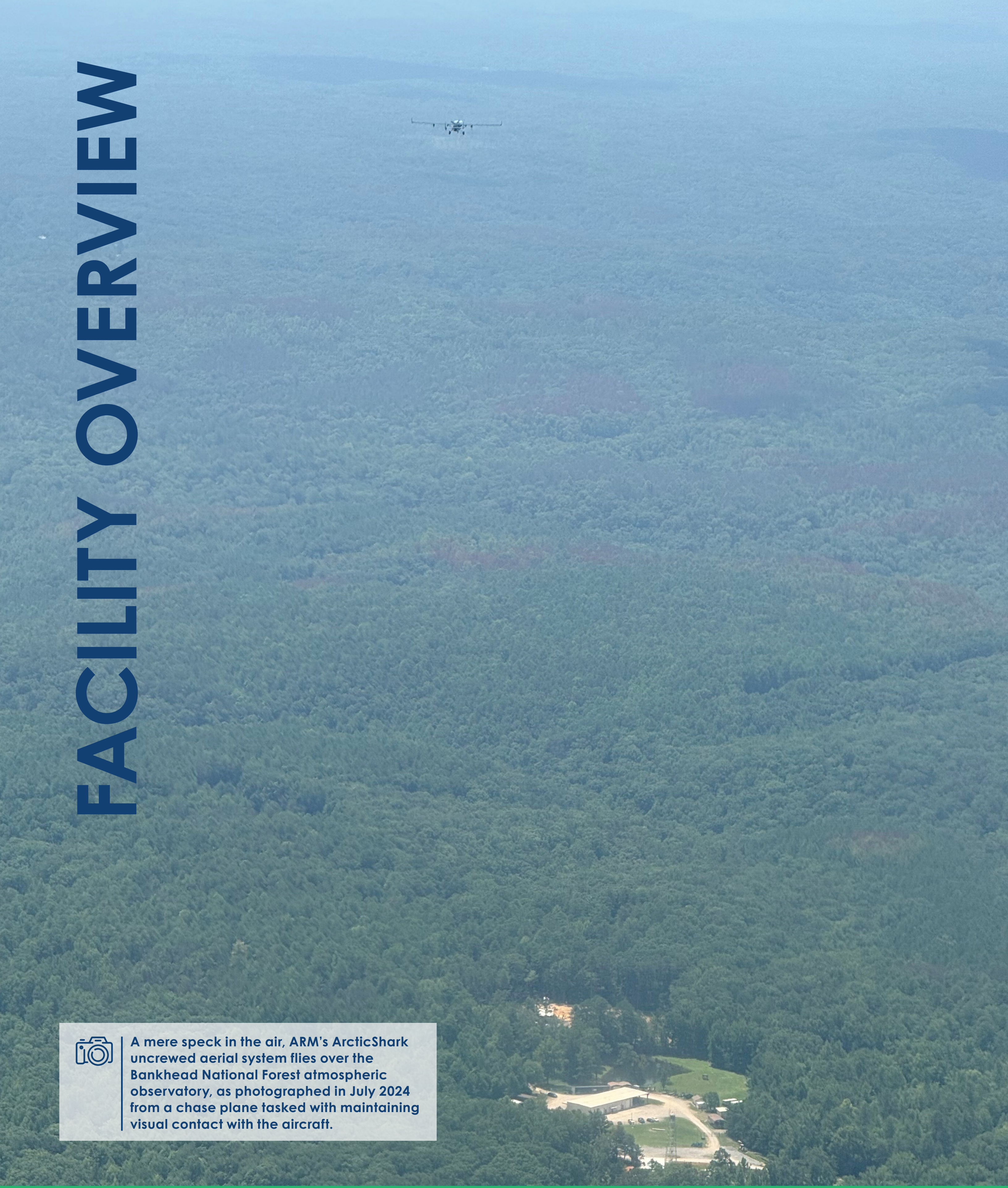
I hope you enjoy reading about ARM's work in FY2024.

JIM MATHER
ARM Director

TABLE OF CONTENTS

ARM instruments for CAPE-k overlook the Southern Ocean.

FACILITY OVERVIEW



A mere speck in the air, ARM's ArcticShark uncrewed aerial system flies over the Bankhead National Forest atmospheric observatory, as photographed in July 2024 from a chase plane tasked with maintaining visual contact with the aircraft.

The World's Premier Ground-Based Observations Facility to Advance Atmospheric Research

This report provides an overview of the Atmospheric Radiation Measurement (ARM) user facility and a sample of achievements for fiscal year 2024 (FY2024).

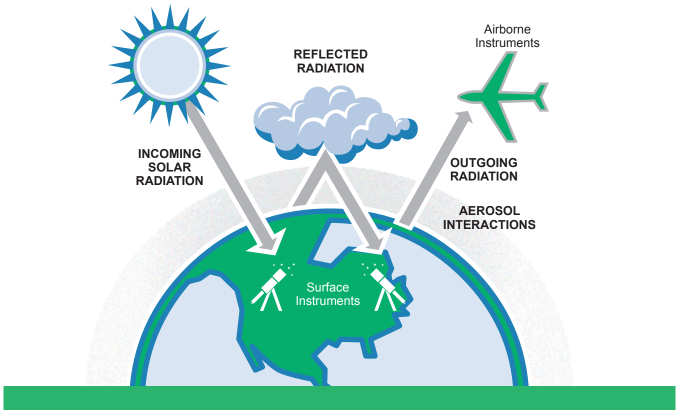
ARM is a multi-laboratory, U.S. Department of Energy (DOE) Office of Science user facility and a key contributor to national and international atmospheric and climate research efforts. ARM offers scientists cutting-edge, ground-based observatories, aerial observation capabilities, and high-performance computing. ARM's capabilities have enabled more than 30 years of continuous measurements of cloud and aerosol properties and their effects on Earth's energy balance.

Collected since 1992 in diverse climate regimes around the world, ARM data are helping researchers answer basic science questions about clouds, aerosols (small particles in the air), cloud formation, and Earth's energy balance.

ARM observations have yielded insights into a range of scientific issues, including measuring absorption of radiation (energy) from the sun by clouds, aerosols, and water vapor; identifying factors that trigger cloud formation; and detailing the characteristics of aerosol and cloud properties, such as ice crystal sizes. ARM data have led to greatly improved techniques for measuring cloud properties from the ground.

In addition to advancing scientists' understanding of how the atmosphere works, ARM observations contribute to improving the predictability of the earth system. ARM observations are used to improve and evaluate the representations of clouds, aerosols, precipitation, and their interactions with Earth's radiant energy in regional- and global-scale weather and earth system models. Better models help our nation develop sustainable solutions to energy and environmental challenges.

ARM was the first atmospheric research program to deploy a comprehensive suite of ground-based, cutting-edge instruments to continually measure cloud and aerosol properties and their effects on Earth's energy balance. This strategy revolutionized scientists' ability to collect long-term statistics of detailed cloud properties and now serves as a model for similar programs around the world.



Researchers use data collected from ARM ground-based and airborne instruments to study the natural phenomena that occur in clouds and how those cloud conditions affect incoming and outgoing radiative energy.

Strong collaborations between nine DOE national laboratories enable ARM to successfully operate in remote locations around the world. This unique partnership supports the DOE mission to provide for the energy security of the nation. Without the support of the following laboratories, ARM would not be the state-of-the-art facility that it is today.

Argonne National Laboratory | Berkeley Lab | Brookhaven National Laboratory | Lawrence Livermore National Laboratory | Los Alamos National Laboratory | NREL National Renewable Energy Laboratory | Pacific Northwest National Laboratory | Oak Ridge National Laboratory | Sandia National Laboratories

ARM Observatories

ARM operates three heavily instrumented fixed-location atmospheric observatories, three mobile facilities, and an aerial facility, and provides freely available data for use by scientists around the world. The sites of the fixed-location, long-term observatories were chosen to represent a broad range of atmospheric conditions and processes:

- Southern Great Plains (SGP) – Established in 1992, the first ARM observatory includes a heavily instrumented Central Facility near Lamont, Oklahoma, and smaller satellite facilities in Oklahoma.
- North Slope of Alaska (NSA) – Since 1997, ARM has operated a site at Utqiaġvik (formerly Barrow) near the Arctic Ocean.
- Eastern North Atlantic (ENA) – In operation since 2013, ARM's youngest fixed observatory is located on Graciosa Island in the Azores, an area characterized by a wide variety of meteorological conditions and cloud types, including marine stratocumulus.

Measurements obtained at the fixed atmospheric observatories are supplemented with data obtained from intensive field campaigns proposed by the scientific research community. ARM has observations from all seven continents, and data from all past sites and campaigns are still available for research.

Campaigns may use an ARM Mobile Facility (AMF), a collection of advanced measurement systems that can be deployed to locations around the world for six months to two years, or capabilities of the ARM Aerial Facility (AAF).

Each fixed or mobile observatory operates a broad suite of advanced measurement systems to provide high-quality research data sets. The current generation of instruments includes three-dimensional cloud and precipitation radars, advanced lidars that provide information such as profiles of aerosol extinction and vertical air motion, infrared interferometers that measure radiant energy from the atmosphere, in situ aerosol observing systems, microwave radiometers, and balloon-borne sounding systems, among others.

Once collected, the data from all ARM observatories are carefully reviewed for quality and stored in the ARM Data Center for use by the atmospheric science community. As part of this effort, ARM personnel apply scientific methods developed in the research community to create enhanced value-added data products. All ARM data products are made available at no cost for the scientific community through the ARM Data Center to aid in further research.

During their October 2023 meeting at ARM's Southern Great Plains atmospheric observatory, ARM leaders and User Executive Committee members look out across the Central Facility.

LONG-AWAITED OBSERVATORY OPENS IN ALABAMA

After years of planning and working through a series of construction delays, ARM began official operations at the Bankhead National Forest (BNF) atmospheric observatory in Alabama on October 1, 2024.

With support from ARM and DOE's Atmospheric System Research (ASR) program area, a multi-institutional site science team developed the science plan and initial research project for the BNF. The team, led by Brookhaven National Laboratory in New York, also created and applied science-driven siting criteria to identify the preferred region for the observatory.

"Our goal in selecting this site and the configuration of instruments is to enable studies from the canopy to the clouds," said BNF site science team lead Chongai Kuang.

For at least five years, the BNF will investigate the complex interactions among clouds, vegetation, and aerosols. The data collected will also advance weather and climate models for a more comprehensive understanding of Earth's atmospheric dynamics.

The observatory would not be possible without the support of the U.S. Forest Service (USFS), which is hosting BNF buildings and instruments.

"Our partnership with the USFS has been amazing," said BNF Manager Mike Ritsche. "Their assistance, guidance, and knowledge of not only the Bankhead National Forest but the local area was critical to our success. This partnership will be instrumental during our deployment for the next five years."

Like all ARM sites, the BNF is open to scientists to propose guest instrument deployments and to use the data in their own research projects and proposals.

On September 18, 2024, technician Kris Bennefield prepares for a test launch of a balloon-borne radiosonde at the main site of ARM's Bankhead National Forest atmospheric observatory.

Infrastructure Achievements

All FY2024 Infrastructure Updates

ARM Moves Forward on Operational and Engineering Priorities

ARM prioritizes its operational and engineering activities each fiscal year to meet user needs and achieve mission-critical facility goals.

In FY2024, ARM developed several new capabilities to support upcoming field campaigns. In preparation for the Bankhead National Forest (BNF) atmospheric observatory in Alabama, ARM instrument mentors designed new vertical measurements of aerosol, radiation, and turbulent heat fluxes that will be deployed on a 42.7-meter (140-foot) tower near the main site. New mini-aerosol samplers were also built for deployment to supplementary sites during the Coast-Urban-Rural Atmospheric Gradient Experiment (CoURAGE) in Maryland.

At other sites, ARM replaced its total sky imagers with newer technology. To fill in measurement gaps at the North Slope of Alaska, ARM installed new aerosol instruments in partnership with NOAA, which has historically made aerosol measurements at the site and provided them to ARM.

In the air, ARM tethered balloon system flights took place at the Southern Great Plains (SGP) observatory in February, June, July, and August.

The ARM Aerial Facility had its first proposal call for ArcticShark uncrewed aerial system flights, and the selected campaign took place in May around the SGP. Gannet Hallar and Gerardo Carrillo-Cardenas of the University of Utah co-led the campaign to help scientists better understand the relationship between turbulence and new particle formation. In July and August, ARM flew the ArcticShark in the BNF area to prepare for future missions in the region.

ARM's science translators and developers released core value-added products (VAPs) for recent field campaigns in Colorado and California. ARM's merged aerosol size distribution VAP was released to operations and is now available for sites in Oklahoma, Texas, and California, and a snowfall retrieval algorithm was applied to scanning radar in Colorado. New process-oriented diagnostics for land-atmosphere interactions and a lidar simulator are now available to ARM users and included in the DOE Energy Exascale Earth System Model (E3SM) diagnostics package.

To support ARM's operational processes and user experience, tools developers spent much of FY2024 upgrading database hardware and software, as well as improving tools to track ARM property and monitor data flow. ARM's Data Discovery interface now features improved search accuracy and integration with external repositories, making it easier for users to find and access the data they need. Staff also made progress on adding new features to the ARM Data Workbench, an ecosystem in which users can work with ARM data.

The Large-Eddy Simulation (LES) ARM Symbiotic Simulation and Observation (LASSO) team ran test simulations of marine stratocumulus cases at the Eastern North Atlantic observatory. The team also evaluated existing LASSO products and considered how to improve LASSO in the future based on user input from a November 2023 workshop. LASSO ties together ARM measurements and high-resolution simulations to support model development and process studies.

ARM's ArcticShark uncrewed aerial system takes off in May 2024 from the Blackwell-Tonkawa Municipal Airport in Oklahoma.

Collaborations and Science Outreach

By its very nature, ARM is a collaborative entity. As a national scientific user facility, ARM was designed to provide scientists with atmospheric observations needed to conduct their research. While ARM works closely with the Atmospheric System Research (ASR) program area to meet the objectives of DOE's Earth and Environmental Systems Sciences Division, ARM also supports research by scientists with diverse programmatic and institutional affiliations around the United States—and the world.

To reach new users, including students and early career scientists, ARM hosts training events, such as summer schools and short courses in how to work with ARM data and tools.

In addition, ARM frequently leverages measurements obtained by other organizations to provide a more complete description of the environment around its observatories and regularly coordinates with other agencies on field campaigns. Though each agency has its own goals and priorities, the coordination of observational activities produces more comprehensive data and leads to broader science outcomes. These collaborations are key to ARM's success.

ARM PARTNERS WITH EUROPEAN GROUP TO ADVANCE ATMOSPHERIC SCIENCE

ARM is working with a European network of atmospheric science observatories and data centers to help move toward an era of more widely shared data.

The Aerosol, Clouds and Trace Gases Research Infrastructure (ACTRIS) has a head office and a data center, in addition to central facilities that support different parts of the research infrastructure. It seeks to establish a coordinated, collaborative system of atmospheric observations and then integrate itself into a land- and space-based global observing system to improve earth system models.

Building on ideas first developed during a 2012 workshop, ARM representatives and ACTRIS developers renewed discussions in 2022 about how the two groups could work more closely together. What eventually emerged from the dialogue was a joint project called Cooperation and AgReements enhancing Global interOperability for Aerosol, Cloud and Trace gas research infrastructures (CARGO-ACT).

ARM Director Jim Mather said the intent of CARGO-ACT "is to make our data more similar across our networks to better serve the global research community, including modelers and satellite users."

CARGO-ACT work is divided into tasks, with different ARM leads focused on topics such as governance, data interoperability, and aerosol in situ observations. CARGO-ACT is also facilitating the development of the Center for Aerosol Measurement Science (CAMS) at Brookhaven National Laboratory in New York. CAMS will be the first aerosol calibration facility in the Western Hemisphere.

Meanwhile, ARM and ACTRIS are involved in validation activities for the European-Japanese Earth Cloud, Aerosol and Radiation Explorer (EarthCARE) satellite, which launched in May 2024.

This illustration shows the EarthCARE satellite in orbit. ARM and ACTRIS are among the organizations involved in EarthCARE validation activities.

ARM SUMMER SCHOOL IMMERSES STUDENTS IN OPEN SCIENCE

In May 2024, 23 students participated in the ARM Open Science Summer School at Cleveland State University. Ranging from undergraduates to postdoctoral researchers, the students learned how they could use ARM-supported open-source tools to connect observations with high-resolution model data.

Fifteen members of the ARM community, including staff and users from DOE national laboratories and external institutions, served as instructors and mentors.

The weeklong program consisted of a combination of lectures and hands-on exercises. Most of the lectures had at least some component focused on web-based Jupyter Notebooks, interactive environments in which users can create, edit, and share documents and run code. Students could adapt the notebooks for their own workflows.

On the first day of the summer school, the class separated into four groups. Each group developed a unique science question related to an ARM atmospheric observatory or field campaign. The groups then worked on their projects during the week, looking at deep convection initiation, cold-air outbreaks, aerosol influence on ground snow properties, and the impact of large-scale forcing on shallow cumulus fields.

Each project culminated in an open science cookbook, a citable scientific work for which each student received credit.

Yan Xie, a University of Michigan PhD student who studies rainfall events on Alaska's North Slope, found it interesting to learn about tools she could use to advance her work with ARM data. Also, she said, "I think the summer school really provides a good guideline for a new data user to ARM."

Students work together during the 2024 ARM Open Science Summer School at Cleveland State University.

KEY ACCOMPLISHMENTS

At a tundra study site in northern Alaska in June 2024, Jennifer "Jen" Delamere pulls a sled carrying snow-probing equipment during ARM's Snow ALbedo eVOlution (SALVO) field campaign. SALVO documented the springtime transition from snow to no snow in 2019, 2022, and 2024.

Featured Field Campaigns

In addition to providing continuous data collections from fixed observatories around the world, ARM sponsors field campaigns for scientists to obtain specific data sets or to test and validate instruments. The following pages highlight key campaigns in FY2024.

Scientists Explore Southern Ocean Cloud and Precipitation Processes

On April 15, 2024, the Cloud And Precipitation Experiment at kennaook (CAPE-k) began on the northwestern coast of Tasmania at the Kennaook / Cape Grim Baseline Air Pollution Station.

The 17-month ARM campaign is studying atmospheric conditions and processes over the Southern Ocean, which has a large influence on global climate and ocean circulations.

"What motivated CAPE-k was understanding processes in the Southern Ocean that the warming climate is most sensitive to," said Gerald "Jay" Mace of the University of Utah. Mace co-leads CAPE-k with Roger Marchand of the University of Washington.

Past campaigns by ARM and other entities have provided some data in the region, but CAPE-k will capture seasonal variations missed by shorter efforts.

DOE supports CAPE-k with help from the Australian Bureau of Meteorology (BOM) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia's government agency for scientific research. BOM and CSIRO jointly manage the air pollution station that is hosting ARM and guest instruments during CAPE-k.

The station, which is a premier site in the World Meteorological Organization-Global Atmosphere Watch network, has collected almost 50 years of aerosol and trace gas data. "Now the goal (of CAPE-k) is to connect the aerosols to the clouds," said Mace.

In May 2025, a CSIRO research vessel will gather cloud and precipitation data at sea to complement and validate CAPE-k's land-based observations.

Using data from CAPE-k and related studies, scientists will work to answer critical questions about the seasonality of cloud and precipitation processes over the Southern Ocean to help improve climate models.

An ARM mobile observatory (foreground) and guest Aerosol Observing System (back right) are located at the Kennaook / Cape Grim Baseline Air Pollution Station in Tasmania.

Coastal Marine Cloud Campaign Generates Bounty of Data

In mid-February 2024, the Eastern Pacific Cloud Aerosol Precipitation Experiment (EPCAPE) concluded its yearlong observational phase in La Jolla, California. The campaign was designed to provide unprecedented four-season data on the properties of coastal marine clouds, including their radiative effects and the role of human-made particles.

EPCAPE "was amazingly successful," said principal investigator Lynn Russell of Scripps Institution of Oceanography at the University of California San Diego. "We got more clouds, more data, and more investigators than we expected."

EPCAPE involved 17 co-investigators from a dozen U.S. and Canadian universities, three DOE national laboratories, NASA, and Environment and Climate Change Canada.

ARM deployed one of its mobile observatories along the Ellen Browning Scripps Memorial Pier. A smaller set of ARM and guest instruments operated on Mount Soledad, 3 kilometers (1.9 miles) from the pier.

"To my knowledge, EPCAPE has produced the most detailed and extensive probing of California coastal marine stratus to date," said co-investigator Mark Miller of Rutgers University.

EPCAPE instruments also observed extreme weather events, such as a record rainstorm in March 2023 and Tropical Storm Hilary in August 2023.

Researchers are eagerly diving into this wealth of data. Russell and Scripps colleagues are working with modelers to analyze the campaign's turbulence, cloud, and aerosol measurements. In addition, a number of graduate students and early career scientists have contributed to EPCAPE studies on ultrafine marine particle formation, cloud condensation nuclei activity, and individual particle composition.

From the Ellen Browning Scripps Memorial Pier in La Jolla, California, EPCAPE Principal Investigator Lynn Russell launches the campaign's final radiosonde at 6 p.m. Pacific on February 14, 2024.

All ARM Campaigns

BUILDING COURAGE: CAMPAIGN PROMISES MULTIFACETED DATA, COLLABORATION

ARM spent FY2024 preparing for the Coast-Urban-Rural Atmospheric Gradient Experiment (CoURAGE) in the Baltimore, Maryland, area from December 2024 through November 2025. CoURAGE will collect data to help models better predict the impacts of climate change on similar urbanized regions worldwide.

CoURAGE's main instrument site will be in northeast Baltimore on property owned by Morgan State University. Data from suburban, rural, and island sites will add vital context to the urban measurements, said principal investigator Kenneth Davis of Pennsylvania State University.

At the 2024 American Meteorological Society Annual Meeting in Baltimore, attendees discussed ideas that could help the city better adapt to a changing climate.

"We're looking for really simple, broad-scale solutions," said Benjamin Zaitchik of Johns Hopkins University.

In addition to being one of CoURAGE's 27 co-investigators, Zaitchik leads a DOE Urban Integrated Field Laboratory project that is studying how climate change is affecting Baltimore. Data from the urban lab project and CoURAGE will complement one another.

During a CoURAGE site tour in February 2024, a group of campaign scientists, DOE funders, and other officials gather on a former high school athletic field in Baltimore's Clifton Park area. The field will serve as the main instrument site for CoURAGE.

ARM GEARS UP FOR DESERT DEPLOYMENT IN ARIZONA

An ARM campaign announced in FY2024 will study how urban and desert environments influence convection and precipitation around Phoenix, Arizona, especially in relation to the summertime North American Monsoon.

ARM plans to operate a mobile observatory from April 2026 through September 2027 in northwest Phoenix as part of the new campaign, which is called Desert-Urban SysTem IntegratEd AtmospherIc Monsoon (DUSTIEAIM) in the Southwestern United States. DUSTIEAIM's principal investigator is ARM veteran Allison C. Aiken of Los Alamos National Laboratory in New Mexico.

DOE selected DUSTIEAIM from a fall 2023 call seeking proposals for ARM campaigns that would support the DOE Biological and Environmental Research program's interests in advancing the fundamental understanding of atmospheric processes to improve regional and global earth system models.

A planned partnership between DUSTIEAIM and a DOE Urban Integrated Field Laboratory project in the Flagstaff-Phoenix-Tucson corridor aims to improve understanding of atmospheric processes in urban regions.

A plane cuts above the Phoenix skyline. ARM plans to conduct a campaign in the Phoenix area from April 2026 through September 2027.

Past Campaign Results

All ARM-Supported MOSAiC Publications

Echoes of ARM's Role in an Epic Arctic Expedition

September 2024 marked the five-year anniversary of the start of the international Multidisciplinary Drifting Observatory for the Study of Arctic Climate (MOSAiC) expedition. MOSAiC was a 13-month investigation of the atmosphere, sea ice, snow, ocean, and ecosystem in the central Arctic.

Participants from 20 nations sought to observe, understand, and ultimately help model conditions in Earth's fastest-changing region. Temperatures in the Arctic are warming nearly four times faster than the global average, while sea ice is thinning and spatially declining.

DOE was a significant contributor to MOSAiC. ARM deployed more than 50 instruments on and around the German icebreaker *R/V Polarstern*, which froze into and drifted with the arctic sea ice.

By the end of FY2024, ARM's publications database showed that the user facility had supported 97 MOSAiC-related publications, including 77 peer-reviewed papers. Nearly one-third (24) of those papers were published in FY2024 alone.

Published ARM MOSAiC research has boosted scientists' understanding of ice-nucleating particles and ice formation in arctic clouds. Researchers also know more about arctic snowfall rates, surface energy budgets, and the annual cycle of aerosol size distribution.

ARM data from MOSAiC have pointed to new connections between sea salt aerosol and blowing snow, and they have provided insights on boundary-layer stability and warm-air intrusions. In addition, they have filled knowledge gaps on the Arctic's large-scale circulation systems, aerosol-cloud interactions, surface reflectivity, and heat fluxes.

Modelers are using MOSAiC radiosonde measurements from ARM and other entities to get baseline atmospheric data on pressure, temperature, humidity, and wind speed. Thanks to the extensive collection of ARM instruments, MOSAiC data products contain a broad set of measurements such as cloud and aerosol properties, surface radiative fluxes, and other relevant quantities for modelers.

"Overall, MOSAiC has been wildly successful," said the University of Colorado Boulder's Matthew Shupe, who co-coordinated the expedition and led the ARM MOSAiC deployment. "DOE observations are interwoven into a lot of the research, and DOE was such an important, foundational component of the expedition."

Since ending in 2020, MOSAiC has inspired fieldwork in the Norwegian Sea, Alaska, the Southern Ocean, and Antarctica. Some scientists are combining measurements from this new fieldwork with ARM MOSAiC data to better understand and model changes in the Earth's high latitudes.

Through MOSAiC, said Shupe, "DOE's data (are) being used by many international scientists and in interdisciplinary research that expands beyond the typical domain of influence for these data."

The *R/V Polarstern*, the flagship vessel of the Alfred Wegener Institute, served as a laboratory and hotel for MOSAiC expedition participants.

CONFERENCE SPURS REFLECTION, JOY OVER MOSAIC SCIENCE

Attendees at the 3rd MOSAiC Science Conference (3MSC) in Potsdam, Germany, reminisced about the expedition and rejoiced in the research it has generated so far.

"It's been a long and winding path with many challenges," wrote MOSAiC co-coordinator Matthew Shupe in a March 2024 blog post for ARM, "but at the 3MSC, I was able to sit back and appreciate the magnificence of the whole thing, as conveyed through a broad range of cutting-edge science and the blossoming of a new generation of arctic scientists."

Interdisciplinary sessions—several led by early career researchers—focused on topics such as chemical tracers in the Arctic, atmosphere-ice-ocean interactions, the distribution and fate of sunlight, sea-ice fractures and ridges, and upscaling and downscaling of information.

The conference also highlighted the growing use of ARM MOSAiC data. "These data have found their way into numerous model assessments and the verification of satellite observations," wrote Shupe.

In fall 2019, Matthew Shupe poses in the central Arctic during MOSAiC. Behind him is the *R/V Polarstern*, whose bow is stacked with ARM instruments for measuring cloud and atmospheric properties.

Coupling Clouds and Land to Mitigate Aerosol-Cloud Uncertainties

Aerosol-cloud interactions have a notable influence on the Earth's energy and water cycles. However, they remain a significant source of uncertainty in climate modeling. This uncertainty is partly due to the incompleteness of current measurement approaches for capturing aerosols at the cloud level, leading to inadequate representations that go into models.

A May 2024 paper presents a new approach to tackling aerosol-cloud interactions by better representing the aerosol particles that serve as cloud condensation nuclei. Rather than relying just on satellite and ground-based sensors, which assume uniform mixing in the vertical direction, scientists used field measurements, including aircraft data, from ARM's Southern Great Plains atmospheric observatory. The data helped them gain detailed insights that aid in the quantification of aerosol-cloud interactions.

"The discrepancies between observations and model estimates of aerosol-cloud interactions have been a persistent challenge in our community," said lead author Tianning Su of Lawrence Livermore National Laboratory in California. "Our study focused on how cloud-surface coupling can influence aerosol-cloud interactions."

They found that in a coupled system, interactions with aerosols from the lower atmosphere lead to an increased efficiency of particles activated into more, smaller cloud droplets and stronger aerosol-cloud interactions. In decoupled systems where cloud and surface interactions are weak, aerosols from the free atmosphere predominantly influence cloud properties. There is a disconnect between the cloud properties and boundary-layer aerosols, leading to weaker aerosol-cloud interactions and inconsistencies in aerosol measurements and cloud properties.

"Using either ground-based or spaceborne measurements of aerosol loading can lead to biases in estimates of aerosol-cloud interaction," said the University of Maryland's Zhanqing Li, who oversaw the research. "This is likely a major contributor to the discrepancies found between observational and model-based estimates."

This work underscores the critical importance of accounting for cloud-surface coupling in analyzing aerosol-cloud interactions. Incorporating information about land surface influences can lead to more accurate estimates of aerosol-cloud interactions and the overall climate.

Cloud-surface coupling, involving the exchange of aerosols, humidity, and turbulence between the land surface and cloud base, can influence aerosol-cloud interactions.

Reference

Su, T, Z Li, N Henao, Q Luan, and F Yu. 2024. "Constraining effects of aerosol-cloud interaction by accounting for coupling between cloud and land surface." *Science Advances* 10(21), https://doi.org/10.1126/sciadv.adl5044.

All Highlights for FY2024 Journal Articles

Are Atmospheric Models Too Cold in the Mountains?

Snowcapped mountains are more than just beautiful. The snow acts as a natural reservoir for water resources used by large populations across the world. But the presence and persistence of mountain snow strongly depends on temperature.

A research team at Lawrence Berkeley National Laboratory in California wanted to know if atmospheric models were accurately representing the temperatures across mountain peaks and valleys. Through a review of existing literature, the team found that existing models predict air temperatures that are 1 to 5 C (1.8 to 9 F) colder than observations. This cold bias is consistent for model output across continents and mountain ranges.

Scientists used results from three high-resolution models that cover all or part of the Western United States to find the root causes of these biases, showing that they are the result of multiple, entangled issues. They employed data sets from ARM's 2021–2023 Surface Atmosphere Integrated Field Laboratory (SAIL) campaign in the Colorado Rockies to identify and parse these issues.

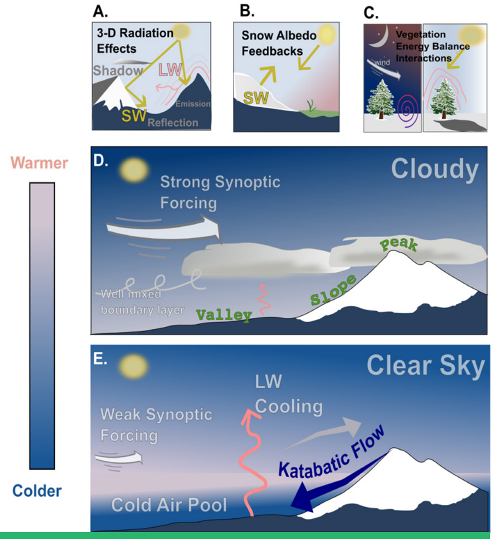
"Numerous studies have reported these biases before," said corresponding author William Rudisill. "But nobody had connected the dots between studies and articulated the fact that this is a common problem."

The work, published in July 2024, found that these biases exist across models and cannot be solved by simply increasing model resolution. The team also noted that elevation alone could not explain the temperature biases. Indeed, the temperatures that models predicted at mountaintops were too cold, while high-elevation valleys were simultaneously too warm.

In-depth analyses revealed that biases in models of the SAIL region can be linked to cold-air pooling, large-scale weather patterns, land surface heterogeneity, ground temperature, and thermal emission.

Determining the underlying physical processes that cause model temperature biases enables researchers to use existing observations and develop new ones to address and improve the identified issues. The approach facilitates targeted, systematic strategies to direct the development of accurate next-generation modeling capabilities.

Depicted are surface and atmospheric processes that control surface air temperature in high-altitude complex terrain. (Copyrighted image from the journal.)



In March 2023, snow blankets the area around SAIL instruments in Gothic, Colorado.

Reference

Rudisill, W, A Rhoades, Z Xu, and D Feldman. 2024. "Are atmospheric models too cold in the mountains? The state of science and insights from the SAIL field campaign." *Bulletin of the American Meteorological Society* 105(7):E1237-E1264, https://doi.org/10.1175/BAMS-D-23-0082.1.

A New Smart Sensing Framework for Severe Weather

Convective storm clouds are important to the Earth's climate, as they transport heat, moisture, and aerosols throughout the atmosphere, but they can be challenging to observe because they tend to change quickly and be short-lived.

"Developing a deeper understanding of storm clouds is important for planning more resilient infrastructure," said Katia Lamer of Brookhaven National Laboratory in New York.

Research published in November 2023 by Lamer and a team of colleagues presents an implementation of the Multisensor Agile Adaptive Sampling (MAAS) cyberinfrastructure to increase the likelihood of observing convective cloud and precipitation properties using radars.

MAAS uses near-real-time data from operational instruments, such as National Weather Service radars, to identify convective clouds. Based on archived input from scientists, MAAS then automatically selects a cloud to be further "sliced and diced" by research radars in the region.

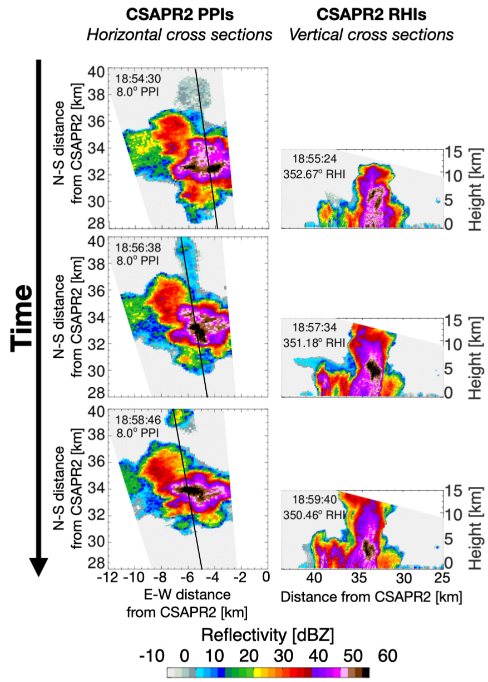
MAAS nowcasts the selected cloud's future location and sends instructions to the radars. Within two minutes, the radars rapidly collect scans through the selected cell to identify its core and other important features. The radars continue tracking and sampling over the cloud's entire life cycle.

The result: large numbers of horizontal and vertical radar scans through evolving convective clouds. The scans reveal new information about the structure of storms and the microphysical processes that shape them.

In the summer of 2022 during concurrent ARM and National Science Foundation campaigns near Houston, Texas, ARM and Colorado State University C-band radars collected over 315,000 scans through approximately 1,300 convective storms. Most of the storms were observed for over 15 minutes.

"The combination of a connected network of instruments, near-real-time data transfer, edge computing, and machine-guided analysis used by the MAAS cyberinfrastructure represents a paradigm shift in atmospheric science experimentation," said Pavlos Kollias, a joint appointee at Brookhaven and Stony Brook University. "The MAAS cyberinfrastructure has the potential to accelerate weather and climate model development and provide a framework for integrating emerging technologies in atmospheric experimentation."

ARM is now working to help scientists make the best use of this unique data set.



During the TRacking Aerosol Convection interactions ExpeRiment (TRACER) near Houston, the MAAS cyberinfrastructure initiated consecutive ARM C-band radar scans of a convective cell over its life cycle. (Image adapted from the journal.)

Reference

Lamer, K, P Kollias, E Luke, B Treserras, M Oue, and B Dolan. 2023. "Multisensor Agile Adaptive Sampling (MAAS): A Methodology to Collect Radar Observations of Convective Cell Life Cycle." *Journal of Atmospheric and Oceanic Technology* 40(11):1509-1522, https://doi.org/10.1175/JTECH-D-23-0043.1.

Small Aerosols Help Clouds Resist Precipitation Depletion

Marine clouds help cool the climate by reflecting more light than the ocean surface. In remote areas with minimal concentrations of larger aerosol particles, these clouds are more easily influenced by the available small aerosols linked to ocean biology. Interactions between aerosols and clouds are difficult to represent in models, and they remain a notable source of uncertainty in climate projections.

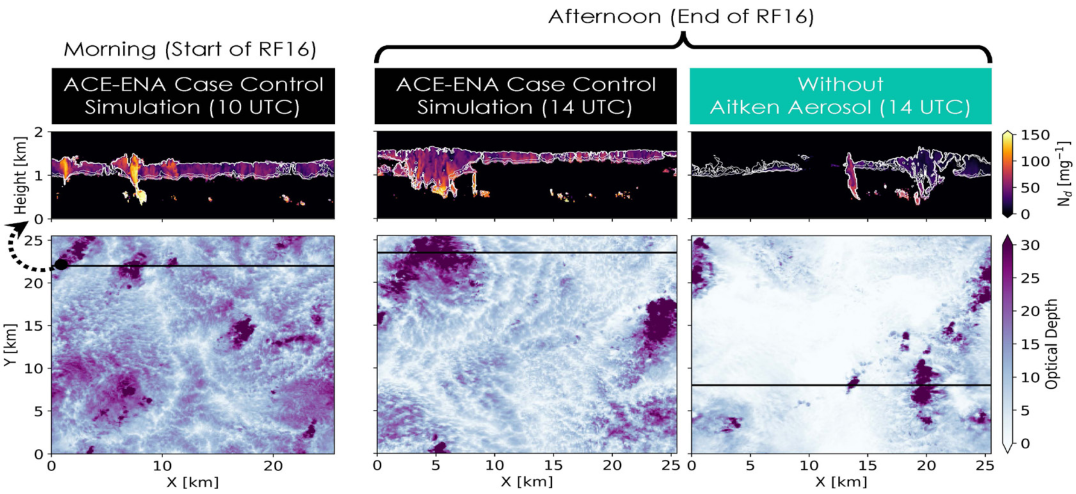
A June 2024 paper used data from ARM's Aerosol and Cloud Experiments in the Eastern North Atlantic (ACE-ENA) campaign to simulate the effects of changing aerosol concentrations on clouds. Researchers focused on how the smallest aerosols modify the formation, brightness, and lifetime of clouds above the North Atlantic Ocean.

"Most research has focused on larger aerosols and their effects on clouds," said co-author Robert Wood of the University of Washington. "In these isolated marine conditions, small, ultrafine aerosols exist in significant quantities and can have a major influence on the cloud life cycle."

The scientists input aerosol concentration data obtained in June 2017 by airborne instruments during ACE-ENA into a high-resolution computer model. They modeled how the aerosol-cloud-precipitation system evolved throughout the day, with a special focus on aerosol interactions. They found that ultrafine aerosols significantly contribute to cloud formation. Removing the small aerosols from the simulation results in clouds breaking up faster.

When the concentration of larger aerosols in the simulation was decreased, however, the breakup of clouds did not increase. Instead, the ultrafine aerosols took a larger role in maintaining the formation of cloud droplets and sustaining the cloud layer. Combined, these results highlight the significant role small aerosols can play in North Atlantic marine cloud life cycles.

"It is useful to see how small and large aerosols influence different types of clouds, which can vary from clustered to sheet-like or be mixed as in this case," said lead author Isabel McCoy of the Cooperative Institute for Research in Environmental Sciences and NOAA's Chemical Sciences Laboratory. "Studying these different cloud types helps us better understand how changes in aerosol concentrations over time will influence clouds globally."



Compared with the control simulation (left column evolving to the middle), simulations without Aitken—or ultrafine—aerosols evolve (third column) to have less opaque clouds (bottom) and fewer cloud droplets (top). Without Aitken aerosols, which resupply cloud condensation nuclei lost through precipitation, clouds break up faster.

Reference

McCoy, I, M Wyant, P Blossey, C Bretherton, and R Wood. 2024. "Aitken Mode Aerosols Buffer Decoupled Mid-Latitude Boundary Layer Clouds Against Precipitation Depletion." *Journal of Geophysical Research: Atmospheres* 129(12):e2023JD039572, https://doi.org/10.1029/2023JD039572.

Simulating the Amazon's Atmosphere in a Global Storm-Resolving Model

The Amazon is a region that experiences significant amounts of rain and storms. It also plays an important role in regulating the Earth's water and energy cycles. This makes developing accurate models of precipitation and cloud behavior over the Amazon essential for global modeling.

In a July 2024 paper, researchers used DOE's Simple Cloud-Resolving Energy Exascale Earth System (E3SM) Model (SCREAM) to simulate clouds and precipitation globally at a resolution of 3 kilometers (1.86 miles). They compared the SCREAM version 0 (SCREAMv0) simulations over the Amazon with ARM data from the Green Ocean Amazon (GoAmazon2014/15) campaign.

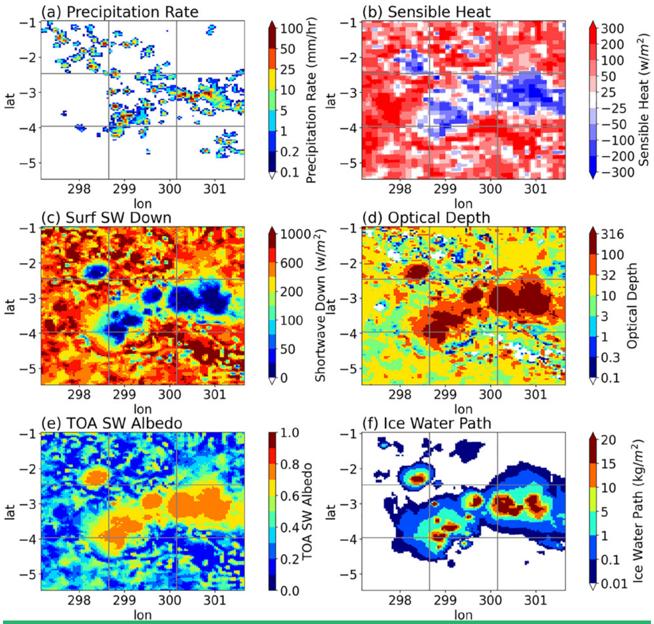
"The Amazon is a fantastic testing region for us to study the performance of SCREAM," said co-corresponding author Jingjing Tian of Pacific Northwest National Laboratory in Washington state.

"The complexity of the atmospheric processes at play combined with the rich ARM data enables us to effectively evaluate where SCREAM has biases or weaknesses," added the study's other co-corresponding author, Yunyan Zhang of Lawrence Livermore National Laboratory in California. Zhang leads a related DOE Atmospheric System Research (ASR) Science Focus Area project, Tying in High-Resolution E3SM with ARM Data (THREAD).

The researchers analyzed SCREAMv0's debut 40-day global simulation of the daily cycle of clouds and precipitation. Comparing it with the GoAmazon data, they found that SCREAMv0 accurately represented the intensity of precipitation. However, the model demonstrated a clear bias in the size of precipitation clusters. It produced too many small clusters and not enough larger storms.

This bias may stem from misrepresented land-atmosphere coupling as afternoon clusters are associated with heat moving downward from the atmosphere to the land. If this process is not fully accounted for in the model, small clusters might not be able to grow into the larger clusters seen in observations.

The overall process of model evaluation enabled by the GoAmazon data can help provide a blueprint for future work assessing global storm-resolving models such as SCREAM. Comparison with high-resolution data can allow researchers to not only identify model biases but understand their potential sources.



Plots capture different storm and atmospheric properties above the Amazon from the SCREAMv0 model. (Copyrighted image from the journal.)

Reference

Tian, J, Y Zhang, S Klein, C Terai, P Caldwell, H Beydoun, P Bogenschutz, H Ma, and A Donahue. 2024. "How Well Does the DOE Global Storm Resolving Model Simulate Clouds and Precipitation over the Amazon?" *Geophysical Research Letters* 51(14):e2023GL108113, https://doi.org/10.1029/2023GL108113.

What Controls Ice Particle Diversity in Cirrus Clouds?

Despite their thin and wispy appearance, cirrus clouds play a crucial role in modulating the climate. They have significant interactions with radiation coming in from the sun and out from the Earth. To fully understand the properties of these clouds, researchers are exploring how the size and shape of ice crystals change cloud behavior.

A paper published in June 2024 combined laboratory experiments of particle growth with a state-of-the-art model that tracks the growth of individual particles to identify sources of crystal diversity in cirrus clouds. Data from the 2021 Ice Cryo-Encapsulation by Balloon (ICE-Ball) campaign at ARM's Southern Great Plains atmospheric observatory were important to the model simulations.

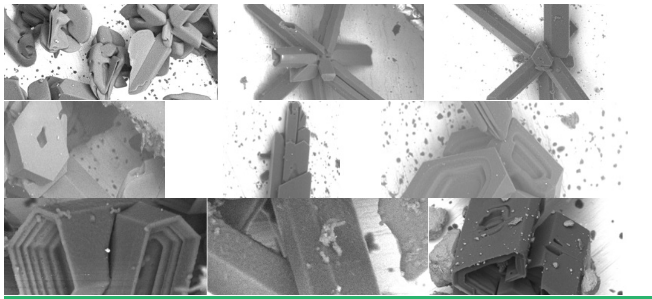
"Most models treat same-sized ice particles identically," said lead author Kamal Kant Chandrakar of the National Science Foundation National Center for Atmospheric Research. "However, the reality is much more complex. The diversity of particle shapes can affect how clouds grow and interact with light."

The team found that variation in the local environment around the particles is the primary factor that influences particle diversity in cirrus clouds. The environmental effect is not a simple, one-time consideration. The environment plays a key role in shaping the particles throughout their growth.

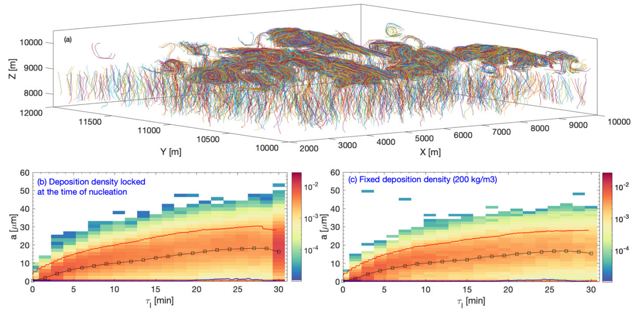
Cirrus crystal diversity is enhanced by the presence of varying morphological characteristics when ice particles first form, which results in different particle growth paths. As smaller particles grow larger, they end up with a range of shapes and sizes.

Accurately representing the constantly evolving nature of the particles requires measuring and modeling how they change over time. This is particularly challenging in current climate models. They usually represent cirrus crystal properties using measurements that are snapshots of numerous ice particles, each with different growth histories. The models generally miss the diversity of ice crystals and how they affect clouds.

These results highlight the importance of understanding how the environmental conditions throughout particle growth can alter the nature of cirrus clouds.



Scientists used instrumented balloons to sample ice crystals in cirrus clouds during the ICE-Ball campaign at ARM's Southern Great Plains atmospheric observatory. The images show some of the diverse crystals sampled.



The figure shows selected ice particle trajectories from the particle model sampled at 15-second intervals (trajectory length > 900 meters [0.56 miles]), and the evolution of simulated ice particle size distributions as a function of particle age after nucleation. (Image adapted from the journal.)

Reference

Chandrakar, K, H Morrison, J Harrington, G Pokrifka, and N Magee. 2024. "What Controls Crystal Diversity and Microphysical Variability in Cirrus Clouds?" *Geophysical Research Letters* 51(11):e2024GL108493, https://doi.org/10.1029/2024GL108493.

How Cloud Condensation Nuclei Affect Cold Pools

When rain falls, evaporation cools the air to form cold pools. These cold pools can form new storms at their leading edges. Little research has been performed into understanding the small-scale processes that influence cold pools.

The presence of higher numbers of cloud condensation nuclei (CCN)—small particles that act as seeds for cloud droplets—slows down rainfall. Historically, there have been limited data of CCN during storms, but ARM has a rare set of these data.

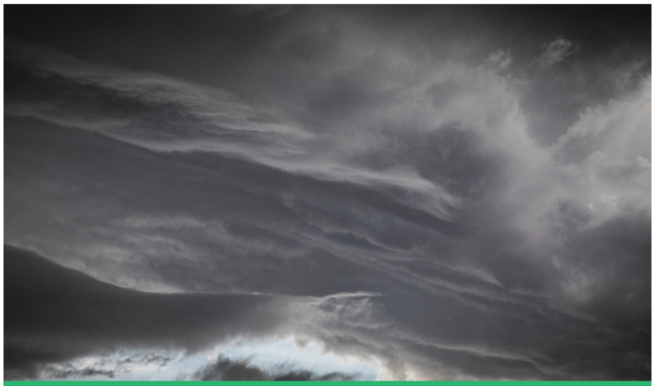
In a March 2024 paper, lead author Toby Ross and Sonia Lasher-Trapp, both of the University of Illinois Urbana-Champaign, used data from concurrent ARM and National Science Foundation campaigns in Argentina as well as model simulations to investigate connections between CCN and cold pools.

ARM aircraft observations made as part of the 2018–2019 Cloud, Aerosol, and Complex Terrain Interactions (CACTI) campaign suggested that more CCN delayed drizzle formation in smaller clouds.

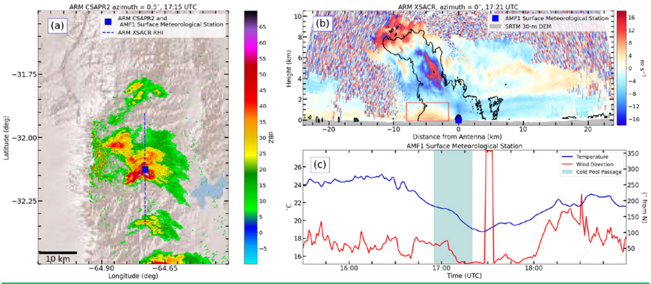
“The data verified that more CCN slows down precipitation in smaller clouds,” said Ross. “We wanted to know if the slowdown would also be seen as a delay in the cold pools formed from thunderstorms. Our analysis of the observations suggested it could occur, but we also used model simulations to test the trends.”

Two of the three storms were relatively ordinary thunderstorms. In both cases, the observations and model simulations showed that more CCN did delay rainfall and cold pool formation. This contrasts with the third and final case: a supercell thunderstorm. For the supercell storm, CCN showed no significant influence on its precipitation or cold pool.

These results indicate that the effect of CCN on thunderstorms can be overpowered in special storm systems with stronger dynamics. But CCN can have a clear and important influence on ordinary thunderstorms and their cold pools, which could be incorporated into models to increase the accuracy of thunderstorm outbreak simulations.



Data suggested that days with more cloud condensation nuclei had delayed formation of drizzle.



Scientists estimated cold pool timing using CACTI storm data, including (a) radar reflectivity showing the storm that produced the cold pool, (b) wind speed (the red box encloses stronger speeds indicative of the cold pool), and (c) surface temperature and wind direction (the shaded rectangle is the cold pool). (Copyrighted image from the journal.)

Reference

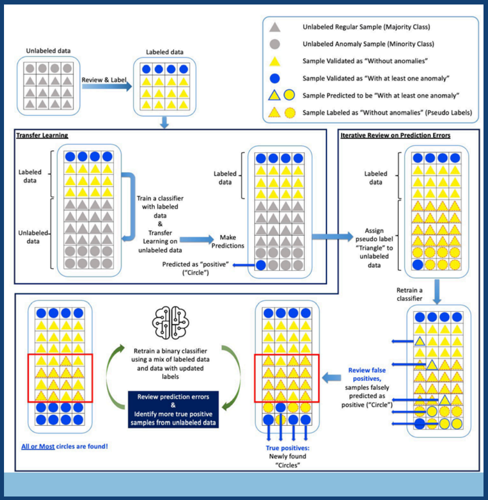
Ross, T and S Lasher-Trapp. 2024. “On CCN Effects upon Convective Cold Pool Timing and Features.” *Monthly Weather Review* 152(3):891-906, https://doi.org/10.1175/MWR-D-23-0154.1.

ARM ALGORITHM BOOSTS EFFICIENCY OF DATA QUALITY CHECKS

Since collecting its first measurements in Oklahoma in 1992, ARM has worked to provide high-quality data to its users. This requires consistent quality control checks based on scientific expertise. However, standard quality control checks might miss issues such as sporadic data spikes or shifts in averages, which require visual inspection with ARM tools.

To improve efficiency in detecting data issues, the ARM Data Quality Office developed and implemented the Iterative Error-Driven Ensemble Labeling (IEDEL) algorithm. Featured in a July 2024 paper, this new artificial intelligence algorithm can rapidly label data quality issues in large-scale data sets, reducing the data review workload by up to 95%.

In addition, IEDEL enables the construction of supervised machine learning models for discovering future data quality issues so ARM instrument mentors can address them promptly.



A diagram of the IEDEL algorithm process provides a legend describing data type in the upper right corner. (Image adapted from the journal.)

Reference

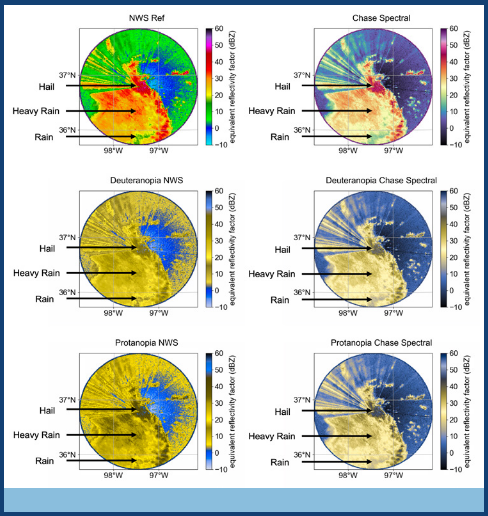
Li, L, KE Kehoe, J Hu, RA Peppler, AJ Sockol, and CA Godine. 2024. "Iterative Error-Driven Ensemble Labeling (IEDEL) Algorithm for Enhanced Data Quality Control for the Atmospheric Radiation Measurement (ARM) Program User Facility." *Journal of Geophysical Research: Machine Learning and Computation* 1(3):e2024JH000192, https://doi.org/10.1029/2024JH000192.

TEAM MAKES ACCESSIBLE RADAR MAPS FOR COLORBLIND SCIENTISTS

Visualizing data is essential to science and particularly important for interpreting radar measurements. However, over 4% of the world's population is thought to have color vision deficiency (CVD), commonly known as colorblindness, which makes it difficult to distinguish between certain colors. The colors used in weather radar colormaps make them particularly difficult for many people with CVD to read, as they often use red and green—which look similar to someone with CVD—close together.

An August 2024 paper describes new work creating CVD-friendly colormaps. The authors used ARM radar data and open-source software to develop their Python package, which is now freely available in the cmweather GitHub repository.

In the new colormaps, different phenomena from drizzle to rain to hail all have their own color. The colors were chosen with thought given to perceptual uniformity, which is when changes in color or lightness and data values have equal weight. The colormaps are close to perceptually uniform, making them easier for everyone, regardless of color vision, to read.



A storm system is visualized using a traditional colormap and a CVD-friendly colormap. The top row shows what an individual without CVD sees, and the middle and bottom rows show what an individual with CVD sees. (Image adapted from the journal.)

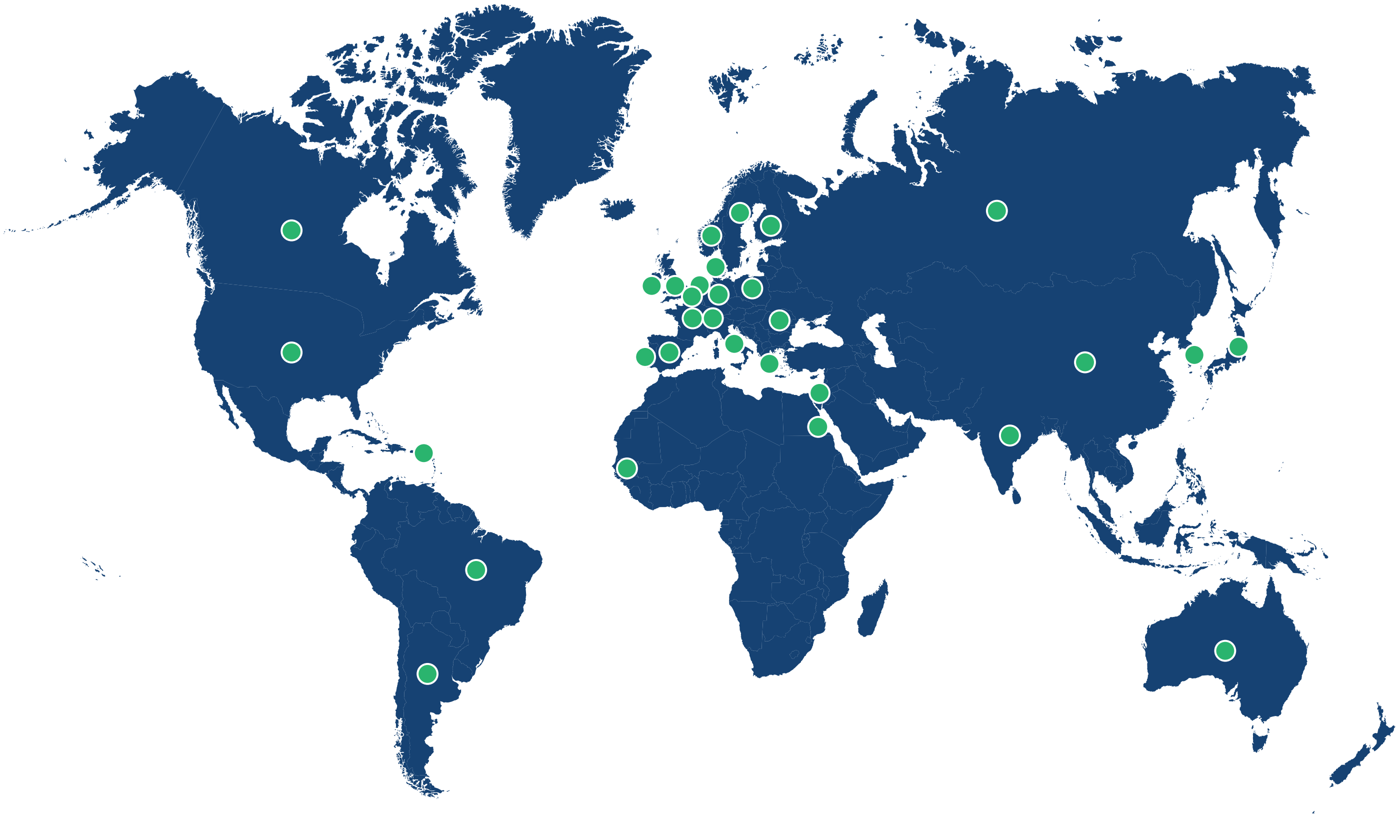
Reference

Sherman, Z, M Grover, R Jackson, S Collis, J O'Brien, C Homeyer, R Chase, TJ Lang, D Stechman, A Sockol, K Muehlbauer, J Thielen, A Theisen, S Gardner, and DB Michelson. 2024. "Effective Visualization of Radar Data for Users Impacted by Color Vision Deficiency." *Bulletin of the American Meteorological Society* 105(8):E1479-E1489, https://doi.org/10.1175/BAMS-D-23-0056.1.

FACILITY USAGE

ARM and guest instruments operated on Mount Soledad in La Jolla, California, as part of the 2023–2024 Eastern Pacific Cloud Aerosol Precipitation Experiment (EPCAPE).

1,062 TOTAL SCIENTIFIC USERS



31

COUNTRIES/TERRITORIES

Users by country/territory

United States **755**
China **79**
Germany **47**
Brazil **29**
United Kingdom **26**
Canada **18**
Australia **10**
France **10**
India **10**
South Korea **9**
Finland **8**
Japan **7**
Sweden **7**
Netherlands **6**
Portugal **6**
Norway **5**
Switzerland **5**
Belgium **3**
Italy **3**
Spain **3**
Argentina **2**
Denmark **2**
Israel **2**
Russia **2**
Senegal **2**
Egypt **1**
Greece **1**
Ireland **1**
Poland **1**
Puerto Rico **1**
Romania **1**

USER STATISTICS

Universities (U.S.)	495	46%
Foreign Entities	309	29%
DOE Labs	166	16%
Other U.S. Gov.	60	6%
Industry	32	3%

PUBLICATIONS USING ARM* 487 TOTAL

236	186	64	1
Abstracts and Presentations	Journal Articles	Technical Reports	Conference Papers

*Publication statistics were collected as of December 2024. Journal article numbers will continue to increase over time.

FACILITY USAGE

Data	Remote	Onsite
746	205	111
70%	19%	11%

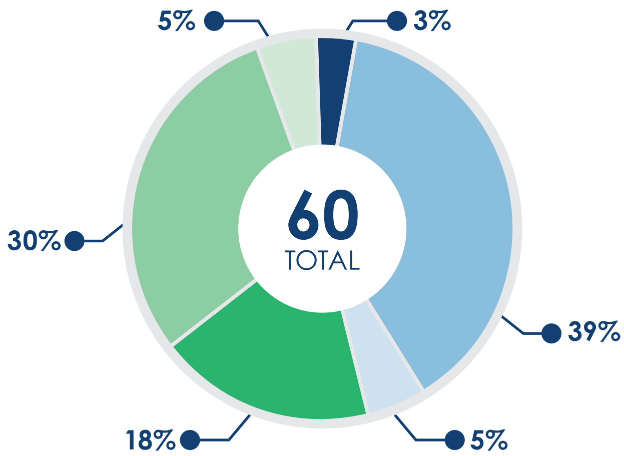
8,000+
Publicly Available Datastreams

430+
Instruments Collect Atmospheric Data

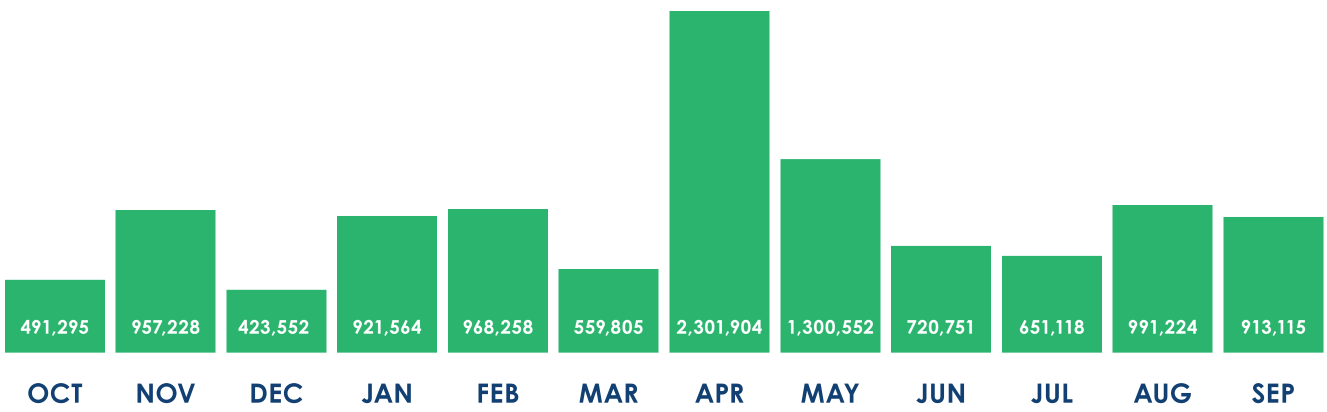
4,700+
Journal Articles Since 1990

FIELD CAMPAIGNS

- AAF **2**
- AMF **23**
- ENA **3**
- NSA **11**
- SGP **18**
- OFFSITE **3**



DATA FILE DOWNLOADS



DATA PRODUCTS

4
Released to Production

- AODBE5CH
- DLMC
- DLMCPROF-WIND
- TBSMERGED

7
Released to Evaluation

- AAFMERGED
- ARMLAGTRAJ
- ARMTRAJ
- CSAPR2CMAC
- LIDARAEROMASK
- PPIHYD
- RWPPRECIPCOR

3
Approved for Development

- CSAPR2 cell tracking statistics for TRACER
- HTDMAKAPPA
- SYNOPCLASS

5
Existing Value-Added Products Updated

- ARM-DIAGS
- MICROBASE
- PCCP
- QCECOR
- SQUIRE

NOTE:
Also in FY2024, ARM customized the ground-based cloud lidar simulator package for the DOE Energy Exascale Earth System Model version 3 (E3SMv3) and E3SM storm-permitting model SCREAM.

To learn more about the value-added data products, visit www.arm.gov/capabilities/science-data-products/vaps.

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Jason Tomlinson .. Pacific Northwest National Laboratory (10, 25)

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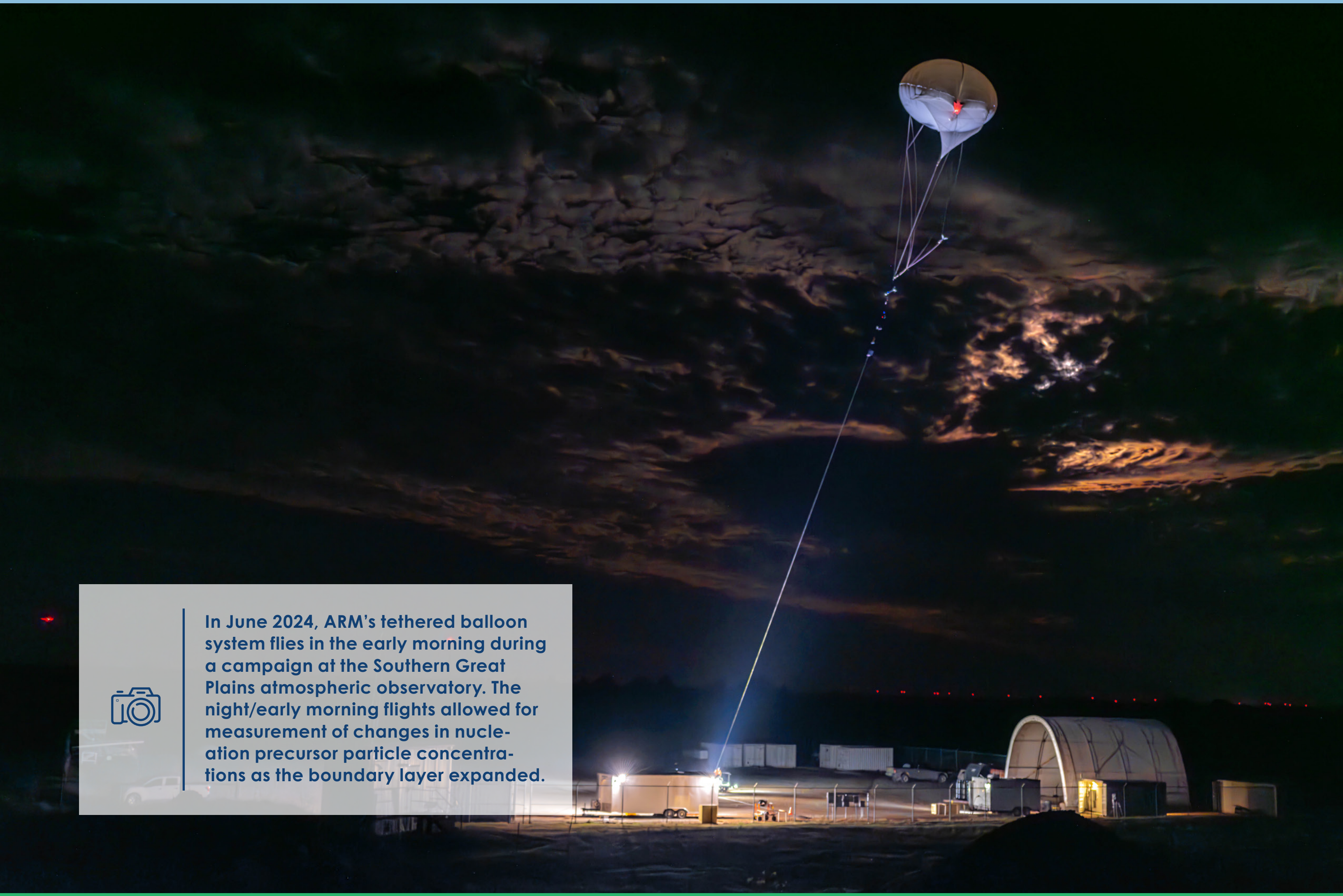

In June 2024, ARM's tethered balloon system flies in the early morning during a campaign at the Southern Great Plains atmospheric observatory. The night/early morning flights allowed for measurement of changes in nucleation precursor particle concentrations as the boundary layer expanded.

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DOE/SC-ARM-24-028