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ANNUAL REPORT

ARM

CLIMATE RESEARCH FACILITY

U.S. DEPARTMENT OF ENERGY | Office of Science

2014

On the cover: BAECC Site Panorama
The Biogenic Aerosols – Effects on Clouds and Climate (BAECC) field campaign is a collaboration with Finnish scientists to measure biogenic aerosols emitted from forests in order to determine their effects on clouds, precipitation, and climate. BAECC placed the second ARM Mobile Facility in a Scots pine forest in southern Finland from February through September 2014 to obtain surface-based measurements of biogenic aerosols and gases.

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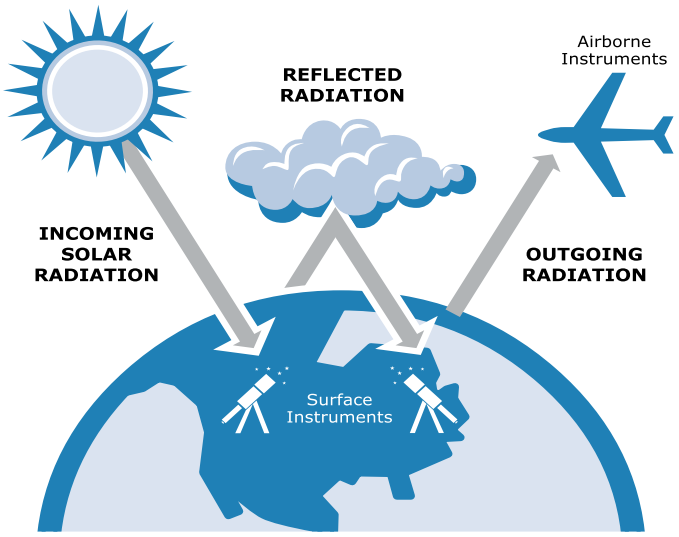


Researchers use data collected from ARM ground-based and airborne instruments to study the natural phenomena that occur in clouds and how those cloud conditions affect incoming and outgoing radiative energy.

The Earth's surface temperature is determined by the balance between incoming solar radiation and thermal (or infrared) radiation emitted by the Earth back to space. Changes in atmospheric composition, including greenhouse gases, clouds, and aerosols, can alter this balance and produce significant climate change. Global climate models are the primary tool for quantifying future climate change; however, significant uncertainties remain in the global climate models treatment of clouds, aerosol, and their effects on the Earth's energy balance.

In 1989, the U.S. Department of Energy (DOE) Office of Science created the Atmospheric Radiation Measurement (ARM) Program to address scientific uncertainties related to global climate change, with a specific focus on the crucial role of clouds and their influence on the transfer of radiation in the atmosphere.

Designated a national user facility in 2003, the ARM Climate Research Facility provides the climate research community with strategically located in situ and remote-sensing observatories designed to improve the understanding and representation, in climate and Earth system models, of clouds and aerosols as well as their interactions and coupling with the Earth's surface. The scale and quality of the ARM Facility's approach to climate research has resulted in ARM setting the standard for ground-based climate research observations.

This report provides an overview of the ARM Facility and a sample of achievements for fiscal year 2014 (FY2014).

Strong collaborations between nine DOE national laboratories enable the ARM Facility 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, the ARM Facility would not be the state-of-the-art facility that it is today.

Sandia National Laboratories · Pacific Northwest National Laboratory · Oak Ridge National Laboratory · NREL · Berkeley Lab · Los Alamos National Laboratory · Argonne National Laboratory · Brookhaven National Laboratory

Wanda Ferrell, U.S. Department of Energy

A Richly Deserved Retirement

After 20 years of leadership, Dr. Wanda Ferrell, DOE Program Director for the ARM Facility, retired on June 30, 2014.

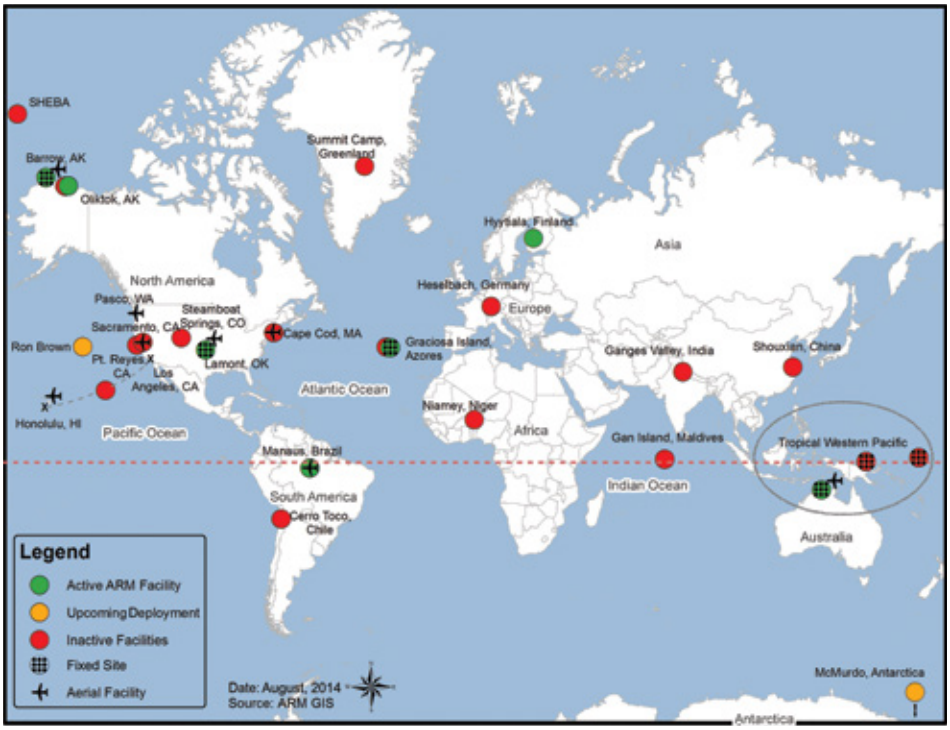
Under her astute guidance, what began in 1989 as an observational testbed network is now entering its third decade, preparing for a strategic reconfiguration to support climate modeling well into the future.

During her tenure, Dr. Ferrell developed three ARM Mobile Facilities to reach under-sampled climate regimes, including Niger, China, India, and the Maldives. She established a fixed research site in the Azores, Portugal; initiated strategic collaborations with the European atmospheric science and observations community; and paved the way for the ARM reconfiguration into megasites to better support high-resolution process and modeling studies.

Dr. Ferrell's determination and dedication to the ARM Facility is a source of inspiration to the team carrying out the mission of the Facility. She will be missed by all, who worked with her.

ARM Climate Research Facility

Through the ARM Facility, DOE funded the development of several long-term, highly instrumented ground stations for studying cloud formation processes and their influence on radiative transfer, and for measuring other parameters that determine the radiative properties of the atmosphere. To obtain the most useful climate data, instrumentation was established at four locales selected for their broad range of climate conditions:



- **Southern Great Plains** (**SGP**)—includes a heavily instrumented Central Facility near Lamont, Oklahoma, and smaller satellite facilities covering a 150-kilometer-by-150-kilometer area in Oklahoma and Kansas.
- **Tropical Western Pacific** (**TWP**)—spanning the equatorial region from Indonesia to the dateline, sites at Darwin, Australia; Manus Island, Papua New Guinea; and Nauru Island; began phasing out of operations as part of ARM's reconfiguration strategy.
- **North Slope of Alaska** (**NSA**)—includes a site at Barrow near the edge of the Arctic Ocean.
- **Eastern North Atlantic** (**ENA**)—the newest ARM site, located on Graciosa Island in the Azores.

Each site operates advanced measurement systems on a continuous basis to provide high-quality research data sets. The current generation of ground-based, remote-sensing instruments includes three-dimensional (3D) cloud and precipitation radars, Raman lidar, infrared interferometers, aerosol observing systems, and several frequencies of microwave radiometers, among others.

Measurements obtained at the fixed sites are supplemented with data obtained from intensive field campaigns using the ARM Mobile Facilities (AMF) or ARM Aerial Facility (AAF).

In addition, data on surface and atmospheric properties are also gathered through forecast models, satellites, and value-added processing. Once collected, the information is sent to the site data systems and carefully reviewed for quality. Approved data are then stored in the ARM Data Archive for use by the atmospheric science community.

Using these data, scientists are studying the effects and interactions of sunlight, radiant energy, and clouds to understand their impact on temperatures, weather, and climate. As part of this effort, ARM personnel analyze and test the data files to create enhanced data products, which are also made available for the science community via the ARM Data Archive (***http://www.archive.arm.gov***) to aid in further research.

In FY2014, the Facility began embarking on a reconfiguration, including the creation of two "megasites" at the Southern Great Plains and North Slope of Alaska sites. In addition, the Eastern North Atlantic and third ARM Mobile Facility at Oliktok, Alaska, expanded measurement capabilities by adding radars and lidars to the baseline operations.

Cooperation and Oversight Enable Success

Nine DOE national laboratories and numerous government agencies, universities, private companies, and foreign organizations contribute to the ARM Facility. Each entity serves a vital role in managing and conducting the operation and administration of the user facility.

The ARM Facility is directed by **DOE Headquarters**. An **Infrastructure Management Board** coordinates the scientific, operational, data, financial, and administrative functions of the ARM Facility. An 11-member **Facility Science Board**, selected by the ARM Program Manager, serves as an independent review body to ensure appropriate scientific use of the ARM Facility. Scientific guidance for the Facility is provided by the science team of the Atmospheric System Research (ASR), a DOE-funded observation-based climate research program, as well as by scientists at other government, academic, and private organizations. ARM Facility users provide feedback on the Facility's activities through workshops and surveys.

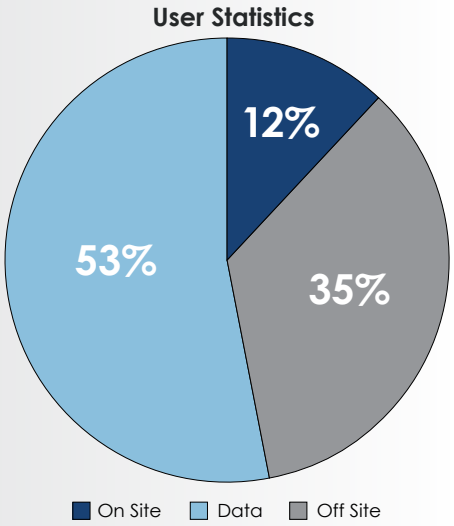
Sally McFarlane, U.S. Department of Energy

Sally McFarlane Named DOE ARM Program Manager

On July 1, 2014, Dr. Sally McFarlane took a new role in DOE as the program manager for the ARM Climate Research Facility, following Dr. Wanda Ferrell's retirement. After a year and half as a program co-manager for Atmospheric System Research, Dr. McFarlane is now responsible for ARM operations and science.

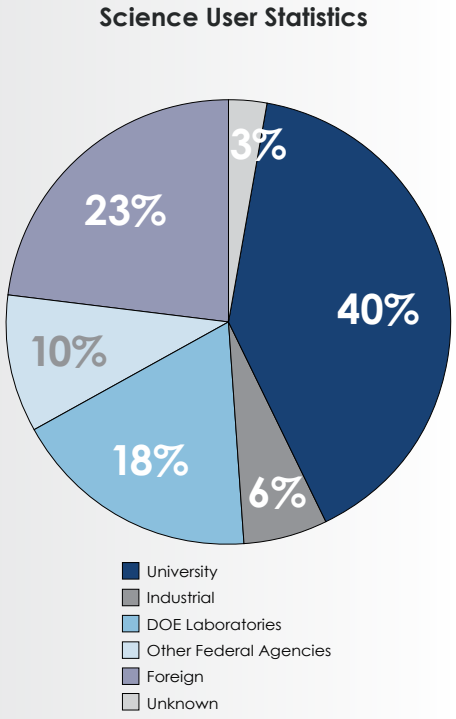
Prior to joining DOE, Dr. McFarlane was a research scientist at Pacific Northwest National Laboratory in the Climate Physics Group where she was actively involved in the ARM Facility. She is an author of nearly 50 peer-reviewed journal articles and has a B.A. in physics and mathematics from Mount Holyoke College. Dr. McFarlane earned her Ph.D. in astrophysical, planetary, and atmospheric sciences from the University of Colorado.

Fiscal Year 2014 Budget Summary and Facility Statistics



FY2014 Budget ($K)	
Infrastructure	*67,779*

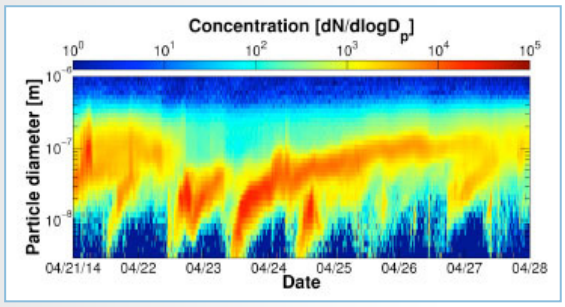
User Statistics for the Period of October 1, 2013–September 30, 2014	
Description	**Users**
On Site	160
Off Site	454
Data	682
Total	**1,296**



Users by Affiliation for the Period of October 1, 2013–September 30, 2014	
Description	**Users**
University	524
Industrial	78
DOE Laboratories	230
Other Federal Agencies	127
Foreign	300
Unknown	37
Total	**1,296**

Key **ACCOMPLISHMENTS**

After completing a very chilly startup in January 2014, the installation of the scanning ARM cloud radar atop one of several containers at the ARM Mobile Facility site in Hyytiala, Finland, gave the radar a better view.



Submicron aerosol number size distribution measured with a SMEAR-II DMPS at Hyytiälä, Finland, between April 21-27, 2014. The data highlight the characteristic feature observed at the site—formation of secondary organic aerosol and their growth to cloud condensation nuclei active sizes.

Long-term, continuous and comprehensive measurements from the 127-meter SMEAR-II mast and platforms (seen in the back of the image) complement the AMF2 instrumentation (located with the buildings) at the BAECC site in Hyytiälä, Finland. Image courtesy of Riikka Väänänen.

Featured Field Campaigns

Biogenic Aerosols – Effects on Clouds and Climate (BAECC)

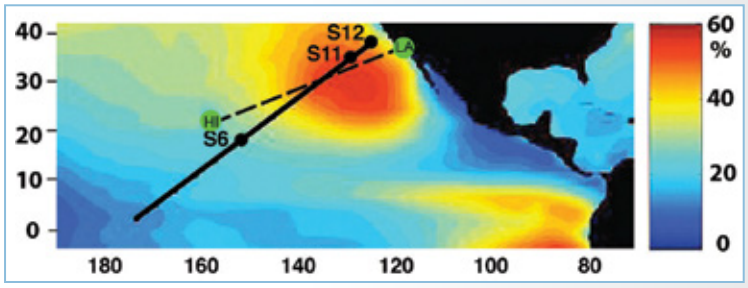
The Biogenic Aerosols – Effects on Clouds and Climate (BAECC) field campaign was a collaboration with Finnish scientists to measure secondary biogenic aerosols emitted from forests in order to determine their effects on clouds, precipitation, and climate. BAECC placed the second ARM Mobile Facility (AMF2) in a Scots pine forest in southern Finland from February through September 2014 to obtain surface-based measurements of biogenic aerosols and gases. These measurements were augmented by aircraft observations of aerosol microphysics, as well as measurements from the University of Helsinki's Station for Measuring Ecosystem-Atmosphere Relations (SMEAR-II).

Biogenic aerosols consist of primary particles released by the biosphere, as well as secondary aerosols formed from gases released into the air by trees, shrubs, fungi, animals, and humans after chemical transformation. These aerosols get swept into the atmosphere and have important impacts on Earth's climate because they can reflect light into space, cooling the atmosphere, or they can combine with other particles to create clouds that have both warming and cooling effects.

Scientists will use the data collected during BAECC and combine it with previous observations over the past 19 years by the University of Helsinki, University of Eastern Finland, and Finnish Meteorological Institute (FMI) to better understand the links between biogenic aerosols, cloud formation, and Earth's climate. In particular, the researchers also will use the data to better understand snowfall microphysics and connect laboratory observations of the chemical and physical properties during their growth stages of organic aerosol.

Results: The BAECC deployment captured a lot of attention within the European atmospheric research community. This was utilized to attract transnational access to SMEAR-II and funding from the European Commission to host additional instrumentation on aerosols and trace gases during the BAECC campaign. A total of 188 research access days were funded by Aerosols, Clouds, and Trace gases Research InfraStructure Network (ACTRIS), which helps integrate European ground-based stations equipped with advanced atmospheric probing instrumentation for aerosols, clouds, and short-lived gas-phase species. Within ACTRIS, visiting scientists from Italy, Germany, Austria, and the United Kingdom were able to determine biosphere-atmosphere exchange processes in detail by performing gap-filling observations, such as detailed aerosol concentration measurements, advanced eddy covariance flux measurements with high-resolution mass spectrometers.

During the BAECC deployment, the University of Helsinki performed aircraft measurements to determine aerosol vertical profiles during three seasons with 140 flight hours on 30 different days. FMI performed two research flights with their aircraft, which included aerosol chemistry and cloud condensation nuclei measurements inside the clouds. FMI included a range height indicator (RHI) scan over Hyytiälä with a regular interval with their C-band weather radar in Ikaalinen. Furthermore, FMI participated by operating their Polly-XT lidar in Hyytiälä, whereas Vaisala and Aerodyne operated their ground-based remote-sensing instruments—along with the AMF2—providing additional information on aerosols, clouds, and turbulence around the BAECC site.



MAGIC route with June-July-August average low-level cloud cover, GPCI* transect, and CGILS** points.

A vast data set was collected during the BAECC campaign and the analysis is ongoing. One of the characteristic features of the in situ aerosol number size distributions is shown in the differential mobility particle sizer (DMPS) plot on the previous page, depicting formation of aerosol particles from biogenic gas-phase precursors. Such events were observed frequently during the BAECC campaign. The co-location of the AMF2 with the SMEAR-II provided benchmarking of the in situ aerosol measurements. Overall, the measurements were in good agreement taking into account that initially the fresh aerosol particles were below the detection limit of the AMF2 instrumentation. The combination of the in situ data with lidar-derived vertical profiles enables assessment of aerosol effects on cloud properties.

During the winter period, snowfall measurements were of particular interest. A follow-on campaign, BAECC-Snowfall Experiment (SNEX) Intensive Operational Period, was conducted. BAECC-SNEX was a collaborative effort between the DOE, University of Helsinki, FMI, National Aeronautics and Space Administration (NASA), and Colorado State University. It took place from February 1 to April 30, 2014, and was dedicated to documenting snowfall microphysics through a combination of multi-frequency (C, X, Ka, W-band) radar, microwave radiometer, and lidar measurements supplemented by a comprehensive suite of surface-based precipitation observations.

Throughout BAECC-SNEX, more than 20 snowfall events were recorded. Over 80 percent of the time, during those events, microwave radiometer observations detected presence of super-cooled liquid water. Due to an extensive suite of instruments and their excellent performance during the BAECC-SNEX, detailed snow microphysical studies are possible and will be used to augment radar based analysis.

First MAGIC Workshop Discusses Future of Marine Clouds

Following the wrap up of the Marine ARM GPCI Investigation of Clouds (MAGIC) field campaign, a workshop was held to provide an overview of existing and planned data analysis from the campaign. In May 2014, the First MAGIC Science Workshop, held at Brookhaven National Laboratory, was attended by 40 scientific experts. Their objectives were to discuss the status of data analysis, present preliminary results from the campaign, make future plans, decide what areas require further attention in order to move forward with model intercomparisons and other analyses, and establish networking and collaborative possibilities.

The workshop explored the following topics: MAGIC observations and data, during which presentations provided introduction, context, availability, and issues/concerns for MAGIC data sets; MAGIC science, during which presentations were made on science questions that have been, can be, or will be addressed with MAGIC data; and future directions of MAGIC.

*GPCI: Global Energy and Water Cycle Experiment (GEWEX) Cloud System Studies (GCSS) Pacific Cross-section Intercomparison

** CGILS: CFMIP-GCSS Intercomparison of Large Eddy Models and Single-Column Models, a joint project of the GCSS and the World Climate Research Programme Working Group on Coupled Modelling Cloud Feedback Model Intercomparison Project (CFMIP)

Green Ocean Amazon (GOAMAZON)

Partially obscured by aerosols in the atmosphere due to a forest fire northeast of Manaus, the sun sets over the ARM Facility's Mobile Aerosol Observing System located southwest of Manaus, Brazil. At the T-3 site in Manacapuru, a sunphotometer measures the optical density of the aerosols in the column.

To understand the intricacies of the natural state of the Amazon rain forest and how these processes are impacted by a nearby city, the Green Ocean Amazon, or GOAMAZON, field campaign is a two-year scientific collaboration among U.S. and Brazilian research organizations in which the ARM Facility is participating. Researchers are conducting a variety of experiments with dozens of measurement tools, using both ground and aerial instrumentation, including the ARM Aerial Facility (AAF) Gulfstream-1 (G-1) aircraft.

The Amazon rain forest is the largest broadleaf forest in the world, covering seven million square kilometers of the Amazon Basin in South America. Due to the sheer size of the Amazon rain forest, the area has a strong impact on the climate in the Southern Hemisphere.

A critical component of GOAMAZON, the first ARM Mobile Facility (AMF1) was deployed near Manacapuru, south of Manaus, Brazil, from January 2014 to December 2015 to obtain aerosol and precipitation measurements. The city of Manaus, with a population of 3 million, uses high-sulfur oil as their primary source of electricity. The AMF1 site is situated to measure the atmospheric extremes of a pristine atmosphere and the nearby city's pollution plume, as it regularly intersects with the site. Along with other instrument systems located at the Manacapuru site, this deployment is enabling scientists to study how aerosol and cloud life cycles are influenced by pollutant outflow from a tropical megacity.

Forest burning near Manaus, Brazil, adds aerosols to the atmosphere that can delay or decrease precipitation because available moisture is spread over a greater number of seeds that must collide and coalesce to form rain drops.

The Manacapuru site is also hosting instrument systems from other GOAMAZON participants to obtain measurements of the strong hydrologic cycle of the Amazon Basin. The hydrologic cycle describes the continuous movement of water, on, above, and below the surface of the Earth. The mass of water on Earth remains fairly constant over a long time frame, but the partitioning of the water into the major reservoirs of ice, fresh water, saline, and atmospheric water fluctuate depending on climatic variables.

This cycle is one the primary heat engines of the Southern Hemisphere, yet it is poorly understood or simulated in climate models. Meanwhile, the growth of cities, industrial logging, and other human influences may be contributing to drying and eventual conversion of Amazonian rain forests into savannas.

The GOAMAZON experiments are designed to study how aerosols and surface fluxes influence cloud cycles under clean conditions, as well as how aerosol and cloud life cycles, including cloud-aerosol-precipitation interactions, are influenced by pollutant outflow from a tropical megacity. These observations will provide a data set vital to constrain tropical rain forest model parameterizations for organic aerosols, cloud and convection schemes, and terrestrial vegetation components and how these are perturbed by pollution.

Results: Ozone is an important atmospheric oxidant. Its concentration affects atmospheric chemistry, plant and ecosystem functioning, and human health. Compared to background concentrations of ozone (5 to 20 parts per billion) under clean conditions, concentrations of 50 parts per billion were observed during the wet season (the first intensive operational period) because of the anthropogenic-biogenic interactions in the Manaus plume. The emissions of oxides of nitrogen from the urban environment couple with the forested environment of high organic emissions and strong sunlight to produce the ozone pollution. Concentrations as high as 100 parts per billion were observed in the dry season (the second intensive operational period), including the influence of regional biomass burning.

For GOAMAZON, the ARM Aerial Facility Gulfstream-1 aircraft participated in two intensive operational periods—time frames when extra measurements are collected. The first period took place in February and March 2014 during the "rainy season," when daily rainstorms dump more than 3 inches of moisture on the lush canopy of the forest. The second period in September and October provided an opportunity to measure atmospheric conditions during the "dry season."

The hydroxyl radical is often referred to colloquially as the "vacuum cleaner" of atmospheric chemistry because of its high and wide ranging activity with many atmospheric species. As such, it is a master variable of climate and ecosystem functioning. The direct measurement of this central species of atmospheric chemistry had been made previously only once over the Amazon forest, in Suriname. The measurements showed concentrations up to ten times higher than anticipated, though there had been questions about the instrumental technique. Even so, this elevated concentration for the past few years has been a mystery that has motivated many laboratory and modeling studies. For GOAMAZON, a different instrumental technique was used, and two sets of measurements (one terrestrial and one airborne) reach the common conclusion that the hydroxyl radical concentrations in the central Amazon in both the wet and dry seasons are more in-line with traditional expectations than with the measurements reported over Suriname. If substantiated in the final data analysis, these new measurements again shift the paradigm for the "vacuum cleaner" of atmospheric chemistry over Amazonia.

Atmospheric particles are key actors in models of climate, air quality, and human health. For instance, clouds are produced by condensation of gaseous water onto preexisting background particles. In the first and second intensive operational periods, major shifts both in extrinsic properties, like number and mass concentrations, and intrinsic properties like optical properties, hygroscopicity, and chemical composition were observed as a consequence of the Manaus plume. As an example, sampled particles were more oxidized yet less hygroscopic than anticipated prior to the first and second intensive operational period measurements. Also, in a surprising and important result, the particles appeared to shift in part between liquid and solid phases with the extent of pollution, potentially affecting both cloud formation and atmospheric chemistry.

These preliminary results will be supplemented by another year's worth of data as the GOAMAZON campaign is being conducted through 2015.

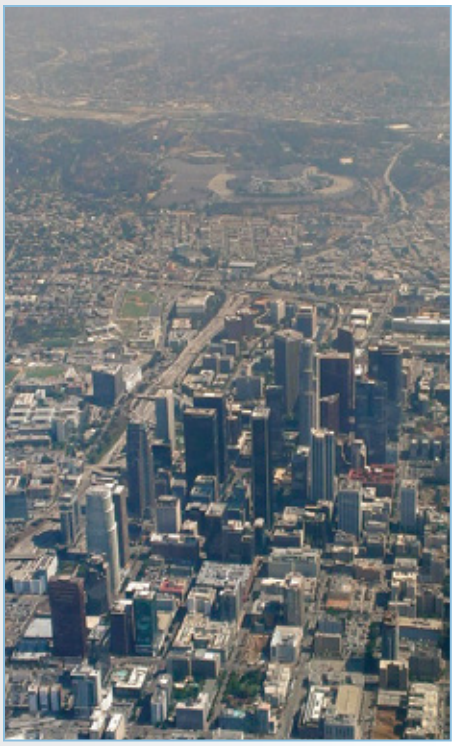
Research Highlights

2014 Publications Summary	
Category	**Total**
Abstracts or Presentations	209
Journal Articles	132
Technical Reports	29
Conference Papers	3
Total	**373**

Atmospheric Chemistry Culprits in Climate

Organic matter like dust and soot is a major contributor to the amount of aerosols in the atmosphere, affecting levels of air pollution and the rate of climate change. While human activities directly emit a fraction of that organic matter into the air, a substantial contribution—often the majority—is generated within the atmosphere through chemistry. Understanding how chemicals change in the atmosphere can provide important insights into how to reduce air pollution and predict climate change.

The organic compound glyoxal, for example, is generated by both human and natural sources and can change chemically in the atmosphere to form secondary organic aerosols. Scientists had studied how glyoxal changed by using laboratory experiments and global-scale modeling, but this research often lacked real-world data for comparison. Now research involving ARM's field campaigns over California (Carbonaceous Aerosols and Radiative Effects Study, or CARES, and the California Research at the Nexus of Air Quality and Climate Change, or CalNex) in 2010 is providing surprising insights into how glyoxal forms other compounds and whether the chemical changes can be reversed.



The Los Angeles Air Basin may be a hotspot for the organic compound glyoxal, which can form secondary organic aerosols in the atmosphere and contribute to air pollution. Image courtesy of Wikimedia Commons, http://commons.wikimedia.org.

In one study, scientists from academia, government agencies, and industry extended a regional-scale model to represent the glyoxal life cycle in more detail. They then compared model results with measurements from the CARES/CalNex campaigns to comprehensively evaluate the model's performance and evaluated different chemical mechanisms that allow glyoxal to form secondary organic aerosols. They also ran the simulation over the continental United States to identify regions most susceptible to these chemical mechanisms.

Results of the California simulation showed that the Los Angeles Air Basin is a hotspot for glyoxal, because of the high availability of other chemicals, aerosols, and humidity. Results from the simulation over the United States revealed that the eastern and especially the northeastern United States are more susceptible to the formation of secondary organic aerosols from glyoxal because of the volume of materials in the air. This work is consistent with another study in which an international team of researchers used a simulation chamber to look at mechanisms for glyoxal to form secondary organic aerosols. That study found that certain kinds of chemicals like sulfates can "salt in" or cause glyoxal concentrations to increase.

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Kampf CJ, EM Waxman, JG Slowik, J Dommen, L Pfaffenberger, AP Praplan, AS Prevot, U Baltensperger, T Hoffmann, and R Volkamer. 2013. "Effective Henry's law partitioning and the salting constant of glyoxal in aerosols containing sulfate." *Environmental Science & Technology*, 47, doi:10.1021/es400083d.

Arctic Multilayered Mixed-Phase Cloud Processes Revealed

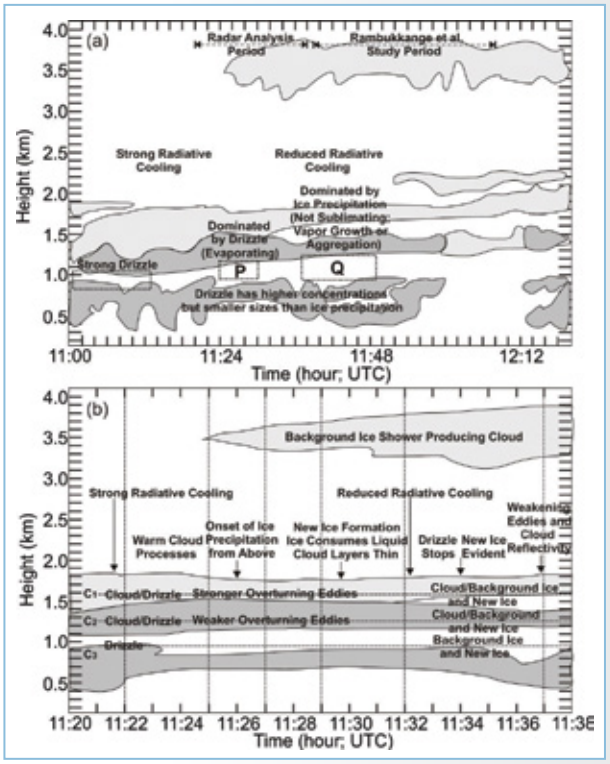
Mixed-phase clouds, which contain both liquid droplets and ice particles, are the dominant cloud type over polar regions and have a large global coverage. But the processes that cause these clouds to form, grow, and dissipate are not well understood and are often poorly modeled. Recent studies used data and instruments from the ARM site at the North Slope of Alaska to pull back the curtain and take a deeper look inside mixed-phase clouds.

In one study, researchers used measurements from ground-based cloud radar and aircraft aloft to investigate the processes within Arctic mixed-phase clouds. These cloud systems frequently consist of multiple liquid-cloud layers at different altitudes. Physical processes in these clouds are complex, with different layers interacting in many ways. The results of the study suggest that strong cloud-top cooling was necessary to produce well-mixed cloud layers. Clouds shielded by overlaying clouds more frequently exhibited absolutely stable layers. The aircraft measurements revealed that most liquid layers contained drizzle, which was interrupted only during times of heavy sleet or ice rain.

In another study, scientists used an innovative approach of combining cloud radar reflectivity measurements with an ice-growth model they developed to determine how ice particles are produced in stratiform mixed-phase clouds. Although aircraft measurements of the concentration of ice in clouds are regarded as a reliable source, these measurements can be fraught with potential errors caused by the ice crystal shattering of sampling probes and limited coverage over time and area. Thus, the lack of a large enough database of measurements makes it difficult for scientists to understand ice generation processes under various conditions.

Four years of data from ARM's available ground-based and space-borne radar measurements fueled the researchers' ice-growth model, which can now be used to improve simulations in other types of atmospheric models.

Studies such as these help scientists better understand mixed-phase clouds and the role they play in climate change.



Studies show that globally dominant, mixed-phase clouds exist in complex layers.

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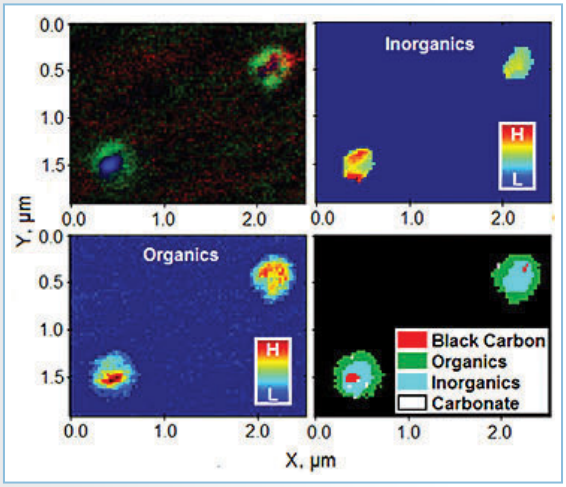
Zhang D, Z Wang, A Heymsfield, J Fan, and T Luo. 2014. "Ice concentration retrieval in stratiform mixed-phase clouds using cloud radar reflectivity measurements and 1-D ice-growth model simulations." *Journal of the Atmospheric Sciences* October 2014: 3613-3635, doi: 10.1175/JAS-D-13-0354.1

Forecast Calls for Better Models

Predicting how atmospheric aerosols influence cloud formation and climate is a challenge that limits the accuracy of atmospheric models. This problem is especially true in the Arctic, where mixed-phase (both ice- and liquid-based) clouds are frequently observed, but the processes that determine their composition are poorly understood. To obtain a closer look at what makes up Arctic clouds, scientists characterized solid residuals of cloud droplets and ice crystals collected at the North Slope of Alaska site as part of the ARM Indirect and Semi-Direct Aerosol Campaign (ISDAC) field study.

Scientists used scanning and transmission electron microscopes, x-ray spectro-microscopy, and other analytical approaches to examine the chemical composition and mixing state of mixed-phase Arctic clouds. Researchers also compared characteristics for the solid residuals to the same characteristics for individual interstitial particles that exist in the spaces between the cloud droplets and ice crystals. The effort allowed them to discover a wide range of components, including organic carbon compounds, inorganic material, carbonates, and black carbon.



Seeing into the sky: Scanning transmission x-ray microscopy images of individual residues from Alaskan clouds.

Results showed that cloud droplet residuals differ from the interstitial particles in existing clouds both in size and in composition, suggesting that each of these properties may impact the formation of mixed-phase clouds. The percentage of residual particles that contained carbonates (47 percent) was almost four times higher than those in the interstitial particles. Residual particles were also enhanced in sea salt and black carbon and reduced in organic compounds relative to the existing interstitial particles. These measurements suggest that chemical processing of atmospheric particles may improve their ability to form clouds. The results also indicate that the number and composition of particles capable of forming clouds over Alaska can be influenced by episodic events such as biomass burning (for example, forest fires) that bring aerosols from the local vicinity and as far away as Siberia.

Future work involving Arctic cloud formation will further improve models and advance understanding of the impact of different types of atmospheric aerosols on climate.

Reference

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Real-World Measurements Test Model Predictions of Land-Atmosphere Interactions

Only 30 percent of the Earth may be covered by land, but the land can sometimes strongly influence the atmosphere. Land-atmosphere interactions can affect moisture levels, the formation of clouds, and regional air movement and precipitation, especially in the summer. But just how well do global climate models simulate the land's influence?

A decade's worth of data from the ARM Southern Great Plains site is shedding light on how global climate models simulate interactions between the land and the atmosphere.

To investigate that question, scientists exploited the extensive archives of data recorded at the ARM Southern Great Plains site near Lamont, Oklahoma. They analyzed measurements of soil moisture and atmospheric characteristics from the summers of 1997 to 2008 to study the local day-to-day influence of the land on the atmosphere.

For instance, the researchers looked at the impact of soil moisture on precipitation, surface temperature and humidity, and the heights and areas of low-level clouds. Although the scientists found that the daily changes in soil moisture clearly influenced most of these atmospheric characteristics, they failed to find a significant connection between soil moisture and local precipitation. This connection may be weak because much of the local summertime rainfall is produced by thunderstorms that originate near the Rocky Mountains, and later pass over the Oklahoma site.

To the extent these local findings can be generalized to the entire Southern Great Plains, they raise questions about model predictions of summer climate for this region. For example, the typical global climate model predicts stronger connections between soil moisture and precipitation over the Southern Great Plains site than what is observed at the ARM Facility.

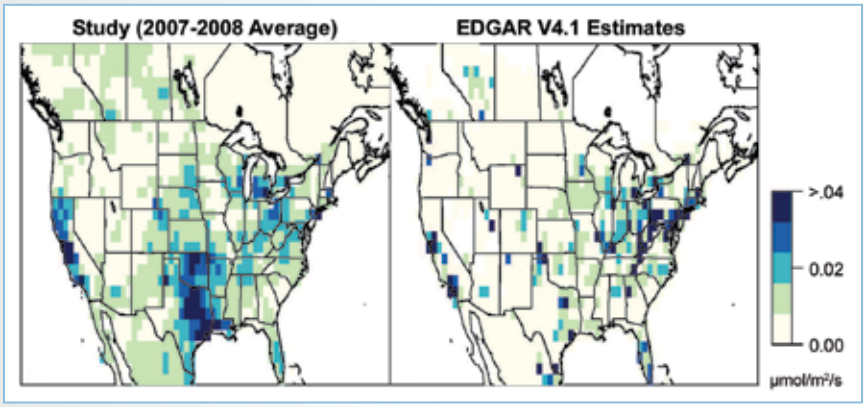
This conclusion may be a result of faulty model representations of land-atmosphere interactions in this region, but it also may reflect global climate models' inability to realistically capture the effects of fine-scale features like thunderstorms. The work of these ARM scientists thus provides a basis to further evaluate and improve climate model predictions over the Southern Great Plains, a major source of the nation's and the world's agriculture.

Reference

Phillips TJ and SA Klein. 2014. "Land-atmosphere coupling manifested in warm-season observations on the U.S. Southern Great Plains." *Journal of Geophysical Research – Atmospheres* 119(2): doi:10.1002/2013JD020492.

Reality Check: Estimates for Human-Caused Methane Emissions in the United States May Be Off by 50 percent

Around the nation, states are gearing up to tightly regulate the emission of methane, the second most important human-created greenhouse gas, following carbon dioxide. Regulators have traditionally relied on estimates from the U.S. Environmental Protection Agency (EPA) and the international Emissions Database for Global Atmospheric Research (EDGAR) to target reductions. Now, a study by an international team of researchers has found that EPA and EDGAR estimates may be lower than reality by as much as 50 percent, and estimates for specific types of sources such as natural gas production could be off by even more.



Estimates of methane emissions from a recent study (left panel) compared against the commonly used Emissions Database for Global Atmospheric Research (EDGAR) database (right panel) show that methane sources may output more of the gas and affect a wider territory than previously thought.

The study, described in the *Proceedings of the National Academy of Sciences*, attempts to quantify the sources and amount of methane generated by human activity in the United States. Researchers used methane measurements from 2007 and 2008 taken from tall towers (nearly 5,000 measurements) and aircraft (more than 7,500 measurements) through studies funded by ARM and the National Oceanic and Atmospheric Administration (NOAA) collaborative global greenhouse gas reference network. The study team input this wealth of data into a model that simulated how methane is moved around the atmosphere in what is considered a top-down approach. They then compared their results with data on human population density, economic activity, and oil and gas production in a bottom-up approach.

The bottom-up and top-down approaches yielded very different results, showing that current output from the EPA and EDGAR databases underestimates national U.S. methane emissions by a factor of approximately 1.5 and 1.7, respectively.

"Based on our work, methane emissions from fossil fuel extraction and processing in the south-central United States could be approximately five times larger than reported in EDGAR, the most comprehensive global methane inventory," said Sébastien Biraud of Lawrence Berkeley National Laboratory, one of the key researchers on the team. "Effective national and state greenhouse gas reduction strategies may be difficult to develop without more accurate estimates of methane emissions."

Reference

Miller SM, SC Wofsy, AM Michalak, EA Kort, AE Andrews, SC Biraud, EJ Dlugokencky, J Elszkeiwicz, ML Fischer, G Janssens-Maenhout, BR Miller, JB Miller, SA Montzka, T Nehrkorn, and C Sweeney. 2013. "Anthropogenic emissions of methane in the United States." *Proceedings of the National Academy of Sciences of the United States of America* 110(50): 20018-20022, doi:10.1073/pnas.1314392110.

When You Cannot Count Small: Improving Estimates of Cloud Condensation Nuclei Concentration

The formation of clouds depends on cloud condensation nuclei, those tiny liquid or solid particles 10,000 times smaller than a raindrop around which water droplets form. Understanding the concentration, spacing, and timing of these nuclei could help seed clouds over drought-stricken areas and improve predictions of cloud and rain formation in weather and climate models. Unfortunately, concentrations have been measured only at a few locations around the world, and more wide-scale measurements have proven infeasible because of cost and sampling complexity. Instead, scientists have tried to estimate concentrations using more easily measurable and readily available surrogates. But which surrogate most closely matches reality?

ARM Mobile Facility instrumentation was installed in June 2011 at the Aryabhatta Research Institute of Observational Sciences (ARIES) Observatory in Nainital, India, for the Ganges Valley Aerosol Experiment (GVAX). Shown in this photo are the stack for the aerosol observing system (AOS, top) and the optics enclosure for the atmospheric emitted radiance interferometer, or AERI.

An international team of researchers began to address this issue by studying measurements taken at ARM sites around the world. They reviewed data at a variety of locations and under different conditions such as the Southern Great Plains (rural continental aerosols), the Azores (sea-salt aerosols, local pollution from airport traffic, and long-range transport of pollutants from Europe), the Black Forest in Germany (agricultural and forested regions with an abundance of aerosols derived from nature), the Ganges Valley in India (human-derived pollution), and Niamey in Niger (dust aerosols). Their results showed that cloud condensation nuclei can be estimated from the more readily available measurements of aerosol optical properties. The team also discovered that the impact of the meteorological environment, such as its relative humidity, must be accounted for to develop accurate estimates.

"Only the large database [with atmospheric measurements] from the different ARM Climate Research Facility sites allowed us to identify the potential and limitations of using certain surrogates to estimate cloud condensation nuclei concentrations," said Zhanging Li (University of Maryland), the leader of the research team.

Information on aerosol composition and size distribution, together with some aerosol parameters and meteorological parameters for each aerosol type and region, promise to help scientists develop more detailed estimates of cloud condensation nuclei concentrations.

Reference

Liu J and Z Li. 2014. "Estimation of cloud condensation nuclei concentration from aerosol optical quantities: influential factors and uncertainties." *Atmospheric Chemistry and Physics* 14(1), doi:10.5194/acp-14-1-2014.

SGP Celebrates Twenty Years of Baseline Data Operations!

ARM program scientists became climate science pioneers when they broke ground on the first ARM Climate Research Facility field site in 1992 in north-central Oklahoma. Chosen for its wide variety of cloud types and surface flux properties, as well as large seasonal variations in temperature and specific humidity, the Southern Great Plains site began baseline operations in 1994 and celebrated 20 years of continuous data measurements in 2014.

Designed for collaborative use, the site and its data set are often utilized by scientists from universities, DOE national laboratories, and other federal agencies. Approximately 240 field campaigns have been conducted at the Southern Great Plains site since its inception. During these campaigns, which typically last for several weeks, users can bring their own specialized instruments, or take advantage of the more than 30 specialized in situ and remote-sensing instrument clusters located at facilities throughout the site.

Infrastructure Achievements

Maintaining multiple instrumented sites around the world is no easy feat. The ARM Facility uses a team of science, engineering, and technical personnel to ensure effective operations, keep up with technology developments, deliver high-quality data, and provide outreach to a global audience.

Site Operations

ARM Facility Embarks on Expansion in the United States

Through 20 years of measurements at its observations sites around the world, the ARM Facility has helped researchers to reduce key uncertainties related to atmospheric processes that affect Earth's energy balance. Building on this progress, the ARM Facility embarked on a reconfiguration strategy in FY2014 for even better observations of atmospheric processes to constrain high-resolution process models. Key elements of the new strategy include the creation of two "megasites" in the United States at the Southern Great Plains and the North Slope of Alaska. Measurements at the Southern Great Plains site in Oklahoma will be augmented to include additional scanning and profiling remote sensors and more detailed measurements of the land-atmosphere interface. Aerial operations at the North Slope of Alaska will link measurements from Barrow and Oliktok, while unmanned aerial systems will provide additional spatial information around Oliktok.

To support the expansion of the continental U.S. site in Oklahoma, operations at ARM sites on Nauru Island, and Manus, Papua New Guinea, in the Tropical Western Pacific were ended in 2013 and 2014 respectively. Darwin operations will end in December 2014. Data obtained from these sites will remain available to the scientific community through the ARM Data Archive to support continuing research in tropical climate. This reconfiguration does not affect operations of the new Eastern North Atlantic site in the Azores or the mobile facilities.

A series of workshops—two of which were completed in FY2014—were organized to optimize this new measurement strategy. The workshops focused on the goal of improving the understanding of atmospheric processes and the representation of those processes in climate models, including ideas for combining ARM's observations with routine high-resolution modeling.

Heartfelt Goodbye to Manus Island

A reconfiguration plan was set in motion for the ARM Facility in 2014 that will result in even better observations of atmospheric processes at the Southern Great Plains site.

After 18 years, the Manus Island observation site in the Tropical Western Pacific ended operations in July. Observations from Manus will play a significant role for many years to come, especially as scientists improve their understanding of the tropical climate. The Manus facility was deeply embedded in the middle of the warm pool region, a location that always provides abundant convection, thus providing data that has led to key scientific findings related to cloud radiative impacts. Long-term detailed observations gathered by the ARM Tropical Western Pacific sites, like Manus and Nauru, have helped scientists to determine that each different cloud type has similar characteristics and effects on the surface radiation no matter where they occur in the tropics. Combined with satellite coverage, this knowledge allows scientists to broaden observational abilities across the Pacific basin.

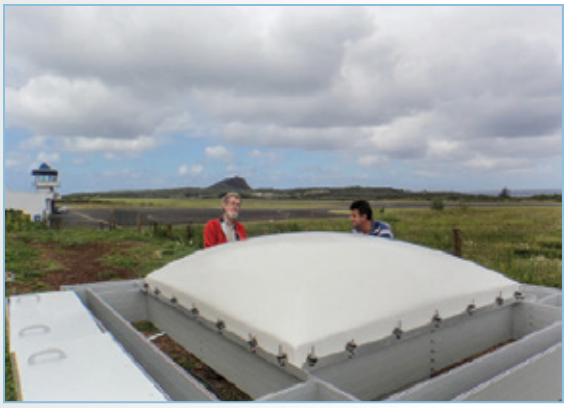
Site operations and data collection officially ended on July 7, 2014. Kim Nitschke, ARM Facility manager from Los Alamos National Laboratory, led the closeout activities in his role as oversight manager for ARM Facilities in the Tropical Western Pacific, including Manus. In recognition of all the partnerships, teamwork, and data collected in Papua New Guinea, Nitschke presented plaques and profound thanks to Sam Maiha, Papua New Guinea's National Weather Service Director, for the local team.

Allison Aiken Receives 'Most Influential Scientific Minds' Award

Los Alamos National Laboratory scientist Allison Aiken was named to Thomson Reuters 2014 list of "The World's Most Influential Scientific Minds." The award recognized Aiken as an author among the top one percent most cited for her research in aerosol measurements within the field of geosciences between 2002 and 2012. Only 3,000 authors were recognized with this status in 2014. This award proves Aiken to be distinguished at an early stage in her career.

In addition to being highly cited over the last decade, Aiken has produced work within the last two years that has made a notable impact on her peers. Her research and experiments are found to be groundbreaking and influential.

Joining the ARM Climate Research Facility in 2013, Aiken is the operations lead for the ARM Mobile Aerosol Observing System. Currently, she is operating 20 instruments—15 aerosol and 5 gas-phase—deployed for the GOAMAZON field campaign in Manacapuru, Brazil. Aiken is also a co-mentor for two ARM photoacoustic soot spectrometers in deployment.



ARM instrument mentor Richard Coulter (left) collaborates with the site operator Carlos Sousa (right) to assemble the radar wind profiler.

Eastern North Atlantic Site Expands Data Capabilities

Situated off the coast of Portugal in the Azores, Graciosa Island hosts one of ARM's newest observation facilities, the Eastern North Atlantic. In September 2014, the one-year-old climate research site completed baseline operations collecting measurements on the interaction of clouds, aerosols, and precipitation in this region. This provides a rare data set from the subtropical marine boundary layer where climate models vary the most about how clouds change and Eastern North Atlantic data will provide long-term statistically robust and physically accurate observational data sets.

Through Los Alamos National Laboratory, ARM operations staff began working on international contracts, site design, and instrument selection in late 2012 and shipped the first 12 instrument systems to Graciosa Island for installation in late September 2013. In 2014, the international team added numerous additional instruments to provide important measurements to add to the data sets needed to create accurate models. Installation activities took place in February and over the summer months to install a remote balloon launcher, an eddy correlation flux with surface energy balance system, the Ka-ARM zenith radar, W-band Scanning ARM Cloud Radar, radar wind profiler, Doppler lidar, and 2-dimensional video disdrometer. The site has continued to grow rapidly as it prepares to host guest instruments in the coming years.

The second phase of the third ARM Mobile Facility installation will be completed in the fall of 2014 with the addition of scanning and vertical-pointing radars, as well as a Raman lidar.

North Slope Megasite Preparations Take Form

With four years remaining in the planned extended deployment of the third ARM Mobile Facility (AMF3) at Oliktok Point, Alaska, the first year of data collections was completed on September 30, 2014. Led by Sandia National Laboratories, the AMF3 is a collection of instruments gathering data to better understand Arctic weather processes that may play an important role in Arctic climate change. The second phase of the AMF3 installation at Oliktok took place in late summer of 2014 with the addition of scanning and vertical-pointing radars, as well as a Raman lidar. With this group of radar instruments—the Ka-ARM zenith radar, Ka-scanning ARM cloud radar and W-band scanning ARM cloud radar, and radar wind profiler—measurements will provide the high-resolution cloud data needed to understand cloud processes in this climatically important region.

In September 2014, DOE held a workshop focused on scientific priorities for observational and high-resolution modeling activities in the North Slope region, including recommendations for the use of unmanned aerial systems at Oliktok Point. The workshop was the second in a series focusing on key scientific needs, gaps, and priorities in linking ARM observational data to improved process model understanding and climate model prediction through the strategic deployment and operation of routine high-resolution modeling at the future ARM megasites at the North Slope of Alaska and Southern Great Plains. The AMF3 is expected to be an essential part of the North Slope megasite.

Data Advancements

ARM Data Archive Registered with Elsevier

In spring of 2014, the ARM Data Archive—containing two decades of continuous measurements of clouds, aerosol, precipitation, and radiative energy from ARM sites around the world—was included on the data repository page of the highly regarded scientific publisher, Elsevier. As the ARM Facility has enhanced its in situ and remote-sensing observation capabilities over the years, its data systems are handling massive amounts of data, up to 30 terabytes (comparable to 500 million typewritten pages) per month. Listed under the category of Earth, Environmental & Oceanographic Data, the ARM entry provides a link to citation instructions for researchers to include a data digital object identifier (DOI) in their manuscript for ARM data, which will take readers to the data at the ARM Data Archive.

Bi-directional linking on the Elsevier page will aid climate researchers in the discovery of ARM data and journal articles that use ARM data. It also provides essential context to data sets and can improve the breadth and reproducibility of published research. The registration with Elsevier resulted from a request by Giri Palanisamy, ARM Data Archive engineer at Oak Ridge National Laboratory, when he contacted Elsevier's Journal and Data Solutions team, based out of the Netherlands. In addition to assigning DOI numbers to ARM data, the 2014 ARM Data Standards Version 1.0 report details the required and recommended standards for new data to be published in the ARM Data Archive. These efforts all support the ability to sustain and enable consistent use and analysis of ARM's multiyear data sets.

At the request of Giri Palanisamy, Oak Ridge National Laboratory, the scientific publisher Elsevier now includes ARM data on its data repository web page.

Status of Value-Added Products for FY2014

Many of the scientific needs of the ARM Climate Research Facility are met through the analysis and processing of existing data into value-added products (VAPs). These products provide an important translation between the instrumental measurements and the geophysical quantities needed for scientific analysis, particularly model parameterization and development. ARM VAPs pass through the stages of initiation, development, evaluation, and release.

At the evaluation stage, a VAP is provided to the larger scientific community for evaluation and feedback. After the evaluation period is complete, ARM quality control and data standards are applied, and the VAP data are released to the ARM Data Archive. In FY2014, 10 new VAPs were initiated, 19 VAPs were released to production, and 8 VAPs were released to evaluation. Data were released to production because algorithms were updated, additional sites were added, or VAP processing code was moved to the ARM Data Integrator Library or a new operating system. See the Value-Added Product Descriptions section, located on page 34, for a list of VAPs that were initiated and released in 2014.

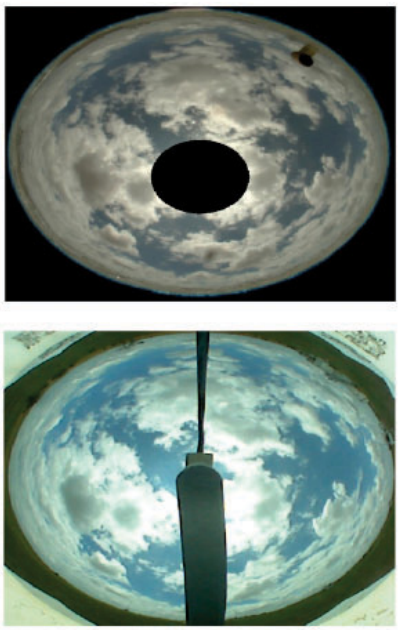
Standards for ARM Assure Consistency, Sustainability

Developed by the ARM Standards Committee, new standards—documented in the 2014 ARM Data Standards Version 1.0—will benefit users with consistency across datastreams, simple and consistent software that is able to read all standardized netCDF files, and will allow for data code reuse.

A separate committee will review any exceptions to these standards prior to acceptance and publication of the data, and all archived ARM data will be reprocessed to be compliant with the new standards.

This is the first report of its kind for ARM data and plans are to update the report as standards evolve. The ARM Standards Committee was appointed by the ARM Technical Director and is comprised of members from multiple organizations, including private corporations and national labs.

Studying the Sky—Day and Night



A comparison between the sky images from the Infrared Sky Imager (top) and Total Sky Imager (bottom) resulted in the Infrared Sky Imager joining the ARM instrument suite.

A new instrument, called Infrared Sky Imager (IRSI), was installed in May at the Southern Great Plains (SGP) Central Facility site in Oklahoma to fill a critical data gap for measurements of nighttime cloud fraction. Featuring both an infrared and a visible-light camera, IRSI captures images of the sky with a 180° field-of-view, day and night. These images provide access to previously missing nighttime cloud-fraction data.

Traditionally, meteorologists at weather observing sites would walk outside, look up, and determine how many eighths of the sky were covered by clouds. An instrument called a Total Sky Imager was developed in 1998 to replace the human observer and increase the number of cloud-fraction observations that could be taken per day and has operated at the Southern Great Plains since 2000. The Total Sky Imager took an image of the sky every 30 seconds, from dawn to dusk, to record how clouds evolve over time. Unfortunately, neither the Total Sky Imager nor any other instrument at the site could effectively measure cloud fraction at night.

The IRSI was originally deployed to the Southern Great Plains site for intercomparison studies in 2007 and 2009 along with a variety of other instruments that measure cloud fraction. The resulting comparison proved IRSI outstanding in both campaigns, for both the quality of data it produced and the technical improvements, and IRSI was selected to join the ARM instrumentation suite.

First-of-its-Kind Radar Toolkit Made for ARM—But Shared With All

Since its inception, ARM has been at the leading edge of instrument development, deploying new technologies and gaining novel insight through innovative retrieval techniques. The scanning radars are no exception. As the radars were deployed, and products developed, it became clear a new architecture was required. This architecture necessitated combining domain-specific knowledge with computational know-how to manage the many hundreds of terabytes of complex data the radars would produce.

To this end, the Python-ARM Radar Toolkit (PY-ART) was developed. PY-ART is the first fully interactive, community developed data-model-based toolkit in the field of radar meteorology. A data-model-based approach is simply a standardization of how software represent structured data as a collection of data elements and metadata. Using a common data model means modules in the toolkit accept a radar object and return a radar object, thus creating a software package that can be developed and extended incrementally. Users can tailor application chains to their needs unrestricted by decisions made for a one-size-fits-all approach. For example, one may like PY-ART's phase-retrieval algorithm but not the way it does attenuation correction. Because the system is modular, users can simply plug in and take out components as they see fit.

As PY-ART's growth is managed using the popular social coding platform, GitHub, the community at large is able to contribute new modules to the code base or start an entirely new development path. Thanks to hard work in unit testing and continuous integration, PY-ART works on many operating systems. Users can test ideas on laptops and desktops using a small number of files, knowing the same software resides on enterprise-scale machines at the ARM Data Center. PY-ART, which has grown from a small project to over 140,000 lines of code, is used across the globe by many agencies and has seven active developers contributing new modules. PY-ART can be installed on Linux, Windows, and OSX. To learn more about PY-ART, see: ***https://github.com/ARM-DOE/pyart/***.

ARM Data Integrator Software Improves Development Time and Money

The ARM Data Integrator (ADI) is an open-source software framework that simplifies the development of scientific algorithms. ADI automates data retrieval, merging of diverse data sets, and the creation of ARM data products that conform to ARM standards. Algorithm development is supported in C, Python, and Interactive Data Language (IDL). Process details are defined and maintained through a web interface and stored in a database. Users can edit these templates to add their own logic and scientific algorithms or call non-ADI functions written in other languages to manipulate the input data and create the new or derived values. Software developed using ADI is more robust and less costly to develop and maintain.

Algorithm development costs have been reduced by 30 to 70 percent, depending on the complexity of the data retrievals and scientific algorithms to be implemented. The data dependency information available in the database has improved the efficiency and planning of ARM reprocessing efforts. Currently, about three quarters of the nearly 150 production ingest and value-added products processes are using the ADI libraries. The ADI libraries are open source and available at ***https://github.com/ARM-DOE/ADI***.

Kevin Widener, Pacific Northwest National Laboratory

Under the Radar—This Time in Retirement

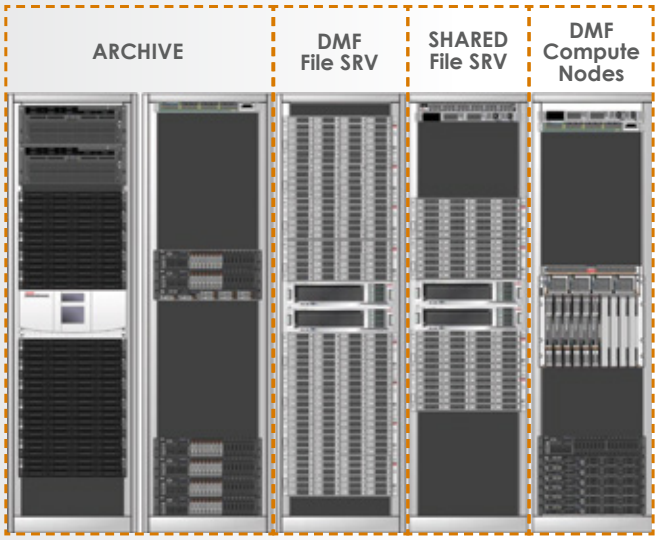
After 30 years with Pacific Northwest National Laboratory, including the last two decades as leader of ARM's radar engineering group, Kevin Widener retired this summer. Widener's hard work and dedication to developing ARM's one-of-a-kind cloud radar network were instrumental to the success and growth of the ARM Facility, which now boasts nearly three dozen radars.

Throughout his career, Widener served in many ARM roles, including key positions like ARM Chief Engineer and North Slope of Alaska Engineering Task Lead. He installed radars at ARM sites all over the world, balancing engineering expertise with a keen understanding of the science goals of the program.

Widener also served 16 weeks on the Arctic icebreaker ship, Des Grosseilliers, for the Surface Heat Budget of the Arctic Ocean campaign, and was responsible for the operation of ARM radars both in the United States and at international sites ranging from Africa to China to Papua New Guinea. He also designed and built the first ARM Mobile Facility—the first of its kind in ARM.

Keeping Data Flowing

Next generation hardware was purchased at the end of FY2013 for the ARM Data Center—representing both the Data Management Facility (DMF) and ARM Data Archive—at Oak Ridge National Laboratory (ORNL). This consolidation of hardware in 2014 enables interchangeability of devices and capacity between processes of the DMF and ARM Data Archive as the ARM data rates continue to grow over the next several years. To improve data flow between the segments of the ARM data system, the DMF moved its hardware from Pacific Northwest National Laboratory to ORNL to prepare for this merger. In order to minimize system configuration changes and limit the interruption of ARM data flow, the DMF team developed a plan to consolidate and relocate services to simplify what was being moved and deployed a system at ORNL ahead of the hardware move to provide continued support to critical services during the transition.



The ARM data system residing at Oak Ridge National Laboratory installed new hardware in FY2014, resulting in the ability to interchange devices and capacity between processes.

As a result, the DMF began operating on an isolated segment of the network outside of the ORNL network domain in early 2014. It used its own network security hardware and software, which prevented the DMF and ARM Data Archive from defining its own set of network rules and efficiently sharing network storage devices. With the successful move completed, the next step was to create a unified ARM data network at ORNL. This network became the first research enclave, or private network, at ORNL and allows the ARM Data Archive and DMF systems to continuously share storage devices, system administration processes, and define ARM-specific rules for persistent network connections. During this expansion, security policies were consolidated and all network hardware were upgraded from 1 gigabytes to 10 gigabytes. Upgrading the network speed and removing external network devices—that were previously between the Archive and DMF—changed data transfer rates between these systems from several hours per terabyte to several terabytes per hour.

With this structure, the DMF and ARM Data Archive gained access to a shared online copy of some of the archived data. The scope and specific contents of the online repository is a joint collaboration of DMF and ARM Data Archive processes for the control, maintenance, and review of the data. The DMF uses this data copy for software development and value-added processing, while the Data Quality Office uses it to evaluate historical trends. The ARM Data Archive uses this same copy for distribution of data to the users.

Communication and Community Outreach

ARM Tutorials from ASR Science Team Meeting Available Online

Realizing the increasing importance of new methods of science communication, the ARM Facility began efforts last year to expand its multimedia outreach. To begin this process, during the Atmospheric System Research (ASR) Science Team Meeting, also referred to as a principal investigator meeting, ARM created four video tutorials based on lunchtime workshops. These tutorials covered an introduction to ARM data and the ARM Python Radar Toolkit, and how to submit highlights to ARM and access NetCDF files.

Workshop attendees received help during a pause in instruction.

ARM provides its data to users to enable scientific discovery and innovation in the climate and atmospheric science fields. These tutorials guide both experienced and novice Python users through the steps and possible issues when using the ARM Python notebooks. With these new resources at the user community's disposal, the accessibility of ARM data became easier. Workshop tutorials can also supplement "classroom" training sessions saving scientists and researchers valuable travel time and funds. Training videos are available on the ARM YouTube channel (***http://www.youtube.com/armgov)***.

ARM's Educational Outreach Recognized

ARM's lesson plan, "Thermal Expansion of Water" was selected for inclusion in the Climate Literacy and Energy Awareness Network's (CLEAN) collection of educational resources. The CLEAN efforts are funded through research grants from the National Science Foundation (NSF), National Oceanic and Atmospheric Administration (NOAA), and DOE. Receipt of the prestigious CLEAN seal means that the selected resource passed an extensive peer-review by educators and scientists to ensure adherence to stringent Climate Literacy and Energy Awareness Principles, as approved by numerous organizations, including the U.S. Climate Change Science Program.

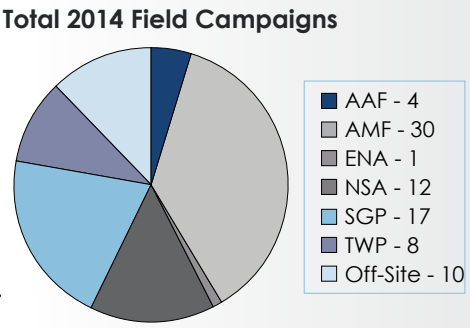
This was ARM's second seal of approval from the network; the first was awarded for "Effects of Solar Radiation on Land and Sea" in 2012. Since its launch in November 2010 as a National Science Digital Library Pathways project, the CLEAN team has reviewed thousands of climate and energy resources. The selected ARM lesson plans are among the distinguished 600+ chosen that match the collection's scope and requirements for accuracy and effectiveness.

One of ARM's educational outreach lesson plans received the "CLEAN" seal of approval. Climate Literacy and Energy Awareness Network (CLEAN) resources must pass an extensive peer-review process to verify the accuracy and relevance of the science.

Field Campaign
SUMMARY

Field Campaign Summary

The ARM Facility routinely hosts field campaigns at all its sites, plus special data collection efforts and off-site campaigns. Many of these activities span several years. The pie chart here shows the total number of field campaigns and special data set collections that occurred in FY2014, including these ongoing efforts. The subsequent table summarizes just those campaigns that began in FY2014. For more information, visit the field campaign web page at ***http://www.arm.gov/campaigns***.



Dates	Campaign Name	Status	Description
ARM Aerial Facility			
October 2013–September 2015	ARM Airborne Carbon Measurements IV (ARM-ACME IV)	In Progress	The goal of ARM-ACME is to quantify trends and variability in atmospheric concentrations of carbon dioxide and other greenhouse gases in North America and improve understanding of the influence of convective processes, advection, and boundary layer-free troposphere exchanges on atmospheric carbon dioxide concentrations.
February–October 2014	Observations and Modeling of the Green Ocean Amazon: Aerial Campaign	In Progress	For GOAMAZON, the ARM Aerial Facility Gulfstream-1 aircraft participated in two intensive operational periods. The first period took place in February and March 2014 during the "rainy season," when daily rainstorms dump more than 3 inches of moisture on the lush canopy of the forest. The second period in September and October provided an opportunity to measure atmospheric conditions during the "dry season."
ARM Mobile Facility			
January 2014–December 2015	Observations and Modeling of the Green Ocean Amazon	In Progress	This campaign seeks to understand aerosol and cloud life cycles, particularly the susceptibility to cloud-aerosol-precipitation interactions, within the Amazon Basin. The locations for the GOAMAZON field campaigns are at the following sites: T0, Amazonian Tall Tower Observatory T1, National Institute for Amazonian Research in Manaus, Brazil T2, Iranduba, Brazil T3, Manacapuru, Brazil ZF2, TES Measurement Sites north of Manaus and Manacapuru, Brazil.
January 2014–March 2015	Observations and Modeling of the Green Ocean Amazon: Cloud Condensation Nuclei Activity of Aerosols	In Progress	A key requirement for simulating aerosol-cloud interactions is the ability to calculate cloud condensation nuclei (CCN) and ice nuclei concentrations as a function of supersaturation from the chemical and microphysical properties of the aerosol. This campaign seeks to understand how aerosol and cloud life cycles are influenced by pollutant outflow from a tropical megacity.
February–October 2014	Observations and Modeling of the Green Ocean Amazon: Proton-Transfer-Reaction Time-of-Flight (PTR-TOF)	In Progress	This campaign will enable the study of how aerosol and cloud life cycles, including cloud-aerosol-precipitation interactions, are influenced by pollutant outflow from a tropical megacity.
February–April 2014	Observations and Modeling of the Green Ocean Amazon: Harvard Bounce Apparatus	Completed	The Harvard Bounce Apparatus investigates the phase state of particles to determine if they are from secondary organic aerosol (from the Amazon) or if they are influenced from urban pollution (from Manaus).

Dates	Campaign Name	Status	Description
ARM Mobile Facility			
January–March 2014	Observations and Modeling of the Green Ocean Amazon: Oxidation Flow Reactor	Completed	An oxidation flow reactor (OFR) was used to quantify and understand secondary organic aerosol (SOA) formation and aging at the T3 site. Particle-phase and gas-phase data were compared and contrasted between pristine and polluted air masses to investigate the anthropogenic influence on SOA sources, formation, and aging in the Amazon rainforest.
February–October 2014	Observations and Modeling of the Green Ocean Amazon: NPSD	In Progress	An aerosol size spectrometer (i.e., NPSD), developed and optimized for the detection of aerosol down to below 1 nanometer in diameter, was deployed at the T3 site during the two intensive operational periods to acquire data on a 5-minute time interval for new particle formation and initial growth.
February–December 2014	Observations and Modeling of the Green Ocean Amazon: Particulate Matter and Gases	In Progress	The focus of this campaign is measurement of inhalable particulate matter and greenhouse gases, focusing on their chemical composition. Size segregated aerosol samples will be collected for analyses of bulk and single particle elemental and molecular compositions.
February–October 2014	Observations and Modeling of the Green Ocean Amazon: Cloud Processes of the Main Precipitation Systems in Brazil: A Contribution to Cloud-Resolving Modeling and to the Global Precipitation Measurement (CHUVA)	In Progress	As one of the Brazilian components of the GOAMAZON field campaign, the CHUVA project employed an X-band radar, which provided volume scans and several range-height indicators in coordination with the ARM cloud radar. Another site was installed, 10 kilometers from the T3 site equipped with impact and laser disdrometers, rain gauges, a microwave radiometer ranging from 22.00 to 30.00 GHz (21 channels), one K-band (24.1 GHz) Doppler spectral vertically pointing micro rain radar, and global positioning system sensor.
February–October 2014	Observations and Modeling of the Green Ocean Amazon: Sounding Enhancement	In Progress	The goal of this campaign is to provide higher temporal sampling of the vertical structure of the atmosphere during the two 2014 intensive observational periods of GOAMAZON.
February–October 2014	Observations and Modeling of the Green Ocean Amazon: Semi-Volatile Thermal Desorption Aerosol Gas Chromatograph (SVTAG)	In Progress	To understand the connection between primary biogenic volatile organic compound (BVOC) emissions and their secondary products that form aerosols, time-resolved molecular-level measurements will be made by deploying a Semi-Volatile Thermal desorption Aerosol Gas Chromatograph (SV-TAG) and a sequential filter sampler during two intensive operational periods of the GOAMAZON field campaign.
December 2013–December 2015	Observations and Modeling of the Green Ocean Amazon: Sources of Volatile Organic Compounds in the Amazon	In Progress	A high-sensitivity quadrupole Proton-Transfer-Reaction – Mass Spectrometer (PTR-MS) is installed at the T3 GOAMAZON site. Ambient air will be analyzed continuously for volatile organic compound concentrations directly outside the instrument container, a 10-meter tower, a remote controlled helicopter, and a tethered balloon system.
January–December 2014	Observations and Modeling of the Green Ocean Amazon: Laser Luminescence	In Progress	The primary objective of the proposed work is to utilize a suite of measurements, especially of glyoxal and formaldehyde to be obtained by Keutsch group instrumentation based on laser-induced luminescence techniques.
January–October 2014	Observations and Modeling of the Green Ocean Amazon: Thernal Desorption Ionization Mass Spectrometer (TDCIMS)	In Progress	As part of both GOAMAZON2014 intensive observational periods, the TDCIMS performed measurements that will be used to address the interactions between anthropogenic and biogenic emissions. The TDCIMS will quantify the composition of nanoparticles nucleated from anthropogenic emissions.

Dates	Campaign Name	Status	Description
ARM Mobile Facility			
January–October 2014	Observations and Modeling of the Green Ocean Amazon: Hydroxide (OH) Chemical Ionization Mass Spectrometer (CIMS)	In Progress	The OH CIMS will be deployed to quantify atmospheric OH, HO_2, RO_2, and H_2SO_4. The outcomes of observations and data analysis will provide information about oxidation capacity and new particle formation potential in the Amazon Basin region in a variety of conditions such as pristine, polluted, dry, and wet conditions in the background of high BVOCs.
January–October 2014	Observations and Modeling of the Green Ocean Amazon: SRI-PTR-ToFMS	In Progress	To quantitatively incorporate the effects of BVOCs and their oxidation products on biogenic organic aerosol (BOA) requires parameterization of their production in terrestrial ecosystems and their atmospheric transformations. This project will reduce the gaps in the understanding of how these processes control BVOCs and BOAs, and their impact on climate.
February–October 2014	Observations and Modeling of the Green Ocean Amazon: Transmission Electron Microscopy (TEM) of Aerosol Particles	In Progress	TEM will be used to determine the spatially resolved compositions, sizes, morphologies, mixing states (aggregated, coated, embedded), and reactions to changes in relative humidity of aerosol particles of natural and anthropogenic origin.
January 2014–October 2014	Observations and Modeling of the Green Ocean Amazon: Neutral Cluster Air Ion Spectrometer (NAIS)	Completed	As a part of the GOAMAZON campaign, a NAIS and a Particle Size Magnifier (PSM) performed size-distribution measurements at the smaller end of aerosol particle sizes. These instruments were able to measure the size distribution of aerosol particles below the size range of standard scanning mobility particle sizer (SMPS) instruments.
January–December 2014	Observations and Modeling of the Green Ocean Amazon: Aerosol Mass Spectrometry	In Progress	The first objective of the proposed project is to understand and quantify the interactions of biogenic and anthropogenic emissions with respect to the production of secondary organic aerosols (SOA). The second objective is to test the hypothesis that new particles, under natural conditions, are produced as a result of evaporation of primary particles emitted by fungal spores.
April 2014–March 2015	Observations and Modeling of the Green Ocean Amazon: Aerosol Sampling	In Progress	Samples will be collected at the GOAMAZON T1, T2, and T3 field sites. T1 is representative of fresh urban emissions while T2 and T3 can experience clean conditions (e.g., when winds are from northwest) and polluted conditions when winds are from Manaus. The different downwind distances of T2 and T3 will enable investigation of the processes of aging and interactions with BVOC.
May 2014–December 2015	Observations and Modeling of the Green Ocean Amazon: Parsivel2	In Progress	The disdrometer being deployed for this campaign provides the necessary reference point to calibrate vertical velocity retrieval from Ka-ARM zenith radar (KAZR) and the wind profiler. In addition, the disdrometer will provide the necessary drop-size distributions to retrieve rain rates in Manaus.
May 2014–December 2015	Observations and Modeling of the Green Ocean Amazon: Scaling Amazon Carbon Water Couplings (SACWAC)	In Progress	Climate models predict a drying in the Amazon with reduced carbon uptake while observationally guided assessments indicate sustained uptake. This research was aimed to resolve the discrepancy in the size and sign of the future Amazon carbon cycle by performing the first simultaneous regional-scale high-frequency measurements of atmospheric CO_2, H_2O, HOD, CH_4, N_2O and CO at the Manacapuru T3 site.

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Dates	Campaign Name	Status	Description
ARM Mobile Facility			
August–October 2014	Observations and Modeling of the Green Ocean Amazon: Oxidation Flow Reactor (OFR) 2	In Progress	An OFR is used to quantify and understand SOA formation and aging at the T3 site. Particle-phase and gas-phase data were compared and contrasted between pristine and polluted air masses to investigate the anthropogenic influence on SOA sources, formation, and aging in the Amazon rainforest.
August–October 2014	Observations and Modeling of the Green Ocean Amazon: Nitrogen Oxide (NOx)	In Progress	A chemiluminescense-based nitrogen oxide (NOx) instrument measured ambient gas phase nitric oxide (NO) and nitrogen dioxide (NO_2) at the site. NO was measured directly and NOx was measured by catalytically converting NO_2 to NO. NO_2 was then calculated by the difference between NOx and NO. These observations will be used to interpret other gas and aerosol phase measurements conducted at the site during the second intensive operational period and cross-compared with existing ARM Mobile Facility instrumentation for validation.
Eastern North Atlantic			
September 2014–August 2019	Atmospheric Electric Field-Mill Sensor	In Progress	Portugal's University of Évora's Geophysics Centre is studying the vertical component of the atmospheric electric field and its relation with the concentration of aerosols and natural radioactivity in the lower troposphere. This work is part of the scientific strategy of the Laboratory of Atmospheric Electricity, part of the University of Évora.
North Slope of Alaska			
November 2013–October 2018	EarthScope Seismic Station A21 K-6	In Progress	The EarthScope Transportable Array is an earthquake observing system, operated and maintained by the Incorporated Research Institutions for Seismology on behalf of the NSF. One of 300 such stations, it uses continuously operating seismic stations to record ground motion caused by earthquakes and volcanic processes.
January 2014–December 2016	Sea Ice Effect on Arctic Climate - Extension II	In Progress	This project intends to provide new data and insight for interpretations of climate information recorded in ice cores, relevant for testing global warming projections, abrupt global change scenarios, and ice age theories, as well as for further verification of climate models.
September 2014–September 2016	Arctic Methane, Carbon Aerosols, and Tracers Study	In Progress	The campaign addresses two short-lived atmospheric species, black carbon (BC) and methane (CH_4), believed to be important climate forcers. To improve understanding of sources of BC and CH_4 in the Arctic, concentration data of these species will be collected and analyzed, along with concentrations of atmospheric species that are either co-emitted by specific source types or are indicative of atmospheric transport history.
Off-Site Campaigns			
October 2013 - January 2014	Soot Aerosol Aging Study (SAAS)	Completed	The objective of the Soot Aerosol Aging Study was to characterize the evolution of BC aerosol mixing state and its climate-related properties as a result of aging (condensation/coating and coagulation) in a laboratory using the ARM Aerial Facility's single particle soot photometer (SP2).
November 2013 - January 2014	Soot Aerosol Aging Study – Optical Properties	Completed	The objective of the Soot Aerosol Aging Study was to characterize the evolution of BC aerosol mixing state and its climate-related properties as a result of aging (condensation/coating and coagulation) in a laboratory using the ARM Aerial Facility's nephelometer, 3-Wavelength Particle Soot/Absorption Photometer (PSAP), and CCN counter.

Dates	Campaign Name	Status	Description
Off-Site Campaigns			
December 2013–December 2014	Integrated Precipitation and Hydrology Experiment (IPHEX): Orographic Precipitation Processes Study	In Progress	This field campaign, led by NASA's Global Precipitation Measurement Ground Validation Program (GPM GV) and with participation of NOAA's Hydrometeorological Testbed Program Southeast Pilot Study, is aimed to test the hypothesis that Bergeron processes govern the enhancement of light rainfall in the Southern Appalachian Mountains.
March - July 2014	Integrated Precipitation and Hydrology Experiment (IPHEX): Cloud Spectrometer and Impactor (CSI)	Completed	For the NASA IPHEX campaign, the ARM Aerial Facility Cloud Spectrometer and Impactor (CSI) was mounted on the University of North Dakota Citation aircraft to provide important measurements of total condensed water vapor to be combined with measurements collected by additional probes on the Citation and NASA ER2.
Southern Great Plains			
October 2013–December 2014	Precision Carbon Dioxide Mixing Ratio System (PGS) Validation 2014	In Progress	A portable flux measurement system is deployed in pasture and switchgrass fields in, or near, the U.S. Department of Agriculture's Southern Plains Range Research Station in Woodward, Oklahoma. Fluxes of CO_2, water, and energy as well as a set of relevant driving variables such as radiation, soil temperature, soil moisture, and precipitation were measured.
November 2013–May 2015	Radar Scanning Intensive Operational Period for Boundary Layer Clouds	In Progress	The purpose of this field campaign is to develop a scanning strategy appropriate for studying small-scale boundary layer cloud 3D structure, using ARM's W- and Ka-band scanning cloud radar to provide insights in cloud microphysical processes.
March 2014–February 2015	Balloon-Borne Full-Column Greenhouse Gas Profiling	In Progress	The purpose of this campaign is to produce vertically resolved measurements of atmospheric carbon-cycle gases. Over the course of this two-year DOE-NOAA collaborative project, there will be an evaluation of the feasibility for first research–mode and then operational balloon-borne sampling, reliable recovery, and on-site trace-gas analysis at the SGP site. If successful, this will provide data to support key DOE radiative-forcing science objectives.
April–October 2014	Measuring Clouds at SGP with Stereo Photogrammetry	Completed	Stereo photogrammetry was added to the SGP site through the siting of two ARM Cloud Digital Cameras at the Central Facility to provide three-dimensional cloud data in the form of the Point Cloud of Cloud Points Product.
June 2014–September 2016	Balloon-Borne Ice Crystal Replicator Measurements	In Progress	This campaign uses a National Center for Atmospheric Research (NCAR) balloon-borne ice crystal replicator system to collect ice cloud vertical profiles over the SGP site.
Tropical Western Pacific			
November 2013–December 2014	Tropical Wind and Rain Climatology	In Progress	Since 2006, a wind profiling radar has operated at the TWP site, but was limited to 3.4 kilometers in vertical acquisition range. Leaving the antenna array, the electronics of the profiler were replaced with the current ATRAD-build standard, allowing continuous sampling to approximately 10 kilometers in low- and high-modes to retrieve rainfall properties from near-ground to the freezing-level.

Value-Added Product **Descriptions**

In FY2014, the following 10 new data products were initiated, 19 products were released to production, and 8 evaluation data products were released for evaluation.

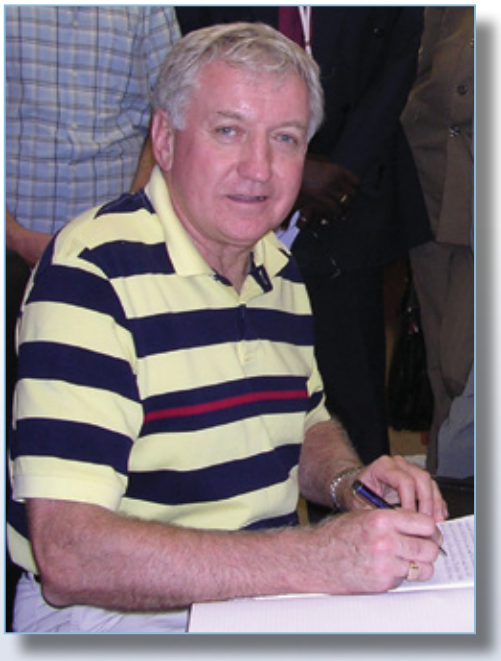
ARM Value-Added Products	Description
New Products Initiated	
AREALB (Areal Averaged Spectral Surface Albedo)	AREALB implements an algorithm developed to calculate the white-sky areal average albedo from only an upward-looking Multifilter Rotating Shadowband Radiometer during overcast conditions.
ARMBE2DGRID (ARM Best-Estimate 2-Dimensional Gridded Surface)	The ARMBE2DGRID data set merges together key surface measurements at the Southern Great Plains facilities and interpolates the data to a regular 2-dimensional grid to facilitate data application.
ARMBE2DSTNS (ARM Best-Estimate 2-Dimensional Station-Based)	ARMBE2DSTNS is an hourly station-based surface data set that contains the same variables as in ARMBE2DGRID.
CMAC2 (Corrected Moments in Antenna Coordinates Version 2.0)	CMAC2 improved upon linear-phase processing, allowing for larger areas of differential phase on backscatter previously not considered.
DLPROF VAD (Doppler Lidar Profile Velocity-Azimuth-Display)	The DLPROF VAD VAP takes the vertical profiles of horizontal wind speed and direction using the VAD algorithm from the Doppler lidar data.
NAVBE (Marine ARM GPCI Investigation of Clouds Navigation)	NAVBE VAP was developed in response to the MAGIC deployment, the first ship-based deployment of the second ARM Mobile Facility.
RADFLUX (Radiation Flux VAP)	RADFLUX uses surface broadband radiation measurements to detect periods of clear skies and produce continuous clear-sky estimates.
RWPCLUT (Clutter Removal in Radar Wind Profiler Doppler Spectra)	RWPCLUT features clutter-free Doppler spectrum and moments data in a cloud fraction/radial compliant format.
SACRCORR (Scanning ARM Cloud Radar Correction VAP)	SACRCORR was proposed to develop a SACR corrections VAP to enhance the scientific value of data collected by the Ka-, W- and X-band Scanning ARM Cloud Radars (Ka-, W-, and X-SACRs).
Ship Motion Correction for CEIL, HSRL and MPL	The Ship Motion Correction for CEIL, HSRL and MPL VAP will post-process data from the unstabilized Celiometer, High Spectral Resolution Lidar, and Micropulse Lidar (CEIL, HSRL, MPL) for ship deployments.
Products Released to Production	
ABE (Aerosol Best Estimate)	ABE provides best-estimate time series of total column aerosol optical depth and the associated column Ångström exponent.
AERINF (Atmospherically Emitted Radiance Interferometer Noise Filter)	AERINF uses a noise filter to significantly reduce the amount of uncorrelated random errors in the AERI observations.

ARM Value-Added Products	Description
Products Released to Production	
AERIPROF (Atmospherically Emitted Radiance Interferometer Profiles)	AERIPROF retrieves high-temporal resolution temperature and water-vapor profiles through the planetary boundary layer from high-resolution spectral data observed by the AERI.
AIP (Aerosol Intensive Properties)	AIP computes several aerosol intensive properties including hygroscopic growth factor, aerosol single-scattering albedo, hemispheric backscatter fraction, angstrom exponent, submicron scattering, and absorption fraction.
AOD (Aerosol Optical Depth)	AOD generates robust calibrations for the Multifilter Rotating Shadowband Radiometer and Normal Incidence Multifilter Radiometer from Langley analysis.
BAEBBR (Bulk Aerodynamics Energy Balance Bowen Ratio)	BAEBBR provides a best estimate of sensible and latent heat fluxes to provide the "best estimate" of the diurnal cycle of fluxes.
BEFLUX (Best-Estimate Surface Radiative Flux)	BEFLUX processes data from three Southern Great Plains radiometer systems to obtain the best estimate of all surface radiative energy budget data.
INTERPSONDE (Interpolated Sonde)	INTERPSONDE produces a daily file of thermodynamic variables such as temperature, humidity, and wind speed and direction from instruments on the ground and carried on radiosondes.
LANGLEY (Langley Regression)	LANGLEY computes values necessary to calculate the air mass and the total optical depth of an air column from measurements of direct sunlight. The results are used in calibrating instruments.
LSSONDE (Microwave Radiometer-Scaled Sonde Profiles)	LSSONDE generates radiosonde profiles with the profile of relative humidity scaled to match the profile of precipitable water vapor.
MFRSRCLDOD (Cloud Optical Properties)	MFRSRCLDOD generates cloud optical depth and effective radius for overcast liquid-water clouds.
MICROBASEPI (Continuous Baseline Microphysical Retrieval Profile-Instantaneous)	MICROBASE is a baseline retrieval of cloud microphysical properties. MICROBASEPI provides scientifically relevant measurements of ice- and liquid-water content.
MPLCMASK (Micropulse Lidar Cloud MASK)	MPLCMASK uses micropulse lidar measurements to help determine individual cloud layers and how much an area is obstructed by clouds.
NDROP (Droplet Number Concentration)	NDROP calculates the number concentration of droplets in clouds for studying aerosol-cloud interactions.
PBLHTSONDE (Planetary Boundary Layer Height Radiosonde)	PBLHTSONDE estimates the planetary boundary layer height from radiosonde profiles of temperature, humidity, and wind speed using several different algorithms from the literature.

ARM Value-Added Products	Description
Products Released to Production	
SASHE AOD (Shortwave Array Spectroradiometer-Hemispheric Aerosol Optical Depth)	The SASHE Calibration/AOD VAP processes the intermediate files created by the SASHE Langley VAP to yield a robust calibration time series of top-of-atmosphere irradiances suitable for retrieval of optical depth.
SONDEADJUST (Sonde Adjust)	SONDEADJUST produces data that corrects documented biases in radiosonde humidity measurements.
SURFSPECALB (Surface Spectral Albedo)	The SURFSPECALB VAP creates a near-continuous best estimate of broadband and narrowband downwelling irradiance, upwelling irradiances, and surface albedo using the multifilter radiometers on the 10-meter and 60-meter towers and the multifilter rotating shadowband radiometers at the Southern Great Plains Central Facility.
TWRMR (Tower Water-Vapor Mixing Ratio)	TWRMR calculates water-vapor mixing ratio at two heights on the tower at the Southern Great Plains Central Facility.
Products Released to Evaluation	
ARMBE2DGRID (ARM Best-Estimate 2-Dimensional Gridded Surface)	The ARMBE2DGRID data set merges together key surface measurements at the Southern Great Plains sites and interpolates the data to a regular 2-dimensional grid to facilitate data application.
ARMBE2DSTNS (ARM Best-Estimate 2-Dimensional Station-Based)	ARMBE2DSTNS is an hourly station-based surface data set that contains the same variables as in ARMBE2DGRID.
DLPROF VAD (Doppler Lidar Profile Velocity-Azimuth-Display)	The DLPROF VAD VAP takes the vertical profiles of horizontal wind speed and direction using the VAD algorithm from the Doppler lidar data.
DLPROF – WSTATS (Cloud and Vertical Velocity Statistics from the Doppler Lidar)	The purpose of the Doppler lidar vertical velocity and cloud statistics VAP is to produce height- and time-resolved estimates of vertical velocity variance, skewness, and kurtosis from raw measurements.
MICROARSCL (Micro ARM Cloud Radar Active Remote Sensing of Clouds)	MICROARSCL provides information about the Doppler characteristics of millimeter-wavelength cloud radars and helps identify radar clutter (e.g., insects).
MWRRET (Microwave Radiometer Retrievals)	MWRRET provides precipitable water vapor and liquid-water path from the microwave radiometer.
VARANAL (Variational Analysis Products)	VARANAL contains large-scale forcing and evaluation data sets for single-column models and cloud-resolving models.
WACRARSCL (W-band ARM Cloud Radar Active Remote Sensing of Clouds)	WACRARSCL combines observations from the W-band cloud radar, micropulse lidar, and ceilometer to produce cloud boundaries and time-height profiles.

In Memoriam

Peter J. Lamb (1947–2014)



A valued friend and colleague, ARM Facility pioneer, and site scientist for the ARM SGP site for many years, Dr. Peter Lamb passed away unexpectedly, but peacefully, at his home in 2014.

Lamb was a key member of the science team for the first and only deployment of the ARM Mobile Facility in Africa to date, the RADAGAST field campaign, located in Niamey, Niger. A persistent and vocal advocate for the ARM Facility, Lamb took time to participate in site visits and ARM outreach activities whenever his schedule allowed. His contributions and many friendships throughout the ARM Facility and scientific community are a testament to his passion and dedication to a lifetime of science.

On the inside covers: In May 2014, photographer Terri Weifenbach visited the Southern Great Plains site to merge art and science together. Her work is shown in museums, galleries, and books she publishes—and now the ARM annual report. This sunrise shot captured the beauty of the guest instrument facility (far left) and the ARM radars (far right).

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