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ANNUAL REPORT

ARM

CLIMATE RESEARCH FACILITY

U.S. DEPARTMENT OF ENERGY | Office of Science

2013

On the cover: From October 2012 through September 2013, the second ARM Mobile Facility (AMF2) was deployed on the container ship, *Spirit*, operated by Horizon Lines, for the Marine ARM GPCI Investigation of Clouds (MAGIC) field campaign. During approximately 20 round trips between Los Angeles, California, and Honolulu, Hawaii, AMF2 obtained continuous on-board measurements of cloud and precipitation, aerosols, and atmospheric radiation; surface meteorological and oceanographic variables; and atmospheric profiles from weather balloons launched every six hours. For more information, see the *Featured Field Campaigns* section of this report.

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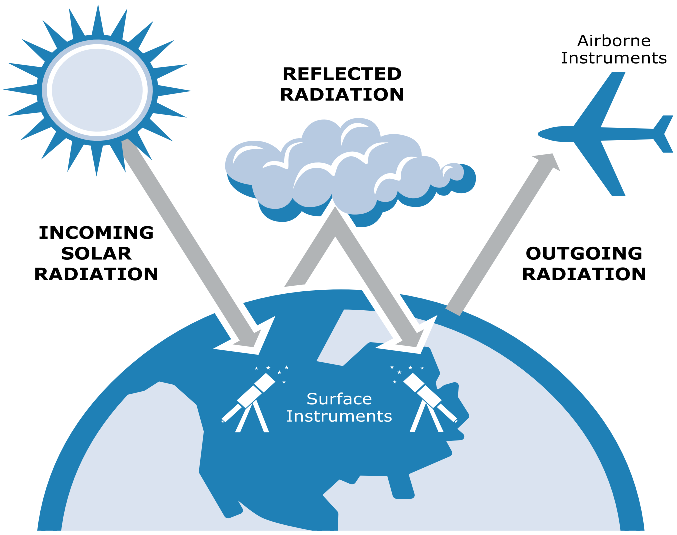
Facility
OVERVIEW

The Importance of Clouds and Radiation to Climate Change



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 (GCMs) are the primary tool for quantifying future climate change; however, large uncertainties remain in the GCM 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 (FY) 2013.

Science in the Amazon Rainforest. *From January 2014 through December 2014, the ARM Mobile Facility (AMF) will be deployed in Brazil near Manacapuru, south of Manaus, for GOAMAZON. Scientists will be conducting a variety of different experiments with dozens of measurement tools, using both ground and aerial instrumentation, including the ARM Aerial Facility's G-1 aircraft. The city of Manaus, with a population of 3 million, uses high-sulfur oil as their primary source of electricity. The AMF site is situated to measure the atmospheric extremes of a pristine atmosphere and the nearby cities' pollution plume, as it regularly intersects with the site. Numerous other observational efforts coinciding with GOAMAZON are sponsored by the U.S. DOE, Brazilian, and German collaborators. These combined observations will provide a benchmark data set vital to constrain tropical forest models for organic aerosol, cloud, and convection schemes, as well as vegetation components. The data set will provide insights into how these components are perturbed by pollution and how they influence climate.*

Wanda Ferrell, U.S. Department of Energy

Wanda Ferrell Receives Atmospheric Leadership Award

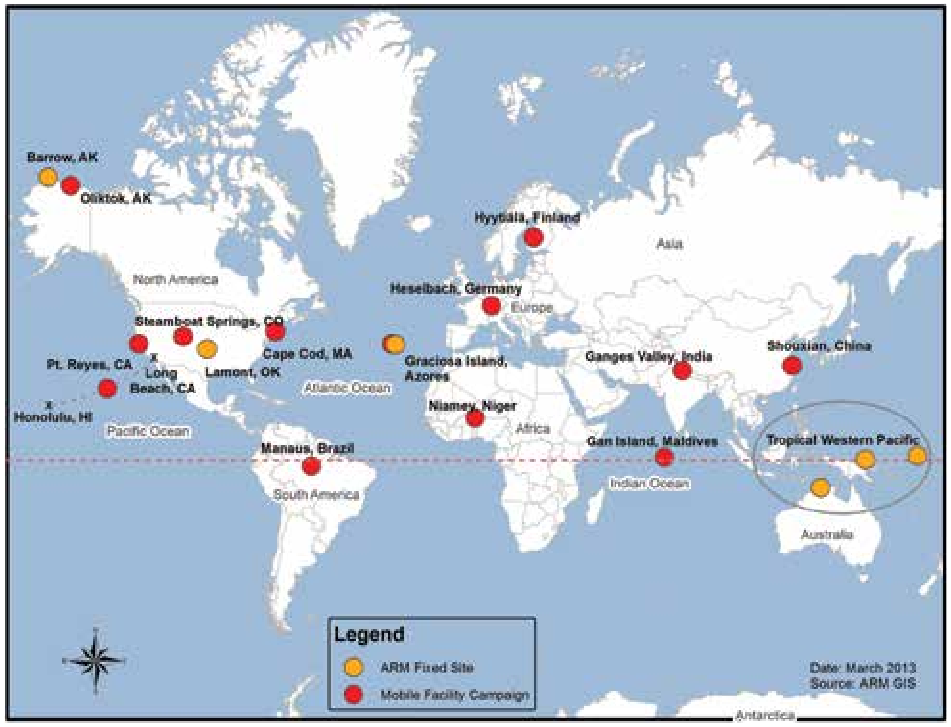
After nearly two decades leading ARM, DOE's Wanda Ferrell received the prestigious "Cleveland Abbe Award for Distinguished Service to Atmospheric Sciences" at the 2013 American Meteorological Society Annual Meeting. The award recognizes Ferrell "for skillful, dedicated leadership in managing the ARM Climate Research Facility, which has improved knowledge about the interactions among clouds, radiation, and aerosols."

Ferrell joined the ARM Program management team in 1994, and led the ARM science team from 2000 to 2006. In 2001, she restructured the program to ensure that the infrastructure would be continually maintained. In 2005, after a decade of successful operation as an observational testbed, the ARM infrastructure was designated a DOE Office of Science national user facility.

Ferrell earned a master's degree in physics from Clemson University and a doctorate in physics from the University of Tennessee. Prior to leading ARM, Ferrell was a faculty member at Clemson University and Appalachian State University.

ARM Climate Research Facility

Through the ARM Facility, DOE funded the development of several permanent, 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 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)**—includes three sites spanning the equatorial region from Indonesia to the dateline: Darwin, Australia; Manus Island, Papua New Guinea; and Nauru Island.
- **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 began operations in September 2013, 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. The ARM Facility's instrument arrays represent some of the most sophisticated tools available for conducting atmospheric research.

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 FY2013, two new sites were deployed. The first is an extended-deployment mobile facility in Oliktok Point, Alaska. The second is a new fixed site, the Eastern North Atlantic, or ENA, located on Graciosa Island in the Azores.

In addition to the observational data, special data sets are created to address quantities of interest that are difficult to measure directly or routinely. A specific category of these value-added products (VAPs) are the ARM Best Estimate data products that represents "best estimates" derived from several instruments and/or VAPs. All data are carefully reviewed for quality and approved data are then stored in the ARM Data Archive for use by the climate research community.

Using these data, scientists are studying the effects and interactions of aerosols, 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 through the ARM Data Archive (*http://www.archive.arm.gov*) to aid in further research.

Scott Collis, Argonne National Laboratory

Popular Science's *Brilliant 10 Includes ARM Radar Meteorologist*

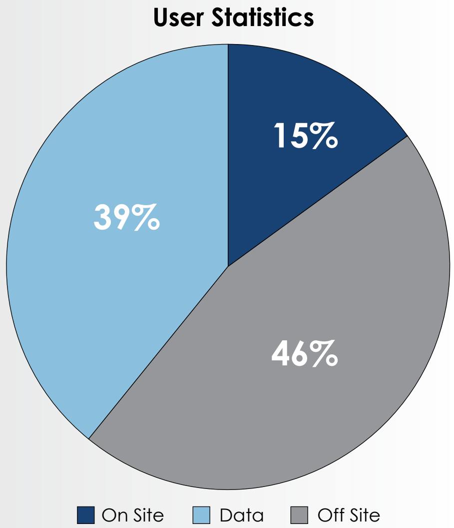
Scott Collis, a radar meteorologist at DOE's Argonne National Laboratory (ANL), earned the distinction of being named to Popular Science's "Brilliant 10" for the year 2013. This group represents researchers under 40 who have made revolutionary contributions to their fields. The Brilliant 10 appeared in the October 2013 issue of the magazine.

Collis' research covers weather phenomena from Darwin, Australia, to Oklahoma, to the Arctic, with a particular focus on the interplay between large-scale forcing and local-scale impacts.

In 2008, Collis began working with ARM radar data while at the Australian Bureau of Meteorology. He moved to the United States in 2010 to join ANL and the ARM radar team as they began installing an influx of new dual-polarization radars at all ARM research sites.

He holds a Ph.D. in meteorology from Australian National University.

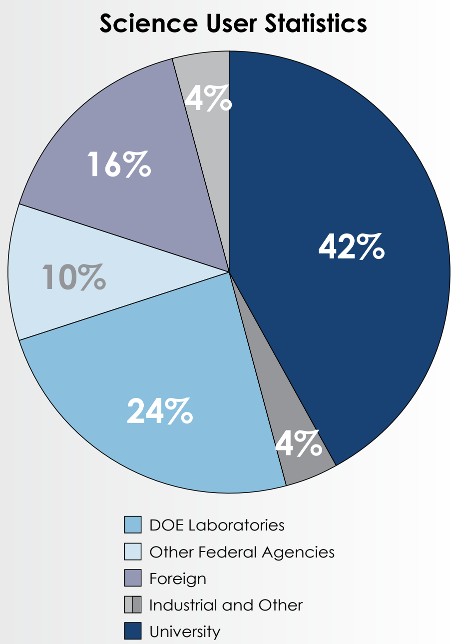
Fiscal Year 2013 Budget Summary and Facility Statistics



FY2013 Budget ($K)	
Infrastructure	*67,779*

User Statistics for the Period of October 1, 2012–September 30, 2013

Description	Users
On Site	145
Off Site	457
Data	381
Total	**983**



Science Users for the Period of October 1, 2012–September 30, 2013

Description	Users
University	415
Industrial	42
DOE Laboratories	238
Other Federal Agencies	99
Foreign	154
Other	35
Total	**983**

Key
ACCOMPLISHMENTS

Featured Field Campaigns

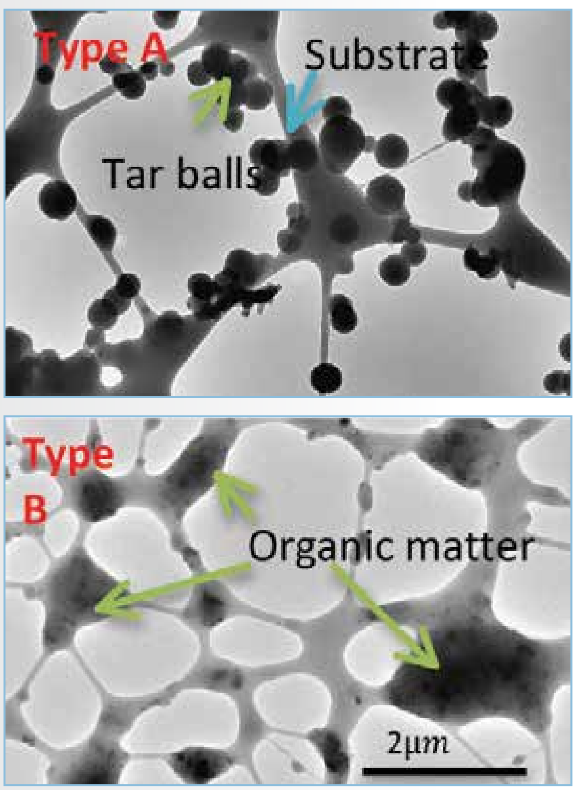
Biomass Burning Observation Project

The Biomass Burning Observation Project (BBOP) sought to better understand how aerosols generated from burned biomass affect the atmosphere and climate. Utilizing the ARM Aerial Facility (AAF), BBOP deployed the Gulfstream-1 (G-1) over active wildfire and agricultural smoke plumes to help identify the impact of agriculture burning and wildfires and how these particles evolve over time.

The G-1 flies into the smoke plume during a research flight for BBOP.

Biomass burning is estimated to produce 40 percent of microscopic airborne carbon particles in the atmosphere. Biomass refers to biological material derived from living or recently living organisms. Burning biomass produces a large amount of aerosols in the atmosphere, affecting the regional climate. While there have been plenty of biomass burning studies done in tropical climates, few campaigns have been conducted within the United States, where millions of acres are burned each year, making this study particularly important.

Six primary topics: aerosol mixing state and morphology, mass absorption coefficients, chemical composition of non-refractory material, production rate of secondary organic aerosols, microphysical processes to determine aerosol size distribution, and cloud condensation nuclei activity.



Type A shows particles from an urban pollution plume. Type B shows regional pollution particles. Photos courtesy of Peter Buseck and Kouji Adachi, Arizona State University.

The G-1 research aircraft was deployed in two locations during this campaign. From July to September, the G-1 was deployed in Pasco, Washington, measuring naturally occurring uncontrolled fires across Washington, Oregon, Idaho, northern California, and western Montana. This location allowed the G-1 aircraft to gather data from smoke plumes under 5 hours of age, which was the primary target for this phase of the campaign. In October, the G-1 aircraft was moved to Memphis, Tennessee, to sample agricultural burns in that area. Measurements were taken from varied distances and ages to establish a clear picture of aerosol evolution.

The G-1 aircraft was equipped with 35 instruments for measuring various atmospheric components, including a dozen new instruments not previously used in airborne research. The G-1 instrumentation included aerosol concentration and size distribution, aerosol composition and gas chemistry, aerosol optimal properties, energy coming from the sun and Earth, as well as temperature, pressure, humidity, wind speed, and direction.

Results: In just under 4 months, 17 wildfires were sampled, including more than two dozen agricultural burns and a handful of urban emissions, which were used as a contrasting data set. By conducting an aircraft measurement campaign that uniquely targeted near-field biomass burning aerosols, an important data set was collected that will contribute a process-level understanding of how these aerosols evolve and their forcing impact.

During the first phase of BBOP, 17 flights were devoted primarily to sampling plumes from wildland fires. There were three overflights of a surface site at Mount Bachelor Observatory (MBO) in Oregon; instrument comparisons are ongoing. One MBO flight examined a complex of forest fires in northern California, which were observed at MBO and sampled by the National Aeronautics and Space Administration aircraft, in collaboration with the G-1. During the second half of BBOP, several dozen prescribed agricultural burns were sampled in the lower Mississippi River Valley. Urban plumes from Portland, Seattle, Spokane, Nashville, and Memphis were sampled multiple times to provide contrasting data.

Results found that plumes are dominated by organic aerosols, with soot accounting for only a few percent of mass, meaning these plumes would yield a net cooling. Transmission electron microscopy showed that aged aerosol particles found in regional smoke haze is often dominated by high viscosity organic aerosols, or "tar balls," while within the active plume, there are low viscosity organic aerosols.

Formation of secondary organic aerosols increased organic aerosols by around 20 to 100 percent within 1 to 4 hours. Formation of aerosol nitrate increased by up to an order of magnitude, while sulfate remained near constant. An active hotochemistry is indicated by a several fold increase in oxygenated volatile organic compounds, as well as by ozone production. There is a wealth of size distribution information between 10 and 1000 nanometers with 1-second time resolution.

Flight patterns for wildland fires included multiple transects at varying downwind distances with multiple repetitions of these transects. This flight pattern assisted in assessing the role of natural variability in comparison to downwind trends attributed to aging of emitted and secondary pollutants. Since agriculture burns are generally smaller in size, the primary comparison is between fresh pollutants and regional haze caused by multiple burns.

Marine ARM GPCI Investigation of Clouds

The Marine ARM GPCI* Investigation of Clouds (MAGIC) field campaign used the second ARM Mobile Facility (AMF2) onboard the *Horizon Spirit* cargo ship, traversing the route between Los Angeles and Honolulu from October 2012 through September 2013. The primary focus of MAGIC was to improve representation of cloud regime transitions in climate models, specifically the transition between the stratocumulus and cumulus regimes. Current climate models do not properly display the small-scale physical processes associated with this transition, such as turbulence, convection, and radiation. The relationship between clouds, precipitation, and aerosols is complex and vital to weather and climate systems. Cloud drops begin as tiny water droplets that form around an aerosol particle. For the MAGIC campaign, the route between Los Angeles and Honolulu was ideal because of the variety of cloud structures on this route. Near the Californian coast, the dominant cloud type is stratocumulus, a low-level cloud layer, while toward Hawaii, the dominant cloud type is cumulus.

The aerosol observing system is the primary ARM platform for in situ aerosol measurements at the surface and was used aboard the ship *Horizon Spirit* during the MAGIC campaign.

*Note:
GPCI = GCSS Pacific Cross-section Intercomparison, a working group of GCSS;
GCSS = GEWEX Cloud Systems Study;
GEWEX = Global Energy and Water Cycle Experiment, a core project of the World Climate Research Programme.

The ship-board deployment of the AMF2 provided scientists with the capability to collect data from a vast cloud region in the Pacific Ocean. Measurement capabilities of the AMF2 included three radars, two lidars, standard meteorological instrumentation, a broadband and spectral radiometer suite, and other remote sensing instruments.

MAGIC had a number of supplementary campaigns mostly revolving around specific instrumentation. In addition, this campaign included intensive observational periods (IOPs) in July 2013, where weather balloon launches were increased to every three hours.

Results: During 20 round trips and nearly 200 days at sea, the AMF2 obtained continuous measurements of clouds and precipitation, aerosols, and atmospheric radiation; surface meteorological and oceanographic variables; and atmospheric profiles from weather balloons launches every 6 hours. These data will provide a detailed picture of the boundary layer and cloud structure along this Pacific Ocean transect, especially the transition between the stratocumulus and trade cumulus regimes. The MAGIC science team will use the AMF2 data gathered to develop better representations of this transition to use in global climate models.

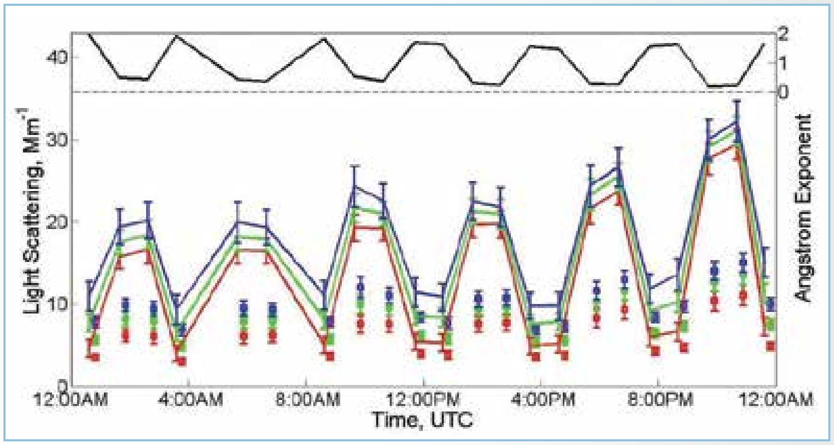
Preliminary results from MAGIC were presented at the Atmospheric System Research (ASR) Science Team Meeting in March 2013. Additional results will be presented at the ASR Science Team Meeting in March 2014. Some of these results focused on light scattering from aerosol particles and the aerosol size distribution.

The way light interacts with aerosol particles is affected by particle size and composition. Aerosol size distribution measurements were made with the Ultra-high Sensitivity Aerosol Spectrometer (UHSAS), a guest instrument in the Aerosol Observing System (AOS). The UHSAS counted how many particles flowed through it, categorizing them into 99 different size bins. Using this data, a size distribution was constructed, showing the number of particles in each size bin. From the size distribution, the expected amount of scattering could be calculated for red light (700 nanometers wavelength), green light (550 nanometers wavelength), and blue light (450 nanometers wavelength).

According to data collected by the UHSAS, the largest contribution to light scattering comes from larger aerosol particles, whose concentrations are very low, and the majority of the aerosol particles—with diameters between 100 and 200 nanometers—contribute little to the scattering. Although most of the particles were between

100 and 250 nanometers in diameter, the particles that accounted for the bulk of the scattering were larger, between 500-900 nanometers in diameter. Thus, in terms of light scattering, it appears that a few larger particles play a more significant role than many tiny particles. This has considerable implications in terms of climate modeling, as larger sea-salt particles suspended over the Pacific Ocean scatter light more than the tiny anthropogenic pollution particles near Los Angeles.

Light scattering at the same three wavelengths was also measured by the nephelometer, another instrument in the AOS. The nephelometer only extended to particles with diameters as large as 1 micrometer. The nephelometer switched between sampling air that removed particles with diameters greater than 1 micrometer, and air that included all particles with diameters less than 10 micrometers. Hence, if everything worked correctly, the measured light scattering would agree with that calculated from the size distribution measured by the UHSAS, but only when the sampled air contained particles with diameters of less than 1 micrometer. According to the data collected during the MAGIC campaign, it appears that the agreement is good in such situations. When the nephelometer measured light scattering from the air that contained particles with diameters less than 10 micrometers, there was roughly twice as much scattering, implying that particles with diameters greater than 1 micrometer are responsible for roughly as much scattering as those with diameters less than 1 micrometer.



This graph compares the expected amount of light scattering to the amount that was measured using the nephelometer. The squares refer to the amount of light scattering calculated from the UHSAS size distributions; the lines connect points that represent the measured light scattering.

The Angstrom Exponent refers to the upper graph (solid black line), and takes on values between 0 and 2. This Angstrom Exponent is a quantity that provides information on the sizes of particles that contribute to scattering. Large values, near 2, mean that smaller particles contribute most to the scattering, whereas small values, near 0, indicate that larger particles contribute most to the scattering.

A number of researchers are looking at MAGIC data and comparing results from different instruments. Because of the amount of interest in MAGIC, and due to the vast amounts of data generated from the MAGIC campaign, there will be a MAGIC Science Workshop in May 2014, at Brookhaven National Laboratory. This workshop will provide an opportunity for those working on MAGIC to meet, learn the status of data processing, present results, form collaborations, as well as discuss future research and directions.

Two-Column Aerosol Project

The Cape Cod National Seashore provided researchers with an ideal opportunity to measure air properties as air flows between the Atlantic Ocean and the North American continent. Along with Cape Cod's unique geography—a long isolated coastal peninsula, downwind from a major metropolitan city—this area provided a data-rich climate. The Two-Column Aerosol Project (TCAP) occurred from July 2013 to June 2013 and utilized the capabilities of the first ARM Mobile Facility (AMF1) to study climate processes on airborne particles.

The AMF1 was deployed on Cape Cod National Seashore during TCAP. This view, facing west, shows several radiometers operating on the left, and the Mobile Aerosol Observing System on the right.

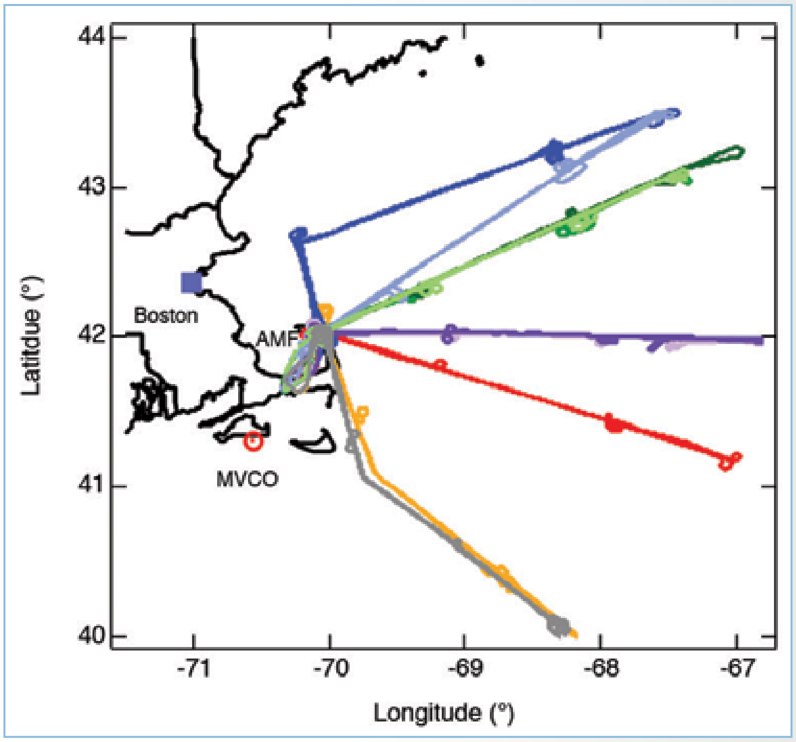
TCAP sought to fulfill four primary objectives; perform radiative and cloud condensation nuclei closure studies, evaluate a new retrieval algorithm for aerosol optical depth (AOD) in clouds, extend previously developed technique to investigate aerosol indirect effects, and evaluate the performance of a regional-scale model and global-scale model in simulating particle activation.

Despite scientific advances in understanding, the effects of how aerosols evolve and affect clouds and the Earth's climate, there are vital gaps in climate models particularly around the evolution of aerosol particles. Important climate processes depend on aerosols that undergo perpetual changes, which vary not only in size, but composition. Measurements obtained during TCAP allowed scientists to study the effects of aerosols in important climate processes.

This campaign gathered data from two separate air columns. The first column utilized the capabilities of the AMF, using sensors to measure the sky "column" directly over the AMF site. These instruments took data from the clouds, wind, sun, and dust. The second maritime column was located 155 miles off the Cape Cod coast. The G-1 research plane flew through this column taking a variety of measurements to compare with the onshore measurements gathered.

A number of supplementary campaigns occurred during the campaign, primarily revolving around measurements taken by specific equipment in response to a certain query. These additional campaigns also included two aircraft intensive operational periods, one in the summer and the other in the winter.

Results: TCAP marked the first science deployment of a number of new instruments both on the ground and on board research aircraft. TCAP was also the first deployment of dual-wavelength scanning cloud radars with AMF1. These new cloud radars, in conjunction with the existing vertically pointing cloud radar, gave an unprecedented set of observations that could be used to better understand the cloud dynamics (including the vertical velocity within clouds), cloud microphysics, and cloud life cycle. During TCAP, the scanning Doppler lidar was configured to provide the vertical velocity below cloud, and when coupled with the cloud radar, provided the vertical velocity from near the surface to the cloud top. New techniques are being developed to mitigate the impact of drizzle on the vertical velocity derived from the cloud radar and increase the utility of the data collected. The cloud data sets will be a valuable tool for the evaluation of the atmospheric models and for studies related to aerosol indirect effects. TCAP was also the first deployment of the Mobile Aerosol Observing System (MAOS) with the AMF. The MAOS was designed to provide more insight into trace gases and aerosol chemical composition than is possible from AMF1. During the first phase of TCAP, the amount of sulfate aerosol was found to vary widely, ranging from zero to 30 percent of the total aerosol mass loading.



Aircraft flight tracks flown during phase 1 of TCAP. Colors indicate different days, as well as the location of the Martha's Vineyard AERONET site (red circle). Flight patterns used were chosen to sample air as it moved off the coast of North America or to sample regions where there were large changes in the aerosol properties.

New airborne instruments included the miniSPLAT, a new single-particle mass spectrometer, the Spectrometer for Sky-Scanning, Sun-Tracking Atmospheric Research (4STAR), and the second-generation NASA High Spectral Resolution Lidar (HSRL-2). The miniSPLAT provided a detailed look at the chemical composition of individual particles, including changes in the degree of mixing of various chemical compounds across the population of particles. These data show many of the elevated aerosol layers observed during the study had enhanced amounts of biomass burning particles and were likely associated with long-range transport of biomass burning plumes. During Phase 2, the miniSPLAT was combined with a Counterflow Virtual Impactor Inlet that selectively sampled only cloud drops, providing data about the size and chemical composition of the particles that act as cloud condensation nuclei. The 4STAR and HSRL-2 were used to document changes in the aerosol optical properties as a function of height within the atmosphere. A recent study (Shinozuka et al. 2013) showed very good agreement between the two instruments.

One key finding of TCAP was the significant impact of diurnal variability that the AOD could have on the amount of the sun's energy reaching the Earth's surface. Many remote sensing instruments, including state-of-the-art satellites, measured the AOD once, and possibly twice, a day. This is not an issue when the AOD is nearly constant or changes slowly, but can lead to significant errors when that assumption is not valid. Using data collected during TCAP, it was documented that the error in the direct aerosol radiative forcing could be as large as 100 percent (Kassianov et al. 2013).

Another key finding was the large impact of elevated particle layers on the AOD. Data collected by the HSRL-2 has been used to document the presence of layers of particles well above the surface, as well as contribution to the column's AOD. These elevated layers of aerosol have been found to have a significant impact on the total AOD. Depending on the day of the study, the elevated layers contributed anywhere from 10 to 90 percent of the total optical depth.

TCAP was designed to provide a data set that can be used to evaluate both regional and global scale atmospheric models. Current research efforts are focused on testing both the Weather Research and Forecasting model coupled with chemistry (WRF-Chem) and with the Community Atmospheric Model (CAM). The model results will be analyzed to determine if the aerosol optical properties and vertical distribution are well represented. If not, additional effort will focus on understanding the model shortcomings and the development of improved parameterizations.

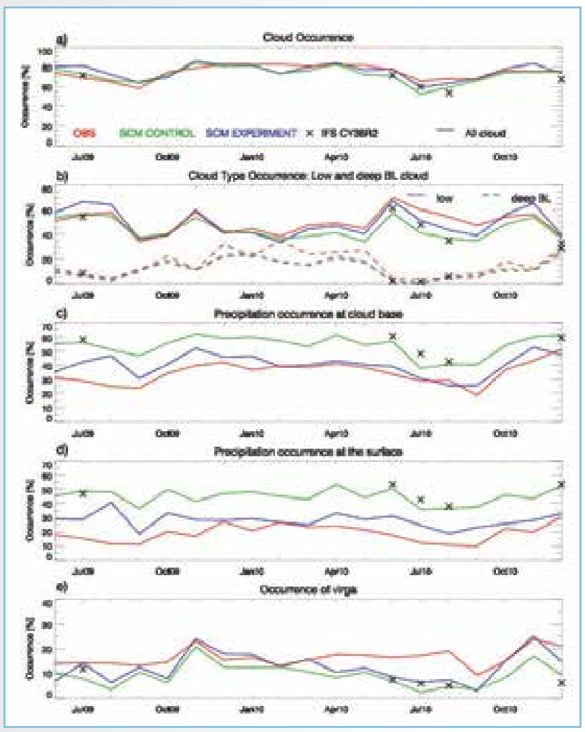
Research Highlights

2013 Publications Summary	
Category	**Total**
Abstracts or Presentations	283
Books	0
Book Chapters	0
Journal Articles	114
Technical Reports	16
Conference Papers	0
Total	**413**

Scientists around the world use data from the ARM Facility for their research. In FY2013, ARM data were cited in a total of 413 publications. The following pages feature a selection of ARM research highlights from these publications. ASR funding is a primary resource for principal investigators who contribute to these highlights. For more publications information, search the ARM Publications Database at: *www.arm.gov/publications/publist*.

Addressing the "Light Precipitation Problem" in the ECMWF Global Model

It is common for global models to overestimate the frequency of light precipitation events, and underestimate the occurrence of more rare, but intense, precipitation events. Comparisons with global precipitation observations suggest that the Integrated Forecast System (IFS) run at the European Center for Medium-Range Weather Forecasting (ECMWF) for global numerical weather prediction (NWP) is no exception. Observations obtained during the 19-month-long AMF deployment to Graciosa Island, in the Azores, provided an opportunity to further assess systematic model errors in the occurrence of clouds, liquid water path, precipitation, and surface radiation. The synergy and collocation of cloud and radiation observations, together with vertically resolved observations of hydrometeors, offered deeper insights into model errors than could be gained from a satellite perspective alone.



Monthly mean cloud and precipitation occurrence from observations (red), the control version of the single column model (green) and the SCM experiment (blue). (a) Total cloud occurrence; (b) Low cloud (solid) and deep boundary layer (dashed) cloud occurrence; (c) Precipitation occurrence at cloud base; (d) At the surface; and (e) For virga. Symbols mark values for select months of the full IFS forecast cycle 38R2.

Observations showed that boundary layer clouds are the most frequently observed cloud type at Graciosa (Remillard et al. 2012), and that these were underestimated by 10 percent in models. Systematic, but partially compensating surface radiation errors existed and could be linked to opposing cloud cover and liquid-water path errors in broken and overcast low-cloud regimes. This was consistent with previously reported results from the continental ARM Southern Great Plains site. On the other hand, occurrence of precipitation was overestimated by a factor of 1.5 at cloud base and by a factor of 2 at the surface, suggesting deficiencies in both the warm-rain formation and sub-cloud evaporation parameterizations.

Three specific parameterizations were identified as contributing to the model errors: (1) triggering of cloud in the boundary layer and shallow convection parameterizations; (2) the autoconversion/accretion parameterization; and (3) the parameterization of drizzle evaporation.

The single-column version of the ECMWF IFS model (SCM), forced with data from the operational model for the 19-month-period, was used to assess the impact of changes to the parameterizations.

The SCM sensitivity results showed a change in the representation of the broken cloud and overcast regimes, which reduced compensating errors in the cloud radiative forcing. This was particularly evident in the shortwave radiation at the surface, affected by cloud cover and liquid water path.

A global observation data set of top-of-atmosphere net shortwave radiation from the Clouds and Earth's Radiant Energy System was used as a measure of the impact of the changes in an ensemble of four 1-year simulations of the full global model in climate mode. The annual mean absolute error was reduced over large areas of the globe and locally by up to 10 Wm^{-2}. The changes to the parameterizations are one step towards addressing some of the long-lived cloud, precipitation, and radiation-related systematic errors in the ECMWF IFS model; systematic errors that have similarities in other NWP and climate models.

References

Ahlgrimm M and R Forbes. 2013. "Improving the representation of low clouds and drizzle in the ECMWF model based on ARM observations from the Azores." *Monthly Weather Review*, accepted.

Remillard J, P Kollias, E Luke, and R Wood. 2012. "Marine boundary layer cloud observations at the Azores." *Journal of Climate* 25(21): 7381-7398.

Power in the Vertical: Using Wind Profiler Data to Study Precipitation

For more than two decades, radar wind profilers from the ARM Facility have provided a unique data set valuable for studying a number of atmospheric conditions such as low-level horizontal winds. Now, work published by an international team of researchers in the *Journal of Atmospheric and Oceanic Technology* suggests that the instruments' use can be extended to better study how clouds transition to the precipitation that waters crops or causes flooding.

Because ARM's wind profilers (foreground) can take vertical as well as horizontal measurements, the instruments can be used with appropriate processing and calibration to help study rainfall.

The ARM wind profilers take readings in five directions—south, north, east, west, and vertical. While this cycle is optimal for determining wind directions, the wind profilers are also capable of penetrating deep precipitating cloud systems. This fact gives them an advantage over other instruments typically used to study rainfall. For instance, some cloud radars are challenged to probe deep precipitation because liquid can interfere with the signal.

To fully exploit the potential of the wind profiler to gather data on rainfall, the research team reconfigured a wind profiler at the ARM SGP research site in Oklahoma. In the revised configuration, the instrument spent more time sampling vertically and took quick, successive measurements that looked both near and far. Researchers ran the resulting data through a series of processing and calibration steps to screen out influences that could degrade the data.

To confirm that the screened data represented real-world conditions, the research team used the same process on data gathered during the spring 2011 Midlatitude Continental Convective Clouds Experiment conducted at the SGP site. The experiment was a joint field campaign between ARM and NASA. In that experiment, scientists used a variety of instruments, including a dense network of rain gauges, radars, and wind profilers, to measure clouds and precipitation both at ground level and in the atmosphere.

In the current study, researchers found that the reconfigured wind profilers can supply complementary information from the atmospheric column about surface rainfall and the structure of the precipitation aloft. These results support the use of wind profiler observations as a centerpiece for future rainfall studies.

Reference

Tridon F, A Battaglia, P Kollias, E Luke, and C Williams. 2013. "Signal post-processing and reflectivity calibration of the Atmospheric Radiation Measurement Program 915 MHz wind profilers." *Journal of Atmospheric and Oceanic Technology* 30(6), doi:10.1175/JTECH-D-12-00146.1.

Cloud Cover Homogenizes Arctic Vegetation

Few places on Earth are as vulnerable to even slight changes in environmental conditions as the Arctic tundra—home to plant communities that thrive under cold conditions, weak sunlight, and on permanently frozen soil. The tundra, however, with frozen soil and niche biology, acts as a vast reservoir of carbon—the building block of life—and nitrogen, a critical nutrient stored in plants and released back into to the environment upon decay.

An aerial view taken of the Arctic tundra, near Oliktok Point, Alaska. Photo courtesy of omniterra.com.

A study published in the journal *Global Change Biology* shows that plant communities in the Arctic tundra may adapt their ability to store nitrogen, depending on how the clouds over the region scatter sunlight.

Lorna Street, an ecologist in the University of Edinburgh, made theoretical calculations about how cloud fraction (and associated solar energy reaching the surface) at five places across Sweden, Greenland, Alaska, and Svalbard can affect the rate of nitrogen and carbon exchange rates within plant communities.

According to Street's calculation, under cloudier conditions, the nitrogen stored in plant leaves is spread more evenly throughout the plant canopy. This means that if a region becomes cloudier in the future, the total amount of nitrogen stored in plant leaves could increase, even double.

Street and her colleagues used data from the ARM Facility to verify the effects of diffuse versus direct solar radiation on the allocation of leaf nitrogen in Arctic plant communities.

Clouds scatter incoming sunlight. Under cloudy conditions, the amount of sunlight reaching the Earth is more even, or diffuse. In areas without clouds or other light-scattering elements in the atmosphere, sunlight reaches the surface like a beam of light or direct radiation.

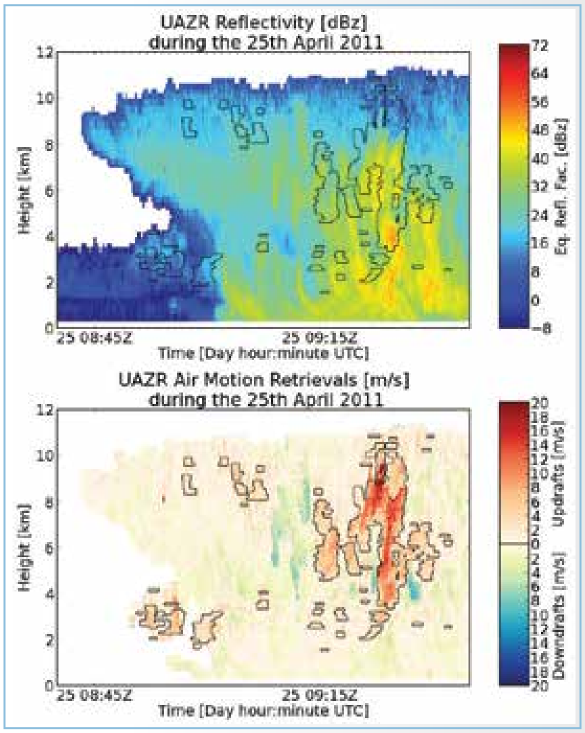
"We argued that some site-level [regional] differences in nitrogen allocation could be explained theoretically by the amount of diffuse radiation, i.e., where radiation is more diffuse, leaf N [nitrogen] allocation is more uniform due to greater light penetration into the canopy. Our field measurements, together with radiation data from ARM, supported this argument," explained Street in an email.

Changes in nitrogen content affect the rate of decomposition, and hence, the amount of nitrogen and carbon that is released back to the atmosphere, as well as below the surface of the soil, where plants use nitrogen as a nutrient. The impact of this study, however, goes even further —in improving ecological models that attempt to simulate how Arctic vegetation will change in response to changing environmental conditions.

Reference

Street LE, GR Shaver, EB Rastetter, MT van Wijk, BA Kaye, and M Williams. 2012. "Incident radiation and the allocation of nitrogen within Arctic plant canopies: implications for predicting gross primary productivity." *Global Change Biology* 18(9), doi:10.1111/j.1365-2486.2012.02754.x.

New Insights into Deep Convective Core Vertical Velocities Using ARM UHF Wind Profilers



For decades, measurements from profiling radars within continental convective thunderstorms provided unique insights into vertical velocity. However, new operating modes unique to ARM UHF wind profilers operate using vertically pointing modes to take samples through deep overhead convection. This matches the sampling requirements for capturing properties typical of warm-season thunderstorms.

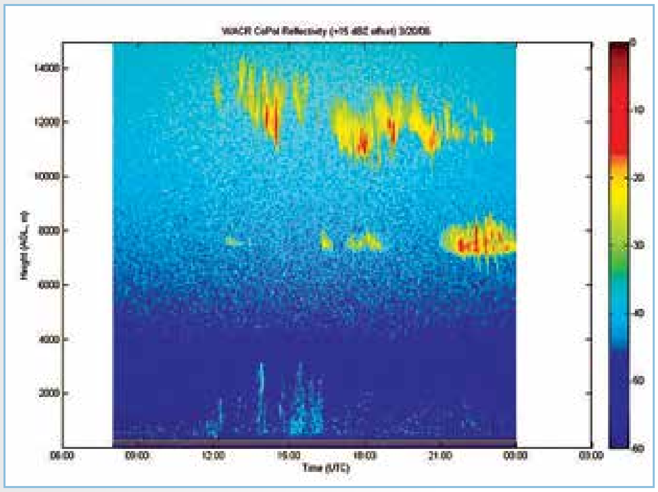
Substantial uncertainty in global climate model predictions of possible climate change can be attributed to the representation of the effects of deep cumulus convection. One important limitation when elucidating the complex interactions between storm dynamics, thermodynamics, and microphysics of deep convection is the practical hazard associated with obtaining direct measurements from within intense convective environments. This includes the measurements of vertical velocity within these deep convective cores, a quantity of known interest as a constraint to the connections between humidity, entrainment, and microphysical treatments of storm-resolving models. Given known aircraft restrictions for flying directly into deep convective clouds, there is a need to advance remote-sensing solutions that encourage longer-term cumulative convective characterization to facilitate cumulus representation in models.

One possible solution explored was the extended deployments of radar wind profilers to estimate vertical air motions in convective systems. Recently, the ARM Facility SGP site reconfigured its existing 915-MHz (UHF) wind profilers to operate in vertically pointing modes to take samples through deep convection passing overhead. New operating modes unique to these commercial Vaisala 915-MHz UHF (33-centimeters wavelength) systems were implemented to better match the sampling requirements for capture of convective core properties typical for warm-season convective storms. This study presented a summary of deep convective updraft and downdraft core properties over the central plains of the United States, accomplished using a novel and now-standard ARM scanning mode for these commercial wind profiler systems. Profiler observations collected during two extended ARM Oklahoma campaigns in 2009 and 2011 were explored. Although these profiler observations cannot replicate aircraft sampling, the study adopted several standard definitions for diameter, intensity of vertical motion, and mass flux from previous airborne efforts.

Capitalizing on the measurements from profiling radars within continental convective thunderstorms has provided unique insights into vertical velocity for decades. Future work will include routine processing of these ARM observations. Advancing these techniques within ARM will also be of additional benefit toward validation of proposed ARM multi-Doppler radar velocity retrieval methodologies in deep convection.

Reference

Giangrande SE, S Collis, J Straka, A Protat, C Williams, and S Krueger. 2013. "A summary of convective core vertical velocity properties using ARM UHF wind profilers in Oklahoma." *Journal of Applied Meteorology and Climatology* 52:2278-2295.



Clouds occurring at different levels in the sky have varying impacts on Earth's energy budget. However, in West Africa, these clouds may have an even more significant impact.

This reflectivity image from the W-Band (95 GHz) ARM Cloud Radar, in Niamey, Niger, demonstrates West African mid-level clouds visible above the surface dust layer and a cirrus layer visible at about 14 kilometers.

West Africa Cloud Survey Reveals Climate Impact of Mid-Level Clouds

Clouds with bases between 5 and 7 kilometers above the Earth's surface, also known as mid-level clouds, occur over West Africa all year-round and may have major impacts on the Earth's energy budget, scientists reported, using a first-ever, detailed survey of cloud types over the region.

Taking advantage of a rich set of ground-based observations collected by the ARM Facility's mobile facility deployed in Niamey, Niger, in 2006, scientists from Europe published a comprehensive survey of different cloud types over West Africa, estimating their impact on the region's climate.

The team identified four types of clouds in the region: cirrus or high-level clouds with bases above 8 kilometers, mid-level clouds with bases between 5-7 kilometers, low-level, and deep convective clouds. The latter two produce rain in the region.

Of these four cloud types, mid-level clouds appear to have the strongest impact on Earth's energy budget. They scatter incoming sunlight but trap outgoing energy from Earth. Being the only ones to do so all year round, they exert a major impact on West African climate.

The only other cloud type that exerts comparable influence on radiation is thunderstorm-causing 'anvil' clouds. However, they only occur in the region during the monsoon season. Thus, their impact on radiation is limited.

Climatologists agree that clouds produce the largest source of uncertainty in climate models. Still, it is difficult to measure the impact of clouds on Earth's energy budget, more so in places like West Africa, where setting up instrumentation is a logistical challenge. This research will provide much-needed information to calibrate weather prediction and climate models.

Reference

Bouniol D, F Couvreux, PH Kamsu-Tamo, M Leplay, F Guichard, F Favot, and EJ O'Connor. 2012. "Diurnal and seasonal cycles of cloud occurrences, types, and radiative impact over West Africa." *Journal of Applied Meteorology and Climatology* 51(3), doi:10.1175/JAMC-D-11-051.1.

Rain and Cloud Resistance

Tropical cloudiness has its own timeline. That's what researchers at Pacific Northwest National Laboratory (PNNL) found when they compared the development of turbulent clouds to timing of atmospheric perturbation that rolls over the region every 60 to 90 days. Contrary to past assumptions, rather than a smooth transition, they found two peaks in cloudiness and rainfall during the active phase of the atmospheric phenomenon known as Madden-Julian Oscillation (MJO).

The research team used high-resolution, ground-based radar data from the ARM site in the TWP to evaluate the impact of MJO on clouds and meteorological conditions over Manus Island. They used data gathered during 13 MJO events over 6 winter seasons to develop a single composite event for evaluation. Data included cloud frequency, precipitation, humidity, temperature, and wind.

Deep tropical clouds are sometimes called the engines of the global climate. They pick up and transport moisture and heat from the ocean into the atmosphere, providing precipitation and driving the global circulation.

Their analysis used a unique view of daily cloud processes, rather than the typical 5-day timescale. They found frequent shallow cloudiness driven by time scales shorter than MJO. Between 4 and 8 days before the MJO convective peak at Manus, deeper convection developed. This was likely inhibited by the dry mid-troposphere, typically not extending beyond 8 kilometers. The team postulated that in previous studies, some of the features of this process may have been masked by the use of 5-year averaged data rather than daily data, or by averaging the cloud and rain characteristics over larger areas.

Scientists are still trying to understand MJO's influence on climate by simulating them in climate models. In this study, they dismissed a previous assumption that a single peak in the timing and intensity of local rain was tied to the passage of MJO. Understanding MJO's impact on climate will help scientists better understand and model MJO, and better project future events influencing climate change.

Reference

Deng L, S McFarlane, and J Flaherty. 2013. "Characteristics associated with the Madden-Julian Oscillation at Manus Island." *Journal of Climate* 26(10), doi:10.1175/JCLI-D-12-00312.1.

ACME Campaign Promotes Interagency Collaboration

The Cessna Turbo 206 aircraft powers up for another flight in the ongoing ARM Airborne Carbon Measurements (ACME) effort over the ARM SGP site. This is a continuation of a multi-institution and multi-agency airborne study of atmospheric composition and carbon cycling. This aircraft is located at the Greenwood Aviation hangar in Ponca City, Oklahoma.

The ARM Airborne Carbon Measurements (ACME) campaign supports studies of atmospheric composition and carbon cycling in North America. Measurements from this campaign give researchers insight on atmospheric sources, sinks, and concentrations of carbon dioxide and other carbon cycle tracers in the SGP region, making them a focal point for evaluating new remote sensing instruments on ground, airborne, and satellite platforms.

DOE is an active member of the U.S. Global Change Research Program (USGCRP) and its carbon cycle interagency working group, which sponsors the U.S. Carbon Cycle Science Plan (CCSP). The ACME campaign works in concert with efforts supported by other agencies to develop the national carbon observing system called for by the CCSP and the North American Carbon Program (NACP).

ACME has contributed to NACP in several ways, including more than 10 publications that explicitly support interagency cooperation for NACP. Data collected during ACME assisted in constructing regional atmospheric carbon dioxide budgets, investigating the effects of atmospheric carbon dioxide on radiation transfer, and informing numerous NACP studies. As a result, ACME constitutes a significant contribution by DOE to USGCRP carbon cycle goals. In addition, ACME data has advanced several NACP measurement programs for such agencies as the National Aeronautics and Space Administration, and National Oceanic and Atmospheric Administration, California Institute of Technology, and Japanese National Institute for Environmental Studies.

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.

Kim Nitschke (white shirt) joined members of the Nauru Government for a walk down memory lane at the ARM Nauru site to help commemorate the site decommissioning, recognized at a closing reception on September 23, 2013.

Site Operations

Success in Nauru

In 1998, ARM leadership ventured to establish an atmospheric measurement site in Nauru despite the challenges—and healthy skepticism—of continuous operations in such a remote location with limited infrastructure. Now, thanks to 15 years of data collected from the site through the cooperation of the Nauruan people, scientists have answered questions about a variety of tropical phenomena, including the El Niño Southern Oscillation, storm clouds and rainfall, and the so-called "island effect."

Site operations and data collection at the ARM observation site on Nauru officially ended on August 30, with all "return to USA" items packed and ready for uplift. Nearly a month later, Kim Nitschke, in his role as oversight manager for ARM Facilities in the TWP, joined three government ministers from the Republic of Nauru for a nostalgic walk through the vacated ARM site. This was followed by a closeout reception to honor the many people who were instrumental in operating the site through the years. Nitschke presented plaques and heartfelt thanks in recognition of all the partnerships, teamwork, data, and memories collected through the years at the tiny island in the Pacific.

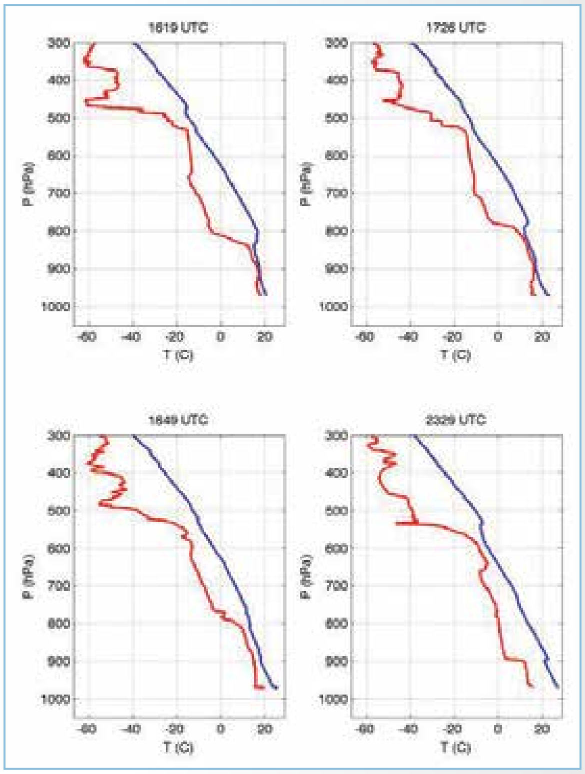
At the closing reception, the Acting President, Minister Cook, graciously accepted the transfer of remaining ARM infrastructure and equipment; the official handover to the Nauru Department of Commerce, Industry, and Environment occurred the following day.

ARM Facility Captures Rare Tornado Data

Every spring, tornadoes thunder across the U.S. Great Plains states, from Kansas to Texas, and alerts are common. But on May 20, 2014, the conditions leading up to the rare EF-5 tornado—the strongest type recorded to-date based on damage estimates—that wreaked havoc in Moore, Oklahoma, provided a unique opportunity for scientists to sample the environment preceding this severe weather event.

Daily operations at the SGP site include weather balloon, or radiosonde, launches every 4 hours to collect vertical data of atmospheric state, which is useful for validating satellite measurements. On the Thursday before the storm, ARM personnel received an emergency request from University of Wisconsin scientists conducting an ongoing satellite validation field campaign at the SGP site. In anticipation of the potential for an unusual weather event, they asked for supplementary radiosondes launches over the weekend and on Monday, coinciding with routine satellite overpasses and a flight plan on file with NASA research aircraft in the area.

Acting quickly, the SGP team confirmed and conducted the extra launches between May 18 and 20, capturing the buildup of conditions leading to the 1.3-mile-wide massive twister. Between the aircraft, satellite, and radiosondes, scientists expect the data set to be very useful in diagnosing the pre-convective storm environment prior to the devastating tornado—research that can potentially improve severe weather predictions.



These graphs illustrate raw data from the additional radiosonde launches preceding the severe weather events of May 20, 2013, in Oklahoma. The blue line identifies the temperature, which decreases with increasing altitude (decreasing pressure). The red line is the dew point; dew point—also expressed as a temperature—is the temperature at which the air is 100 percent saturated with its water vapor content (low values of the dew point represent low relative humidity). Where the dew point approaches the actual temperature, the air is nearing 100 percent relative humidity, or saturation, near the ground—ideal conditions for tornado events.

Unmanned Aircraft Test Flights Completed at Oliktok Point

In October, a flight team from New Mexico State University (NMSU) began the first in a series of test flights for the ARM Facility to evaluate various unmanned aerial systems (UAS) in the frigid Arctic conditions at Oliktok Point, Alaska. Assisted by the ARM NSA personnel from Sandia National Laboratories, the team conducted and documented short flights by a small unmanned aircraft, micro-helicopter, and tethered balloon over the course of 8 days.

These systems hold the potential for autonomous research flights over the Arctic Ocean from ARM's third and newest mobile facility, stationed for the next several years at Oliktok Point. The Restricted Area at Oliktok Point, R2204, gives ARM the opportunity to gather these critical data. The combination of surface- and sky-based measurement will provide atmospheric data to better understand climate processes in the Arctic and improve the computer models that simulate these processes to predict future climate.

In the future, ARM plans to equip UAS and tethered balloons with various sensors to obtain measurements of clouds, atmospheric conditions, sea ice, and heat exchange in this area. The Federal Aviation Administration is considering other airspace options that would allow additional atmospheric sampling operations to be conducted in the Oliktok area, possibly extending hundreds of miles over the Arctic Ocean.

Because of its small size and light weight (72-inch wingspan and weighing about 22 pounds), the Bat-3 is launched using a bungee-powered catapult from the roof of a vehicle and can land autonomously on fixed wheels. Its modular design fits into two suitcase-sized containers.

New England Winter No Match for ARM Experts

Winter snowfall in the Boston area is not uncommon, and in February 2013 they got it in spades. As luck would have it, the "Blizzicane" touched down in New England just as the AAF team was heading into its first full week of the winter phase of research flights for the TCAP at Cape Cod, Massachusetts.

The AAF team and participating scientists gather for a photo outside the hangar in Hyannis.

After a prolonged power outage in Barnstable, "field base of operations" for the AAF team, operations resumed and the team made up for lost time and then some. They compacted 14 research flights—four more than the previous summer phase—into the remaining flight period, in both clear-air and cloudy conditions. They also accommodated several outreach tours, including a visit by Stephanie Coxe from the office of U.S. Representative William Keating (D-Mass.) and several National Park Service colleagues from Cape Cod National Seashore.

Supplementing the airborne measurements, the MAOS resumed operations at the AMF site at the Seashore from mid-January through mid-March. Both platforms safely weathered the battery of February blizzards and high winds with barely a hitch, thanks to adept bobbing and weaving by AMF operations personnel in close communications with park hosts. For more information, see the *Featured Field Campaigns* section of this report.

Data Advancements

ARM's New Data Discovery Interface is shown in the screenshot above.

Announcing: ARM's New Data Discovery Browser

Containing 400 terabytes of available data and growing every day, ARM's Data Archive can be an intimidating web of measurements and data products. To help users quickly find the atmospheric and climate measurements they need, ARM Data Archive personnel developed a completely new and dynamic tool for accessing and ordering ARM data. The new Data Discovery browser includes helpful features such as filtered search logic; multi-pass data selection; filtering data based on data quality; graphical views of data quality and availability; direct access to data quality reports; and the ever-popular data plots.

To begin, users can choose to browse by measurement category or enter a keyword search. See *http://www.archive.arm.gov/discovery/* to try it.

Collaborative Climate Research with India Now Official

A new cooperative agreement between the DOE and the Indian Institute of Science (IISc) formalizes efforts between the two countries to study aerosols and cloud processes and their influence on the transfer of energy through the atmosphere—called radiative transfer—and the Indian Monsoon. The official Memorandum of Understanding, signed in March and effective for 10 years, establishes a framework for collaboration between DOE and the Indian atmospheric research community through the ARM Facility and related science and education activities and exchanges.

Scientific collaborations between the United States and India have been recognized since an official Agreement on Science and Technology Cooperation was signed in 2005. This was followed by the first MOU, signed in April 2011, for ARM to conduct the Ganges Valley Aerosol Experiment in Nainital, India. This year, ARM installed a single-particle soot photometer at the IISc aerosol laboratory in Challakere, located about 150 kilometers north of IISc headquarters in Bangalore, India. The Challakere campus was established by IISc as part of the region's burgeoning scientific community. The aerosol lab there includes many other instruments provided through IISc for measuring various atmospheric parameters relevant to radiative transfer and climate change.

With the new MOU in place, joint experiments can be conducted in both the United States and India, and visiting scientists will be hosted by both countries. In addition, data from this agreement can be stored in the ARM Data Archive, allowing scientists around the world to access these critical data for climate research.

Located at the IISc aerosol lab at Challakere, the single-particle soot photometer can measure the concentration of aerosol particles as small as 10 nanograms per meter cubed. These data, combined with those from IISc instruments, are being used by the collaborators in an experiment to characterize the mixing state of black carbon.

Status of Value-Added Products for FY2013. Many of the scientific needs of the ARM Climate Research Facility are met through the analysis and processing of existing data products into VAPs. VAPs 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 is released to the ARM Data Archive. A brief status of VAPs for FY2013 is provided below; *for more detailed descriptions of these VAPs, see the Value-Added Product Descriptions section at the end of this report*.

13 new VAPs initiated:

SASHE AOD
SASHE Langley
UAPARSAL
ARMBE LAND
NDROP
OACOMP
PBLHT
QPE
MWRET2
MKAZR
MWACR
SST
SASHECIP

13 products released to evaluation:

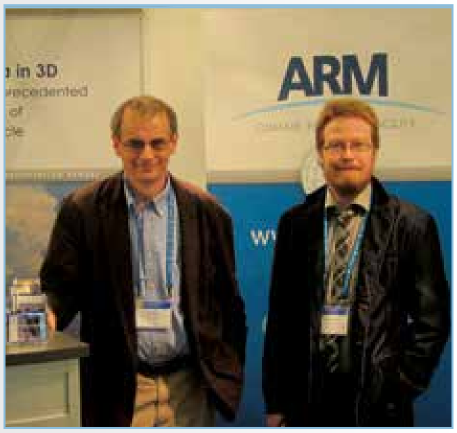
ARMBE LAND
BBHRP/RIPBE – MC3E period
CMAC
KAZRARSCL
NDROP
OACOMP
PBLHT SONDE
PYART
SASHE AOD
SASHE LANGLEY
QPE
VVSR
VARANAL – AMIE GAN

12 products released to production:

AOSCCNAVG
MFRSRCLDOD – Additional sites and AMFs
PBLHT SONDE – All sites for historical data and all AMFs
SURFSPECALB – NSA
INTERPSONDE
MERGESONDE2
SONDEADJUST
RLPROFTEMP
QCECOR
SASHEAOD
SASHELANGLEY
WACRARSCL – some AMFs

Communication and Community Outreach

Reaching Out to the European Science Community



ARM Technical Director, Jim Mather (left), and Tuukka Petäjä (right) pause for a photo at the ARM booth during EGU 2013. Petäjä is the principal investigator for the Biogenic Aerosols-Effects on Clouds and Climate (BAECC) field campaign, which takes place in Hyytiala, Finland, in 2014.

In April, representatives from the ARM Facility joined more than 11,000 scientists from 95 countries at the 2014 European Geosciences Union General Assembly in Vienna, Austria. They presented information about ARM in several sessions and answered questions posed by numerous visitors to the ARM booth in the Assembly's exhibit area. The weeklong meeting saw 4,684 oral, 8,207 poster, and 452 PICO (presenting interactive content) presentations.

This was the second time the ARM Facility has participated in the assembly. About 200 visitors stopped by the ARM booth to pick up information and ask questions. The most common inquiry—leading to further questions and interest—was incredulity that all ARM data are freely available to anyone. Another popular topic was the ARM Mobile Facilities, with visitors interested in field campaigns ranging from Bulgaria and Chile to the Mediterranean and Caribbean.

The EGU General Assembly provides a key forum for heightened awareness about the ARM Facility within the European science community. As both parties are seeking to strengthen ties and mutual observational capabilities, ARM's presence at the largest European meeting for atmospheric science enhances European scientists understanding about ARM capabilities and data.

Junior Rangers Enjoy Science Education at Cape Cod

Children and adults join in the balloon launch countdown at the ARM Mobile Facility site at Cape Cod National Seashore. Weather balloons were launched at regular intervals four times per day throughout the one-year campaign.

School break means vacation, and around Cape Cod, that often means a trip to the seashore. On April 17, families looking for fun and educational outdoor activities spent several hours at Cape Cod National Seashore's Highlands Center for Junior Ranger Day. They were drawn to an event announcement in the park activities newsletter that read, "Kids can participate in a weather balloon launch countdown with park rangers at a special atmospheric observation station located in the park."

From July 2012 through June 2013, the ARM Mobile Facility operated at the park's Highland Center for the Two-Column Aerosol Project. Through an agreement with the park's education team, ARM supported science education activities with an onsite "education ranger" throughout the deployment. The Junior Ranger Day was one of their last educational activities.

A total of 43 junior (and not-so-junior) rangers—25 children and 18 adults—from areas north and west of Boston, as well as local families from one end of the Cape to the other, participated in the event. In addition to the balloon launch, learning activities included:

- Observing the Water Cycle
- Name that Cloud
- Temperature Matters
- It's Leafing Out: Observing Plants.

A Twist on Twister™ at Community Science Nights

In support of science, technology, engineering, and math (known as "STEM") education efforts, the ARM Facility develops and shares climate related lesson plans at public science events and via the ARM website. In November 2012, ARM communications staff from PNNL participated in the popular Chief Joseph Middle School Science Night in Richland, Washington for the third year running. They introduced ARM's latest learning game, Cloud Twist, spinning the arrow and calling out cloud names—cirrus, stratus, cumulus, and fog—to reinforce cloud types with flexible children. Meanwhile, an atmospheric scientist also from PNNL provided hands-on demonstrations of cloud-in-a-bottle.

ARM outreach staff, Stacy Larsen, challenged student's flexibility and knowledge of cloud types with ARM's latest learning activity, Cloud Twist, at Horse Heaven Hill's Science Madness. Instead of colored circles, students spin the arrow among four different clouds types to guide their next move.

On February 26, 2013, Science Madness was the theme at Horse Heaven Hills Middle School's Science Night in Kennewick, Washington. In addition to Cloud Twist and cloud-in-a-bottle, kids also learned how to make their own anemometer, a device for measuring wind speed. This was the first time ARM Educational Outreach participated in the event. Both science nights were open to the public and very well attended.

Designed to energize kids about science through more hands-on science activities and physical demonstrations, these events provide an opportunity for ARM Educational Outreach to share new activities and lessons plans—developed with teacher input—with teachers, students, and parents. Fun activities, like Cloud Twist, engage students in science and expose them to new concepts and ideas while supporting ARM's STEM efforts.

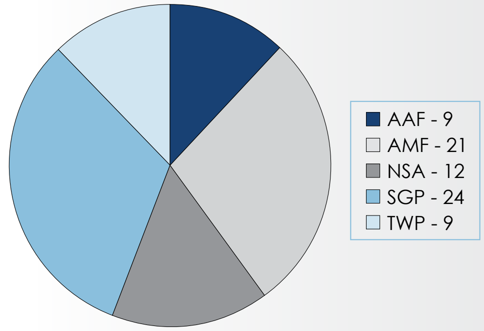
Field Campaign **SUMMARY**

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 figure here shows the total number of field campaigns and special data set collections that occurred in FY2013, including these ongoing efforts. The subsequent table summarizes just those campaigns that began in FY2013. For more information, visit the Field Campaign web page at

www.arm.gov/campaigns

Total 2013 Field Campaigns



Campaign Name	Dates	Status	Description
ARM Aerial Facility			
ARM Airborne Carbon Measurements IV (ARM-ACME IV)	October 2013–September 2014	In Progress	The goal of this campaign is to quantify trends and variability in atmospheric concentrations of carbon dioxide and other greenhouse gases in North America, and to improve understanding of the influence of convective processes, advection, and boundary-layer-free troposphere exchanges on atmospheric carbon dioxide concentrations.
Biomass Burning Observation Project (BBOP)	July 2013–October 2013	Completed	By means of aircraft measurements in biomass burning plumes, this field campaign addressed multiple uncertainties in aerosol intensive properties, which are poorly represented in climate models. Key topics investigated were: (1) aerosol mixing state and morphology; (2) mass absorption coefficients; (3) chemical composition of non-refractory material associated with light-absorbing carbon; (4) Production rate of secondary organic aerosols; (5) microphysical processes relevant to determining aerosol size distributions and single scattering albedo; and (6) cloud condensation nuclei activity.
Laboratory and Airborne Tests of Fast Cloud Droplet Probe (FCDP)	June 2013–November 2013	Completed	Laboratory and airborne measurements with an upgraded PNNL Fast Cloud Droplet Probe (FCDP) were conducted to evaluate the performance of the FCDP, and to provide improved in situ measurements that could be used to improve our understanding of remote retrievals and numerical models.
ARM Mobile Facility			
GOAMAZON: Observations and Modeling of the Green Ocean Amazon: SKIP Pre-campaign Measurements	March 2013–December 2015	In Progress	The Self-Kontained Instrument Platform (SKIP) container was deployed at the GOAMAZON site in Manacapuru, containing a basic set of meteorological and radiometric instrumentation including: SMET, SKYRAD, GRNRAD, and ceilometer, all ARM instruments. Los Alamos National Laboratory provided an ozone monitor and a nitric oxide/ nitrogen dioxide monitor as well.
MAGIC: Marine Ice Nuclei Collections	June 2013–September 2013	Completed	This campaign augmented existing measurements obtained through the AMF deployment for the MAGIC field campaign. With shipboard aerosol collections for offline processing, ice nuclei concentrations and their association with aerosol properties were measured.
MAGIC: Measuring the Composition of Aerosol Particles	July 2013–September 2013	Completed	In July 2013, during the second MAGIC IOP, this work aimed to measure chemical composition of aerosol particles of different origins.

Campaign Name	Dates	Status	Description
ARM Mobile Facility			
MAGIC: Shortwave Hyperspectral Observations	July 2013–September 2013	Completed	Using the shortwave hyperspectral observations of the Solar Spectral Flux Radiometer (SSFR), researchers retrieved cloud optical thickness and cloud effective particle radius, studying the particles in the transition zone between cloud and cloudless skies. They also worked to expand the spectral range of other aerosol retrievals being performed during MAGIC.
MAGIC: Parsivel Disdrometer Support	October 2012–September 2013	Completed	As a means to monitor and provide constraints on the calibration of the radars, a disdrometer was deployed on the ship during the MAGIC campaign.
MAGIC: Ultra-High Sensitivity Aerosol Spectrometer (UHSAS)	October 2012–September 2013	Completed	UHSAS was deployed with the second AMF2 during the MAGIC campaign. The UHSAS used a high intensity infrared laser to count and size individual aerosol particles.
Marine ARM GPCI Investigation of Clouds (MAGIC)	October 2012–September 2013	Completed	AMF2 was deployed on the Horizon Lines cargo ship, *Spirit*, traversing the route between Los Angeles, California, and Honolulu, Hawaii, for 1 full year. During this period, the AMF2 observed and characterized properties of clouds and precipitation, aerosols, and atmospheric radiation, standard meteorological and oceanographic variables, and atmospheric structure. For more information, see the Featured Field Campaigns section of this report.
MAGIC: Cloud Properties from Zenith Radiance Data	October 2012–September 2013	Completed	This campaign had three goals. First, liquid water path was estimated. Second, cloud droplet size retrievals were used to investigate the link between cloud droplet size and precipitation efficiency. Third, sunphotometer measurements were compared to those from the new ARM shortwave spectrometer (SAS-Ze) to explore new uses of the spectrometer.
Two-Column Aerosol Project (TCAP): Winter Aerosol Effects on Cloud Formation	February 2013	Completed	The objective of this study was to determine the effect of aerosol properties on cloud droplet formation in situ and in real time. To accomplish this, a cloud condensation nuclei chamber was combined with a pumped counterflow virtual impactor, separating droplets formed as a function of saturation and temperature from the unactivated aerosols. The composition of the droplet-forming aerosols was then determined with an Aerosol Mass Spectrometer (an instrument provided by Aerodyne Research, Inc., Billerica, Massachusetts) and/or a single particle mass spectrometer.
Two-Column Aerosol Project (TCAP): Field Evaluation of Real-time Cloud OD Sensor TWST	April 2013–June 2013	Completed	This was a project by Aerodyne Research, Inc., to demonstrate the field-worthiness and assess the performance of a real-time Cloud OD sensor (dubbed TWST). This was accomplished through a side-by-side comparison with proven, ground-based operational sensors for the TCAP AMF deployment on the Cape Cod National Seashore.

Campaign Name	Dates	Status	Description
North Slope of Alaska			
Arctic Observing Experiment	March 2013–March 2014	In Progress	The goal of this campaign is to assess the ability to measure polar region parameters during: the Arctic Observing Experiment (AOX), supporting the International Arctic Buoy Programme (IABP); the Arctic Observing Network (AON); the International Program for Antarctic Buoys (IPAB); the BRomine Ozone and Mercury EXperiment (BROMEX); and the Southern Ocean Observing System (SOOS).
North Slope of Alaska Scanning Radar Intensive Operational Period	May 2013–June 2013	Completed	Observations from the Scanning ARM Cloud Radars (SACRs) and Scanning ARM Precipitation Radars (SAPRs) are vital to improving the ability to document the mesoscale structure of cloud systems and improve the ability to retrieve qualitative and quantitative cloud microphysical information. To this end, this campaign aimed to optimize the way cloud systems are sampled using ARM radars to assess the ability to provide high-quality measurements.
Off-Site Campaigns			
Characterization of Black Carbon Mixing State	November 2012–July 2013	Completed	The objective of the proposed experiments was to characterize the mixing state of black carbon produced in biomass burning using the single particle soot photometer. Specifically, the campaign examined two primary BC emission sources: (1) urban settings and (2) biomass burning. Source (1) was captured at the Indian Institute of Science (IISc) in Bangalore. Source (2) entailed a series of 1-2 day measurement excursions to the rural area surrounding Bangalore.
International Arctic Systems for Observing the Atmosphere (IASOA) Metadata Harvest Design Effort	May 2013–August 2013	Completed	IASOA was initiated as an International Polar Year project to address key atmospheric science questions by coordinating the considerable atmospheric observing assets at nine (now ten) pan-Arctic observatories (*http://iasoa.org*). The mission of IASOA was to advance cross-site research objectives from independent Arctic atmospheric observatories through: (1) strategically developing comprehensive observational capacities; (2) facilitating data access and usability through a single gateway; and (3) mobilizing contributions to synergistic science and socially relevant services derived from IASOA assets and expertise.
Radar Wind Profiler for Cloud Forecasting at Brookhaven National Laboratory	July 2013–July 2015	In Progress	This campaign will provide profiles of the horizontal wind to be used to test and validate short-term cloud advection forecasts for solar energy applications, providing vertical profiling capabilities for the study of dynamics and hydrometeors in winter storms.
Severe and Winter Weather Warnings Experiment	April 2013–April 2014	In Progress	The National Weather Service's (NWS) primary mission is the protection of life and property of those residing in the United States and its territories. Using the Weather Surveillance Radar (WSR)–88D to interrogate storms, sample the atmosphere, and provide data for Numerical Weather Prediction (NWP) models, this campaign provided information to improve NWS' ability to fulfill its mission.

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Campaign Name	Dates	Status	Description
Southern Great Plains			
Role of Surface Energy Fluxes for Wind Energy	November 2012–July 2013	Completed	To improve wind forecasting, ARM SGP provided an ideal test site for studying the impact of the subsurface-surface-energy balance on observed and modeled wind speed and turbulence profiles.
Along Line of Site Experiment (ALOSE)	December 2012	Completed	ALOSE was a five-deployment campaign to observe the space and time structure and variability of atmospheric structure for different climate zones. The campaigns included the SGP ARM-site for the months of December, April, and July 2013, the ARM TWP site in Darwin, Australia, during September–October, 2013, and the University of Alaska Poker Flat Research Range (APRR) near Fairbanks, Alaska, during February 2013.
ALOSE: Along Line of Site Experiment 4	July 2013	Completed	ALOSE 4 was conducted at the ARM SGP site as part of a five-deployment campaign to observe space and time variability of atmospheric structures for different climate zones. The objective of these campaigns was the validation of mesoscale structure forecasts by atmospheric prediction models.
Global Energy and Water Cycle Experiment (GEWEX) Synergy Study	March 2013–February 2014	In Progress	For comparison to current GEWEX gridded data products, this study aims to assess the representativeness and uncertainties in point measurements from the ARM sites.
New Particle Formation Study 2013 (NPFS2013)	April 2013–May 2013	Completed	The scientific foci of this study were the formation and evolution of atmospheric aerosols and the impacts of these newly formed aerosols on cloud processes. Specifically, to (1) identify the species and mechanisms responsible for the initial steps of new particle formation; (2) investigate the role of acid-base chemistry in new particle growth; (3) investigate the contribution of other surface area or volume-controlled processes to nanoparticle formation and growth; (4) create a comprehensive data set related to new particle formation; (5) characterize the increase in number and activity of cloud condensation nuclei due to particle formation and growth; and (6) determine the regional extent of new particle formation.
Phased-Array Sensitivity Study	February 2013–March 2013	Completed	This campaign deployed the phased-array radar 2 miles north of the ARM SGP Central Facility (CF) to collect half-day observations, sampling a sector of 60 degrees in azimuth centered around the CF. The phased-array radar observations were analyzed and compared with the observations from the SACR, the KAZR, and the SAPR's at the SGP site. The phased-array data was converted to netcdf by Prosensing and analyzed by McGill University researchers.
Radon Measurements of Atmospheric Mixing (RAMIX 2013)	March 2013–February 2014	In Progress	RAMIX 2013 will continue to collect radon mixing ratio data from the 60-meter tower with the objective of using the radon measurements to help estimate regional carbon dioxide (and later methane) exchange. The project will be conducted with existing instrumentation already operational at the ARM SGP facility.
Semi-Arid Land Surface Temperature and IASI Calibration Experiment (SALSTICE)	May 2013	Completed	SALSTICE had two aligned objectives: (1) diagnosis of surface temperature errors in the Met Office Unified Model, and (2) calibration of IASI-2 (MetOp-B) Level 1b/c radiances and geophysical validation of IASI level 2 products.

Campaign Name	Dates	Status	Description
Southern Great Plains			
Semi-Continuous OCEC Particulate Measurement	June 2013–November 2013	Completed	This campaign's goal was to determine black elemental carbon (EC) by the thermal-optical method, and to determine independent EC by measuring the change of absorbance on the collection filter during collection periods. This was then compared to the thermal/optical measurement of EC.
University of California, San Diego Sky Imager Cloud Position Study	March 2013–October 2013	Completed	The purpose of this study was to improve short-term solar power forecasting algorithms, which used imagery as input. Novel computer vision stereography techniques were employed to compute the cloud-base height for the region between the instruments, and, to the extent that it was possible, outside the instrument areas within an acceptable perimeter.
Tropical Western Pacific			
ALOSE: Along Line of Site Experiment 5	September 2013–October 2013	Completed	ALOSE 5 was held at the ARM TWP site in Darwin, Australia, as part of a five-deployment campaign to observe space and time variability of atmospheric structures for different climate zones. The objective of these campaigns was the validation of mesoscale structure forecasts by atmospheric prediction models.
Lidar Inter-comparison Exercise	January 2013–May 2013	Completed	The objective of this campaign was to evaluate the performances of the new Leosphere R-MAN 510 lidar by testing it against the micropulse and Raman lidars at the ARM TWP Darwin site in Australia.
Manus Water Isotope Investigation	April 2013–March 2016	In Progress	This campaign's research involved: (1) establishing a field component for a rainwater and seawater collection program by measuring water vapor isotopes continuously during a site visit to Manus; (2) measuring the stable isotopic composition of waters collected from Manus; and (3) analyzing the water isotope data in the context of onsite meteorological data and gridded climate data sets.

Value-Added Product **Descriptions**

ARM Value-Added Products	Descriptions
ACRED: ARM Cloud Retrieval Ensemble Data	ACRED is a multi-year cloud microphysical property ensemble data set created by assembling existing ARM cloud retrievals, which are based on multiple cloud-retrieval algorithms.
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.
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.
AEROSOLBE: Aerosol Best Estimate	AEROSOLBE provides temporally and spatially continuous vertical profiles of ambient aerosol optical properties, including scattering, absorption, and extinction coefficients; single-scattering albedo; and asymmetry parameters.
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.
AMT: Aerosol Modeling Testbed	AMT is a means of organizing a wide range of measurements into a single data set that modelers can use to evaluate the performance of aerosol, chemical, and meteorological process modules.
AOD: Aerosol Optical Depth	AOD generates robust calibrations for the Multifilter Rotating Shadowband Radiometer (MFRSR) and Normal Incidence Multifilter Radiometer (NIMFR) from Langley analysis, applies this calibration to the irradiance data, applies a moving filter cloud screen to identify cloud events, and computes aerosol optical depths.
AOSCCNAVG: Average of Cloud Condensation Nuclei from AOS	AOSCCNAVG consolidates the relevant cloud condensation nuclei parameters into a single file and averages the data over the integration time of each value of percent super saturation.
AOSCORR: Aerosol Observing System Correction	AOSCORR applies instrument corrections and calibrations to the historical NOAA AOS data.
ARMBEATM: ARM Best Estimate for ATMospheric state variables	ARMBEATM provides a best estimate of several selected atmospheric quantities from the ARM Facility observations and NWP analysis.
ARMBECLDRAD: ARM Best Estimate for CLouD and RADiative fluxes	ARMBECLDRAD provides a best estimate of several selected cloud- and radiation-relevant quantities from the ARM Facility observations.
ARMBELAND: ARM Best Estimate for LAND	ARMBELAND contains several critical soil quantities for describing land properties in support of community land atmospheric research and land model developments.
ARSCL: Active Remote Sensing of CLouds	ARSCL combines data from multiple active remote sensing instruments to provide fundamental information for retrieving cloud microphysical properties and assessing the radiative effects of clouds on climate.
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.
BBHRP: Broadband Heating Rate Profile	BBHRP employs output from several VAPs as input to a state-of-the-art radiative transfer model that produces profiles of broadband radiative heating rates.
BEFLUX: Best-Estimate Surface Radiative Flux	BEFLUX processes data from three SGP radiometer systems to obtain the best estimate of all surface radiative energy budget terms.

ARM Value-Added Products	Descriptions
CCNPROF: Cloud Concentration Nuclei Profile	CCNPROF removes the influence of humidification from measurements of aerosol extinction and ties this value to the cloud condensation nuclei concentration measured from the ground. Data collected on the ground is projected to the cloud base to study influences of aerosols on droplet formation in clouds.
CLDCLASS: CLouD CLASSification	CLDCLASS uses different ground-based sensors to classify cloud phase and cloud type in different climate regions.
CMAC: Corrected Moments in Antenna Coordinates	CMAC provides radar information corrected for instrument and atmospheric error at the SGP facility.
CONVV: Convective Vertical Velocity	CONVV retrieves storm motions from multiple Doppler radars and other instruments to produce a best estimate of convective vertical velocity.
GVRPWV: G-Band Vapor Radiometer Precipitable Water Vapor	GVRPWV transforms data from the G-Band Vapor Radiometer into the amount of water vapor capable of precipitating.
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.
KAZR-ARSCL: Ka-band Zenith-Pointing Radar Active Remote Sensing of Clouds	KAZR-ARSCL combines measurements from multiple instruments to produce height distributions of water or ice particles in clouds, with information related to their sizes, motions, and temperatures.
LANGLEY: SASHE 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: Liebe Scaled Sonde	LSSONDE generates radiosonde profiles using the profile of relative humidity scaled to match the profile of precipitable water vapor.
MERGESONDE: Merged Sounding	MERGESONDE uses a combination of observations from meteorological instruments on the ground and radiosondes with output of a weather forecast model to define profiles of the atmospheric thermodynamic state over time and altitude.
MERGESONDE2: Merged Sounding 2	MERGESONDE2 is a second version of MERGESONDE based on humidity-corrected radiosonde and model data.
MFRSRCIP: MFRSR Column Intensive Properties	MFRSRCIP estimates the microphysical (e.g., size distribution) and optical (e.g., single-scattering albedo and asymmetry factor) properties of aerosols.
MFRSRCLDOD: Multifilter Rotating Shadowband Radiometer (MFRSR) Cloud Optical Properties (CLDOD)	MFRSRLDOD generates cloud optical depth and effective radius for overcast liquid water clouds.
MICRO-ARSCL: Micro Active Remote Sensing of Clouds	MICRO-ARSCL provides information about the Doppler characteristics of millimeter-wavelength cloud radars and helps identify radar clutter (e.g., insects).
MICROBASE: Continuous Baseline Microphysical Retrieval	MICROBASE combines observations from several instruments to determine profiles of liquid/ice water content, liquid/ice cloud particle effective radius, and cloud fraction.
MMCG: Mapped Moments to Cartesian Grid	MMCG translates radar information in the form of azimuth, elevation, and range to the horizontal and vertical Cartesian grid used for numerical representations of the atmosphere.

ARM Value-Added Products	Descriptions
MPLAVG: MicroPulse Lidar Polarized Average	MPLAVG uses micropulse lidar polarized data averaged to 30-second intervals.
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. The cloud boundaries also improve the efficiency of the ARSCL data product.
MPLCOD: MicroPulse Lidar Cloud Optical Depth	MPLCOD uses information from lidar and radiosondes to measure the transparency of clouds.
MWRRET: MicroWave Radiometer RETrievals	MWRRET provides precipitable water vapor and liquid water path from the microwave radiometer.
MWRRET2: Microwave Retrieval	MWRRET2 updates the current MWRRET retrieval algorithm to be more flexible.
NDROP: Droplet Number Concentration	NDROP calculates the number concentration of droplets in clouds for studying aerosol-cloud interactions.
OACOMP: Organic Aerosol Component	OACOMP calculates the mass spectra and concentration over time of various organic aerosol components that are associated with different sources, formation and evolution processes, and physicochemical properties.
PBLHT: Planetary Boundary Layer Height	PBLHT estimates the planetary boundary layer height from radiosonde profiles of temperature, humidity, and wind speed.
QCECOR: Quality Controlled Eddy Correlation	QCECOR applies corrections and quality control to measurements of surface turbulent fluxes of momentum, sensible heat, latent heat, and carbon dioxide from eddy correlation flux stations.
QCRAD: Quality Control and Continuity of Surface Radiation Measurements	QCRAD assesses data quality and enhances data continuity for the ARM surface broadband radiation data collected at all ARM facilities.
QPE: Quantitative Precipitation Estimate	QPE uses the output of Mapped Moments to a Cartesian Grid (MMCG) to produce a quantitative estimate of precipitation for data from ARM C-band scanning precipitation radar.
RADFLUX1LONG: Radiative Flux Analysis	RADFLUX1LONG provides continuous estimates of clear-sky shortwave and longwave radiative flux to infer the effects of cloudiness.
RIPBE: Radiatively Important Parameters Best Estimate	RIPBE creates a complete set of radiatively important components of the atmospheric column (water vapor, ozone, and temperature profiles; surface albedo; aerosol properties; and cloud properties) on a uniform vertical and temporal grid to help calculate heating rate profiles and evaluate climate models.
RLPROFASR: Raman Lidar Profiles – Aerosol Scattering Ratio	RLPROFASR computes the profiles of radiative energy scattering and backscatter coefficients from Raman lidar data.
RLPROFBE: Raman Lidar Profiles – Best Estimate	RLPROFBE combines output from all other Raman lidar profile VAPs and interpolates the profiles of aerosol scattering ratio, backscatter, extinction, water vapor mixing ratio, and depolarization ratio to a common vertical and temporal resolution.
RLPROFDEP: Raman Lidar Profiles – Depolarization	RLPROFDEP computes depolarization ratio profiles and cloud optical depth using Raman lidar data.
RLPROFEXT: Raman Lidar Profiles – Extinction	RLPROFEXT computes profiles of aerosol extinction (removal) as well as aerosol optical depth.

ARM Value-Added Products	Descriptions
RLPROFMERGE: Raman Lidar Profiles – Merge	RLPROFMERGE merges the analog and photon counting channels measured by the Raman lidar. These “merged” profiles are then inputted to all other Raman lidar profile VAPs.
RLPROFMR: Raman Lidar Profiles – Mixing Ratio	RLPROFMR computes profiles of water vapor mixing ratio using Raman lidar data and relative humidity profiles.
RLPROFTEMP: Raman Lidar Profiles – Temperature	RLPROFTEMP computes temperature profiles using Raman lidar data.
SFCCLDGRID: SGP Area Surface Cloud and SW Radiation Grid	SFCCLDGRID interpolates measurements of cloud fraction and several types of irradiance to a latitude/longitude grid over the SGP domain.
SONDEADJUST: Sonde Adjust	SONDEADJUST produces data that corrects documented biases in radiosonde humidity measurements.
SURFSPECALB: Surface Spectral Albedo	SFCSPECALB calculates the best-estimate albedo (reflection coefficient) for the multifilter radiometer and the Best-Estimate Surface Radiative Flux broadband shortwave albedo, the dominant surface type, and the spectrally resolved estimated albedo at the SGP CF.
SWFLUXANAL: Shortwave Flux Analysis	SWFLUXANAL uses irradiance data from radiometers located at all ARM facilities to identify clear-sky periods and infer the effect of cloudiness on the measured downward-emitted radiant energy. SWFLUXANAL also infers average fractional sky cover.
TWRMR: Tower Water-Vapor Mixing Ratio	TWRMR calculates water-vapor mixing ratio at two heights on the tower at the SGP CF.
UAPARSAL: UHF ARM Profiler Actively Remotely Sensed Atmospheric Layers	UAPARSAL retrieves storm motions from multiple Doppler radars.
VARANAL: Variational Analysis Products	VARANAL contains large-scale forcing and evaluation data sets for single-column models and cloud resolving models.
VERVELSR: Vertical Velocity in Stratiform Rain	VERVELSR generates profiles of vertical air motion during large-scale liquid precipitation from stratus clouds.
WACR-ARSCL: W-band ARM Cloud Radar Active Remote Sensing of Clouds	WACR-ARSCL combines observations from W-band cloud radar, micropulse lidar, and ceilometer to produce cloud boundaries and time-height profiles of cloud location, radar moments, and linear depolarization ratio fields.

On the inside covers: During the 12-month TCAP campaign, the ARM Mobile Facility obtained data from a bluff overlooking the Atlantic Ocean at Cape Cod National Seashore in Massachusetts.

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