DOE/SC-ARM-12-023

ANNUAL REPORT

ARM

CLIMATE RESEARCH FACILITY

U.S. DEPARTMENT OF ENERGY | Office of Science

2012

New Climate Measurement Sites

In 2012, the Atmospheric Radiation Measurement (ARM) Climate Research Facility began developing two new observation sites: a new ARM Mobile Facility for an extended deployment at Oliktok, Alaska, and a new fixed site on Graciosa Island in the Azores. The new sites are scheduled to be operational by the end of 2013, and they will join ARM's existing suite of permanent climate observation facilities around the world. Proposed instrumentation for the two sites includes:

- Radars: zenith cloud radar, scanning cloud radar, scanning precipitation radar, and radar wind profiler
- Lidars: micropulse lidar, Doppler lidar, and high spectral resolution lidar
- Atmospheric and boundary state: surface meteorological instrumentation, boundary layer cloud system, total sky imager, weighing bucket rain gauge, total precipitation sensor, eddy correlation flux measurement system, disdrometer, sun photometry, and balloon-borne radiosondes
- Aerosol observation system: more than a dozen instruments for measuring aerosol size, composition, and trace gases
- Radiometry: atmospheric emitted radiance interferometer, microwave radiometer, 3-channel microwave radiometer, multifilter rotating shadowband radiometer, broadband shortwave and longwave measurements, and spectral albedo measurements.

Oliktok

The Oliktok site, an extended mobile facility deployment, is located approximately 300 kilometers southeast of the fixed ARM site in Barrow. Measurements in the Arctic are vital because dramatic changes are occurring at rates greater than predicted by any model. One of the most pressing remaining questions is why the Arctic sea ice is melting so much faster than the models predict. Answering that question requires data acquired from over the Arctic sea ice.

As part of the 2004 Mixed-Phase Arctic Cloud Experiment (M-PACE), the Federal Aviation Administration (FAA) granted an area of "restricted airspace," allowing tethered balloon operations to be conducted at Oliktok. The Department of Energy currently has a request pending with the FAA to declare a strip of airspace as a "warning area," beginning offshore of Oliktok and heading several hundred miles toward the North Pole. Warning areas over international waters are the rough equivalent of restricted airspace over U.S. territory.

The combination of restricted airspace and warning area provides the potential for different types of operations from Oliktok, including manned and unmanned aircraft operations out over the sea ice, dropping instrument probes, and operating instrumented tethered balloons over the sea ice. This provides a unique opportunity to couple atmospheric observations with ground-based measurements and measurements from over the Arctic Ocean.

Azores

The Azores is an island group located in the northeastern Atlantic Ocean, a region characterized by marine stratocumulus clouds. The response of these low clouds to changes in atmospheric greenhouse gases and aerosols is a major source of uncertainty in global climate models.

The Azores typically experiences relatively clean conditions with northerly wind flow, but with periodic episodes of continentally influenced polluted air masses. Results from the ARM Mobile Facility campaign conducted in the Azores during 2009–2010 confirmed that the Azores have the right mix of conditions to study how clouds, aerosols, and precipitation interact.

Significant enhancements to instruments previously deployed to the Azores include Ka-/W-band scanning cloud radars, precipitation radars, high spectral resolution lidar, and Doppler lidars. The new fixed site in the Azores is identified as the Eastern North Atlantic (ENA) site and has the full support of the Azorean government and collaborators at the University of the Azores.

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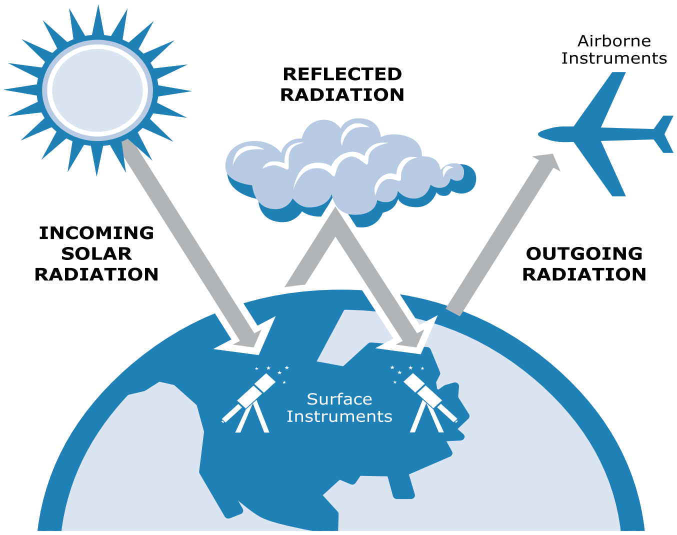
On the cover: From June 2011 to March 2012, the Ganges Valley Aerosol Experiment took place in Nainital, India. The ARM Mobile Facility gathered measurements of clouds, precipitation, and complex aerosols to study their impact on cloud formation and monsoon activity in the region. For more information, see the Featured Field Campaigns section of this report.

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 are the primary tool for quantifying future climate change; however, significant uncertainties remain in the global climate model 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) 2012.

DOE management visits North Slope of Alaska site. *In the summer of 2012, the ARM Facility's Barrow site hosted visitors from the U.S. Department of Energy. As part of an August visit to the Next-Generation Ecosystem Experiments (NGEE) Arctic sites, DOE's Sharlene Weatherwax, Gary Geernaert, and Mike Kuperberg stopped by the Barrow site, located just south of the NGEE field site at the Barrow Environmental Observatory. The Barrow site and staff are providing infrastructure support for NGEE's equipment while their facilities are being built. The NGEE Arctic program seeks to improve the representation of Arctic permafrost processes in coupled earth system models. Weatherwax is the Office of Biological and Environmental Research (BER) Associate Director, and Geernaert is Director of the Climate and Environmental Sciences Division in BER. Kuperberg is a program manager for BER's Terrestrial and Ecosystem Science, the funding organization for NGEE Arctic activities. Before coming to Barrow, the group visited Council, Alaska, near Nome, where another field site will be established for NGEE Arctic.*

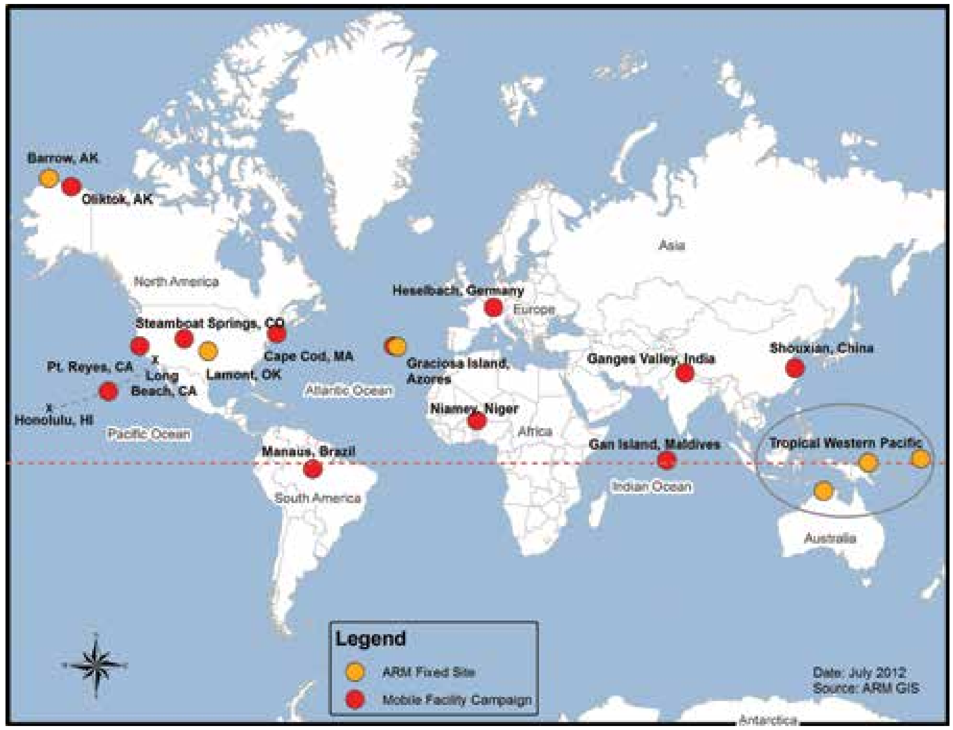
Stalwart of TWP Site Office retires. *After 15 years with the management team for ARM's TWP site office, Larry Jones said goodbye to his co-workers at Los Alamos National Laboratory (LANL) and colleagues throughout the ARM Facility. He said that ARM's overall purpose toward improving climate science made him proud of the work he did every day, and he will especially miss the closeness of the TWP team, including their overseas operations teams.*

Jones stepped into the TWP operations manager role just after the Manus Island site on Papua New Guinea was installed in 1996. He then helped lead the subsequent TWP installations at Nauru Island and Darwin, Australia. He also assisted his colleagues at LANL in the deployment of the first ARM Mobile Facility.

Jones joined LANL in 1988 and worked in the facilities engineering department before joining the ARM team.

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 three 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.

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.

Through the American Recovery and Reinvestment Act of 2009 (Recovery Act), the ARM Facility received $60 million to purchase and deploy new and upgraded instrumentation, equipment, and infrastructure. The ARM Facility's instrument arrays represent some of the most sophisticated tools available for conducting atmospheric research.

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

Development of two new sites began in FY2012: a new fixed site on Graciosa Island in the Azores and a new extended-deployment mobile facility in Oliktok, Alaska (see the inner front cover for more information about these new sites).

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

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

Cooperation and Oversight Enable Success

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

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

Commemorating the visit to the ARM Southern Great Plains site are (left of sign) John Schatz, SGP site operations manager, with Dr. Gyuwon Lee and daughter Sueha Lee; and (right of sign) Dr. Yeon-Hee Kim; Doug Sisterson, SGP site manager; Dr. Seungsook Shin; and Dr. Kwan-Young Chung.

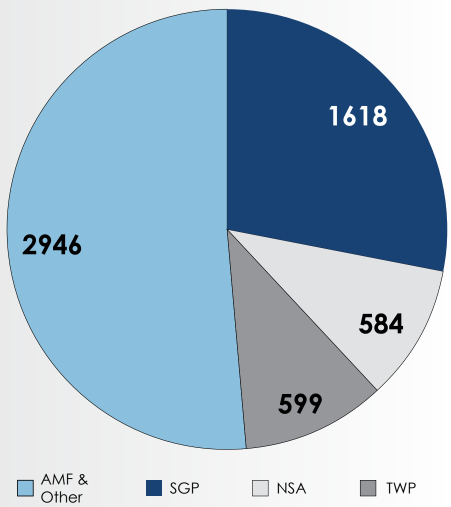
Swapping science with Korean researchers. *To enhance their ability to predict and mitigate the damage from severe weather phenomena, the Korean Meteorological Administration (KMA) is developing a three-dimensional network of ARM-like supersites for observing clouds, water vapor, and other meteorological components. On August 1, 2012, Dr. Kwan-Young Chung, Director of the Forecast Research Laboratory at the KMA's National Institute of Meteorological Research, and scientific colleagues visited ARM's SGP site to discuss their efforts in Korea and to observe operation and maintenance processes.*

Dr. Chung and his colleagues presented on the status and goals of the three KMA supersites, which include instrument rosters comparable to ARM sites, and discussed with SGP staff the daily and long-term operations, methodologies, and opportunities for future collaborations. They then braved record-breaking 114°F heat for a tour of the SGP Central Facility, led by site manager Doug Sisterson, who explained the ARM philosophy for hiring and training technical staff from the local community.

Fiscal Year 2012 Budget Summary and Facility Statistics

FY2012 Budget ($K)	
Infrastructure	*67,679*

Visitor Days by Site



User Statistics for the Period of October 1, 2011–September 30, 2012			
ARM Facility Component	**Unique Scientific Users**	**Unique Non-Scientific Users**	**Totals**
AAF	4	0	4
AMF1	71	62	133
AMF2	54	14	68
NSA	55	46	101
SGP	120	120	240
TWP	38	14	52
Data Management Facility	54	71	125
Computing Cluster	8	17	25
Archive	829	92	921
Total	**1233**	**436**	**1669**

Operational Statistics for the Period of October 1, 2011–September 30, 2012		
	Data Availability (%)	
SITE	**GOAL**	**ACTUAL**
AMF	0.95	0.95
NSA	0.90	0.95
SGP	0.95	0.90
TWP	0.85	0.91
Site Average	**0.90**	**0.95**

Site average is calculated for fixed sites only.

Key
ACCOMPLISHMENTS

Featured Field Campaigns

In addition to providing continuous data collections from its fixed sites, the ARM Facility sponsors field campaigns for scientists to obtain specific data sets or to test and validate instruments. The following pages highlight key campaigns conducted in FY2012. A summary of all ARM Facility campaigns that began in FY2012 is available at the end of this report.

Radiometers at ARM's TWP Manus site gathered data in support of AMIE-Manus.

ARM Madden-Julian Oscillation Investigation Experiment

From October 2011 through March 2012, the ARM Facility obtained data at two locations in the tropics for the ARM Madden-Julian Oscillation Investigation Experiment, or AMIE. AMIE took place in conjunction with the Dynamics of the Madden-Julian Oscillation (DYNAMO) and Cooperative Indian Ocean experiment in intraseasonal variability in the Year 2011 (CINDY2011) campaigns, joining with two dozen other U.S. and international research organizations.

For its first non-U.S. deployment, AMF2 was located on Gan Island in the Maldives, measuring the initiation of the Madden-Julian Oscillation. Instruments at ARM's permanent research site on Manus Island in Papua New Guinea obtained additional measurements of the MJO as it begins to strengthen after passing through the Maritime Continent area of Southeast Asia.

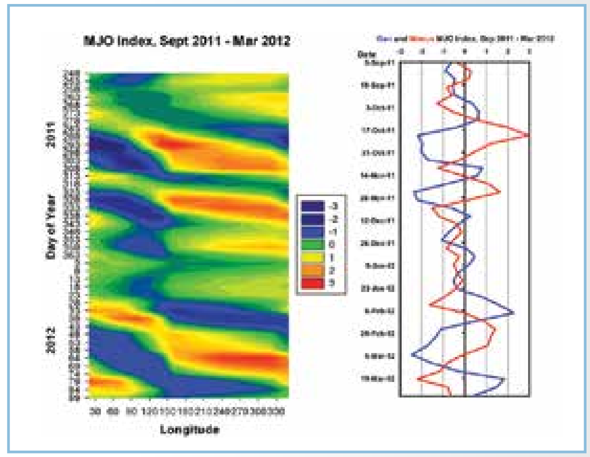
The MJO is a 30–60 day wave that propagates eastward. In the western Pacific, an MJO cycle includes a convectively active phase with widespread maritime convection, increased precipitation, and very cloudy conditions, and a suppressed phase with reduced convective activity and less precipitation.

The MJO dominates tropical intraseasonal variability, but climate models have difficulty predicting its occurrence, as well as its effects and interactions with regional monsoons and El Niño. ARM's unique instrumentation allowed studies of the initiation, propagation, and evolution of convective clouds within the framework of the MJO.

During the campaign, site operations on both Gan and Manus Island included eight-per-day weather balloon launches—one launch every three hours. The overall success rate of sonde launches on Manus landed at 93 percent (without relaunch attempts) and on Gan Island at 98 percent (with relaunches when needed)—an incredible achievement under any circumstances.

The two AMIE campaigns, along with the related collaborative campaigns, will produce a data set that scientists can use to better understand the physical mechanisms behind the MJO and improve the climate models that simulate its effect on global climate.

Results: Through the end of March 2012, each AMIE site experienced multiple MJO events, occurring every 30–40 days. Each system took about 10 days to build eastward from Gan Island to Manus Island. Two Gan Island events, centered on about October 30 and November 30, were stronger, with a weaker event in late December. The first three Manus Island events (September 30, November 9, and December 9) were weaker, due to La Niña conditions, but the final two (February 2 and March 19) were stronger with the dissipation of the La Niña conditions.



These two plots show the occurrence of MJO events at Gan Island and Manus Island from September 2011 through March 2012.

The data gathered during both campaigns show that the MJO is associated with:

- increased mid-level humidity and upper range of column water vapor amounts
- increased low-level westerly and high-level easterly winds
- nearly overcast skies and larger magnitude surface downwelling shortwave cloud effects.

Frequent low and mid-level cloud bases were observed at both sites, with mid-level stable layers slightly more pronounced at Gan Island.

Data from AMIE have been incorporated into several ARM data products that have been made available for evaluation. These data products further enhance the value of the unique AMIE data by providing best estimates and enhanced measurements of instrument observations.

- Ka-Band Zenith-Pointing Radar Active Remote Sensing of Clouds (KAZR-ARSCL)
- Planetary Boundary Layer Height Radiosonde (PBLHTSONDE)
- Mapped Moments to a Cartesian Grid (MMCG)

Additional data products are planned, including a merged data set of KAZR and S-Band polarization radar observations, as well as variational analysis model forcing data sets. For more information on ARM value-added products (VAPs), see the Data Advancements section of this report.

Ganges Valley Aerosol Experiment

From June 2011 to March 2012, the Ganges Valley Aerosol Experiment (GVAX) took place at Nainital, India—the first Indo-U.S. collaborative project to obtain continuous measurements of atmospheric state, energy budgets, clouds, and aerosol properties within India. An intergovernmental agreement with India allowed AMF1 to operate at the Aryabhatta Research Institute of Observational Sciences (ARIES), Observatory.

Instruments deployed on the roof of the ARIES Observatory included radiometers, lidars, and spectrometers.

Growth in industries such as cement factories, steel mills, and the coal-fired plants that power them has added to existing regional sources of aerosols, such as agricultural burning. Tiny particles in the smoke act as hubs for water droplets and ice crystals to gather and form clouds. As these particles and clouds absorb and scatter sunlight, they change the way heat is distributed in the atmosphere. The data gathered by AMF1 will allow researchers to study aerosol effects in the region and determine if they might be drying up clouds that provide moisture to the Ganges River, which millions of people rely on every day.

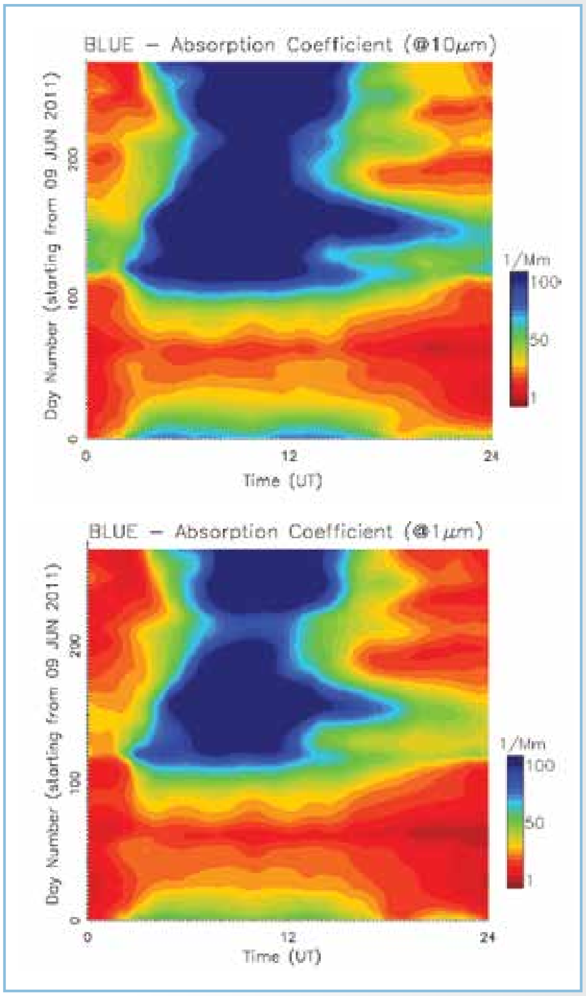
Measurement capabilities for GVAX included meteorological instrumentation, a broadband and spectral radiometer suite, and remote sensing instruments. GVAX represented the first deployment of several new instruments acquired through the Recovery Act. The goal was to obtain various measurements of aerosols, such as composition, size, and evolution. Combined with data from existing ground stations operated elsewhere on the subcontinent, the measurements will show how aerosols absorb or reflect sunlight and can be used to determine how clouds are affected by high concentrations of pollutants.

Working closely with colleagues from ARIES and the Indian Institute of Science (IISc), AMF1 operations began in June 2011 during the monsoon season and continued through the winter, when high pressure confines smoke from post-harvest field burning and increased fossil fuel use. The campaign extended into the dry, hot season, when winds bring dust from deserts to the west.

Results: Data from GVAX suggest the presence of a variety of aerosols, cloud, water vapor, and precipitation characteristics of local and regional origin. Preliminary analysis of aerosol absorption coefficients indicates the presence of strongly absorbing black carbon during the monsoon season. The change in the absorption coefficient from monsoon to post-monsoon is marked by a clear change, indicating a different type of absorbing aerosols. The post-monsoon aerosol was shown to have originated from agricultural waste burning in the northwestern part of the Ganges Valley.

Measurements also show a strong seasonal dependence in the concentration of cloud condensation nuclei, which varied from relatively lower values during monsoon season and then steadily increased during the post-monsoon season and winter. Values were highest during March 2012. This increase corresponds to a measured increase in total aerosol optical depth and a general increase in the number of particles measured by the condensation particle counter (CPC). One distinguishing feature of the data sets is the prevalence of particles of size of the order of 10 microns or more.

Fusion of data from various instruments provides detail on the cloud, aerosol, and precipitating physical and radiative properties. The high temporal resolution of measurements allows scientists to investigate the full spectrum of aerosol and cloud life cycle, from aerosol input to the atmosphere, aerosol nucleation to cloud formation, and precipitation. The analysis of these data is ongoing, and the measurements from this experiment will provide a comprehensive data set for studying atmospheric processes over the highly polluted region of the Indian subcontinent. This will help scientists to constrain global and regional climate models.



Measurements from the particle soot absorption photometer (PSAP) were processed and merged to create a contour map. The top figure shows particles in a size bin less than 10 microns, and the bottom figure shows particles in a size bin less than one micron. Analysis shows that more light is absorbed by the aerosols in the 10-micron size bin.

Absorption in the 1 µm bin is generally attributed to black carbon. The increased absorption in the 10 µm bin could be due to brown carbon (a product of low-temperature combustion such as agricultural waste burning) and dust. Atmospheric emitted radiance interferometer (AERI) measurements at this site will be used to estimate dust contribution to absorption for this region.

2012 Publications Summary	
Category	**Total**
Abstracts or Presentations	242
Books	1
Book Chapters	1
Journal Articles	123
Technical Reports	26
Conference Papers	3
Total	396

Research Highlights

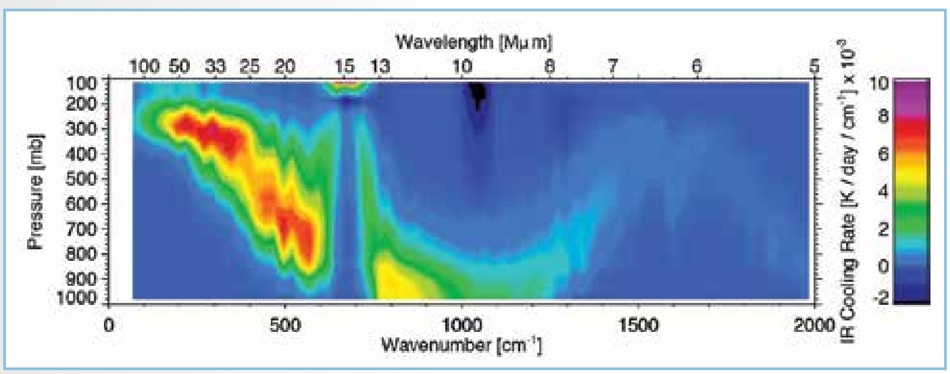
Scientists around the world use data from the ARM Facility for their research. In FY2012, ARM data were cited in a total of 396 publications. The following pages feature a selection of ARM research highlights from these publications. ASR funding is a primary resource for principal investigators who contribute to these highlights. For more publications information, search the ARM Publications Database:

www.arm.gov/publications/publist

Looking at the Full Spectrum for Water Vapor

Absorption and emission of infrared radiation by water high in the atmosphere helps cool the Earth and fuels the updrafts and downdrafts that can lead to cloud formation. Until recently, technology limitations prevented scientists from collecting data in one of the most important subsections of the infrared scale, the far-infrared. Lacking such data, global climate models cannot accurately simulate the movement of heat through the atmosphere.

A two-phased field measurement effort, called the Radiative Heating in Underexplored Band Campaign, or RHUBC, used newly developed spectrometers to gather radiation data across the entire infrared scale. Using these data, researchers were able to improve radiative transfer calculations—the portion of global climate models that simulate how radiant energy moves through the atmosphere.



Radiative cooling across the full infrared spectrum. The far-infrared (the left half of the figure, from 15 to 1000 microns) plays a key role in heat transfer in the atmosphere, but scientists could not measure it, and model calculations were consequently very uncertain. Field observations from newly developed spectrometers, followed by modeling studies, have improved and confirmed advances in radiative transfer calculations.

Earth's climate is driven by the total incoming solar energy versus outgoing infrared energy, as well as how this radiant energy is distributed within the atmosphere. The studies demonstrated and then confirmed that improved radiative transfer calculations can result in significant changes in how climate models predict temperature, humidity, cloud amount, and radiative cooling in the middle and upper troposphere in all regions of the globe, from the tropics to the poles. These types of studies illustrate the importance of using accurate treatments of radiation within global climate models and provide motivation for different modeling groups to improve this aspect of their models—especially since there are large discrepancies among radiation treatments in various models. The RHUBC analysis also identified smaller second-order effects, such as temperature effects on water absorption, which are still deficient in the radiative transfer model and need to be improved.

Scientists used data from the first RHUBC campaign at NSA to revise radiative transfer calculations and test them in a climate model. Compared to the observations, the revised calculations improved model results for water vapor absorption in the far-infrared part of the spectrum by a factor of two. Scientists then used data from the second field measurement campaign, conducted at 17,500 feet in northern Chile's Atacama Desert, where the water vapor amount was five times drier, to evaluate how the revised radiative transfer calculations stood up under different conditions. Data from the second test largely confirmed the improvement in the original calculations.

References: Turner, D, et al. 2012. "Ground-based high spectral resolution observations of the entire terrestrial spectrum under extremely dry conditions." *Geophysical Research Letters* 39: L10801, doi:10.1029/2012GL051542.

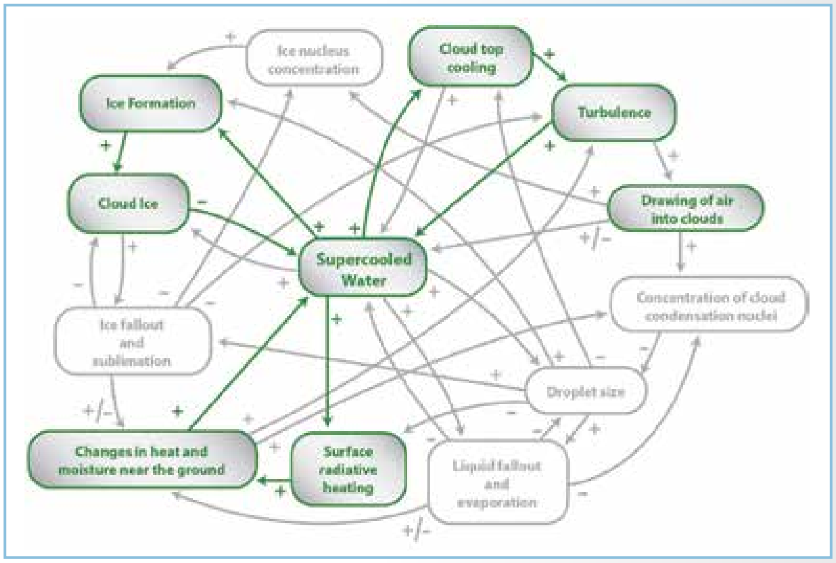
Turner, D, A Merrelli, D Vimont, and E Mlawer. 2012. "Impact of modifying the longwave water vapor continuum absorption model on community Earth system model simulations." *Journal of Geophysical Research* 117:D04106, doi:10.1029/2011JD016440.

Mlawer, E, V Payne, J-L Moncet, J Delamere, M Alvarado, and D Tobin. 2012. "Development and recent evaluation of the MT_CKD model of continuum absorption." *Philosophical Transactions of the Royal Society A* 370: 2520–2556, doi:10.1098/rsta.2011.0295.

Oreopoulos, L, et al. 2012. "The continual intercomparison of radiation codes: Results from phase I." *Journal of Geophysical Research* 117: D06118, doi:10.1029/2011JD016821.

The Complexity of Arctic Clouds

Scientists refer to clouds containing both ice and supercooled water as "mixed-phase" clouds. In the Arctic, these clouds occur frequently during all seasons and can persist for many days at a time. This persistence is remarkable given the inherent instability of ice-liquid mixtures. How is this possible?



Arctic climate feedbacks. The processes that allow mixed-phased clouds to persist in the Arctic are surprisingly complex and could impact the accuracy of climate models.

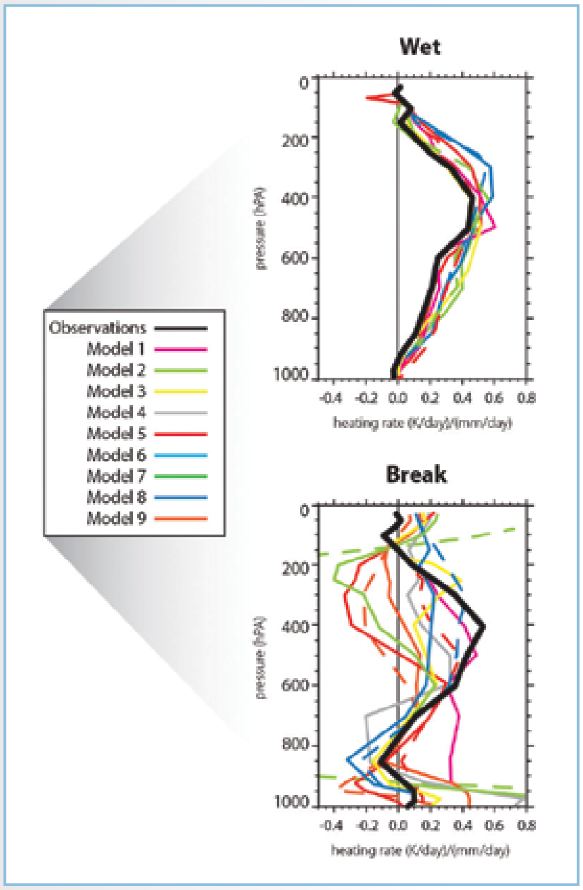
Scientists have identified complex buffering processes that allow mixed-phase clouds to persist in the Arctic long after they would have dissipated in other environments. These processes, including the formation and growth of cloud droplets, limited cloud ice formation, movement of radiation through the tops of clouds, turbulence, and possible contributions from heat and moisture changes near the ground, all participate in an interconnected web of interactions that support the resilience of mixed-phase clouds.

The ability to identify and characterize complex interactions that influence the formation and life cycle of mixed-phase clouds is critical to improve the accuracy of computer models that predict future climate. This is especially true for the Arctic, which is particularly sensitive to climate change. Mixed-phase clouds play a critical role in modulating Arctic energy flow. As little as a 5% shift in the frequency of occurrence between these clouds and clear conditions could have a profound influence on important Arctic climate indicators, including sea-ice concentration, freshwater runoff, and productivity and diversity in marine and terrestrial environments.

Reference: Morrison, H, G de Boer, G Feingold, J Harrington, M Shupe, and K Sulia. 2012. "Resilience of persistent Arctic mixed-phase clouds." *Nature Geoscience* 5: 11–17, doi:10.1038/ngeo1332.

Modeling from a Tropical State of Mind

Scientists have long known that global climate models struggle to accurately simulate tropical storms and the clouds they produce in different kinds of meteorological states. Research has shown that tropical weather patterns can be classified into eight such states, including two monsoon states (active monsoon and break monsoon). Additional research comparing a range of global climate models with observations indicated that the models have more trouble simulating the break monsoon. In simulating the drier conditions of the break monsoon, global climate models gave completely different results about whether it is stormy, the time of day the storms occur, and other important factors. With these limitations in mind, researchers used smaller-scale cloud process models to provide insights into possible ways to improve the global models.



Coming to agreement. Researchers have determined that tropical weather patterns include several states, including wet and break monsoons. Further research is helping identify ways to improve global climate models, which tend to agree with observations on how storms heat the atmosphere in the wet monsoon state but struggle to accurately model storms in the break monsoon state.

Understanding how global climate models simulate tropical weather and clouds allows scientists to pinpoint and resolve areas of concern. For example, researchers found that models in which storm development is more sensitive to atmospheric humidity are more likely to simulate the break monsoon accurately. Cloud-scale modeling also provided insight into several of the physical processes important to tropical weather patterns, such as the effects of downdrafts, the cold pools of air they create, and the broad shields of anvil clouds that accompany some storms. These types of information lead to more robust models of tropical weather patterns, which regulate global climate and influence the severity and duration of precipitation not only in the tropics but also as far away as the U.S.

To identify the states of tropical weather, scientists started with information from a meteorological analysis, which combines available observations with weather prediction models to identify shorter-term weather patterns over a large area. They input these data into a neural network—a statistical way of dealing with large quantities of disparate data to find recurring patterns. They centered their area of analysis on Darwin, Australia, because of its strategic location for observing tropical weather variations and because of the availability of extensive DOE ground-based observations at the ARM site there. They then looked for atmospheric states in which cloud properties were stable over time and distinct from every other state.

To compare the ability of various global climate models to simulate these tropical atmospheric states, scientists then used data from a large DOE field experiment called the Tropical Warm Pool-International Cloud Experiment, or TWP-ICE, to compare results against observations of actual tropical weather. Data from the field experiment also made cloud-scale modeling possible and helped scientists identify potential ways to improve the global models.

References: Evans, SM, RT Marchand, TP Ackerman, and N Beagley. 2012. "Identification and analysis of atmospheric states and associated cloud properties for Darwin, Australia." *Journal of Geophysical Research* 117: doi:10.1029/2011JD017010.

Lin, Y, LJ Donner, J Petch, P Bechtold, J Boyle, SA Klein, T Komori, and C Schumacher. 2012. "TWP-ICE global atmospheric model intercomparison: Convection responsiveness and resolution impact." *Journal of Geophysical Research* 117: doi:10.1029/2011JD017018.

Del Genio, AD, J Wu, and Y Chen. 2012. "Characteristics of mesoscale organization in WRF simulations of convection during TWP-ICE." *Journal of Climate* 25(17): 5666–5688, doi:10.1175/JCLI-D-11-00422.1.

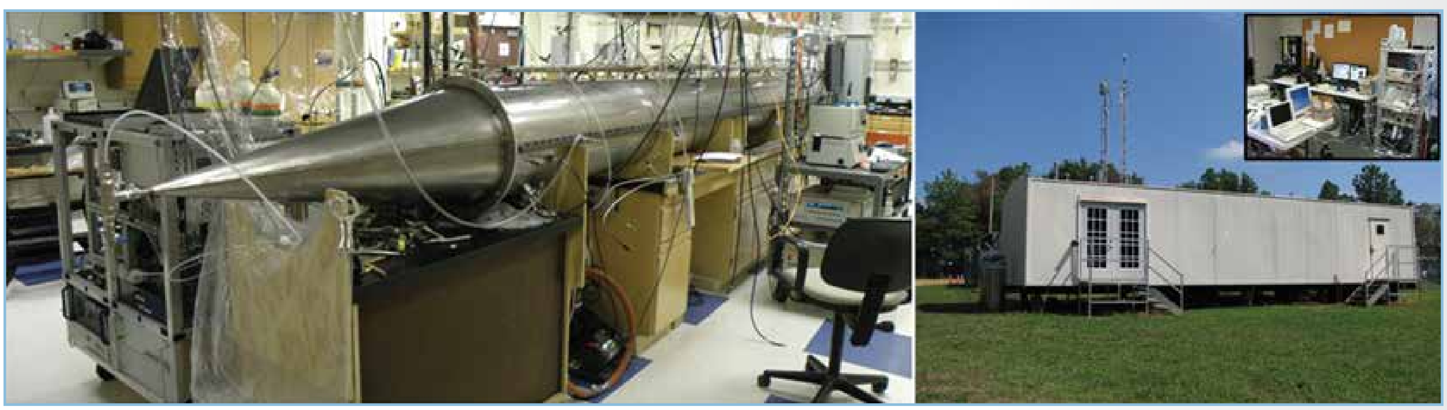
Mrowiec, AA, C Rio, AM Fridlind, AS Ackerman, AD Del Genio, OM Pauluis, AC Varble, and J Fan. 2012. "Analysis of cloud-resolving simulations of a tropical mesoscale convective system observed during TWP-ICE: Vertical fluxes and draft properties in convective and stratiform regions." *Journal of Geophysical Research* 117: doi:10.1029/2012JD017759.

Probing the Birth of New Particles

On local to global scales, newly formed particles contribute significantly to the concentration of atmospheric particles. In general, particles influence climate by affecting the balance of atmospheric radiation, both directly through scattering and absorbing incoming solar radiation and indirectly through impacts on cloud properties and lifetimes. However, the process of particle formation has long puzzled scientists. Currently, researchers model particle formation based on the interactions of only sulfuric acid and water, key components of these particles, but theory and observations simply do not match. The current modeling approach also requires significant computational resources, which can be costly.

Now, researchers have proposed two conceptually new approaches that build on field measurements, laboratory experiments, and theoretical computations. Both approaches tackle the problem of modeling particle formation by looking at the process as a series of acid-base chemical reactions that now include interactions with amines and ammonia. By identifying key steps in the series, these approaches can quantitatively predict formation rates and concentrations of newly formed particles, while keeping the computational cost low enough to be suitable for inclusion in large-scale atmospheric models.

Particle formation plays an important role in predicting aerosol impacts on climate. Realistic assessment of these impacts in large-scale atmospheric simulations depends heavily on particle formation models that not only accurately predict formation rates but require less use of costly computing resources. These two new models provide a framework to better understand formation and incorporate the



The flow of particles. Researchers used complex equipment such as this flow tube (left) and outdoor measurement facilities (right) to determine the series of steps needed to form particles in the atmosphere, resulting in more accurate models.

complex role of amines how these particles and ammonia, which has now been shown to be essential for new particle formation.

Scientists developed the two approaches from different vantage points. One approach involved experiments in a laboratory flow tube in which gaseous chemicals and water vapor interact to form particles. Scientists then measured how the particles were distributed in the vapor using a mobility scanner that determined particle sizes. In the other approach, researchers combined real-world observations from intensive field measurement campaigns in Atlanta and Mexico City with laboratory experiments. Using new instruments developed for this effort, scientists measured a number of previously inaccessible quantities, including the concentrations of reacting vapors and of particles down to sub-nanometer sizes. In both cases, researchers found that by using the new data and identifying the key series of steps needed to form particles, they were able to capture the necessary complexity of particle formation in a simple model.

References: Chen, M, et al. 2012. "Acid-base chemical reaction model for nucleation rates in the polluted atmospheric boundary layer." *Proceedings of the National Academy of Sciences*, doi:10.1073/pnas.1210285109.

Dawson, ML, et al. 2012. "Simplified mechanism for new particle formation from methanesulfonic acid, amines, and water via experiments and ab initio calculations." *Proceedings of the National Academy of Sciences*, doi:10.1073/pnas.1211878109.

More Like Shades of Gray: The Effects of Black Carbon in Aerosols

Black to the core. Scientists are combining field and laboratory measurements to understand more about the physical properties of aerosols containing black carbon and how they impact global warming.

Every day, the incomplete combustion of fossil fuels, biofuels, and biomass forms black carbon particles in the atmosphere. Once deposited in the Arctic, these black carbon particles darken the surface of snow and ice, increasing the amount of the sun's energy converted to heat rather than reflected back to space. At a larger scale, sunlight absorbed by atmospheric black carbon is also converted into heat and increases temperatures, affecting atmospheric circulation and cloud development. What researchers want to know is how much heating takes place and how that change affects global climate.

Through measurements in the field and in the laboratory, research projects in the last year have advanced the understanding of the impacts from black carbon aerosol in the following ways:

- In examining how the amount of black carbon aerosol and the size of snow grains affect heat generation at the Earth's surface, researchers confirmed model predictions and found that the larger the grains of snow, the more heat was generated by the black carbon contamination.

- Research into the different physical characteristics of individual black carbon particles mixed together with other components—commonly modeled as a light-absorbing inner core surrounded by a non-absorbing shell—revealed that many particles are actually shaped differently.

- Measurements of black carbon in the atmosphere around urban centers in California indicate that when black carbon mixes with other atmospheric components, the particle's ability to absorb light and generate heat is significantly less pronounced than often simulated in global climate models.

Various research efforts coupled laboratory and field measurements to yield a better understanding of the concentrations and physical characteristics of aerosols containing black carbon. The research confirmed that black carbon contamination on snow contributes to near world-wide melting of ice, which exacerbates global warming. Using sophisticated instruments, scientists also determined that black carbon particles can adopt a range of internal configurations, which may affect their ability to absorb sunlight and heat the atmosphere. Finally, measurements at specific locations showed that black carbon's influence on light absorption may need to be modeled differently. When combined, the research demonstrates that a more accurate representation of the physical characteristics of black carbon in models can greatly affect the calculated influence of black carbon on global warming and supports development of more effective ways to mitigate its impacts.

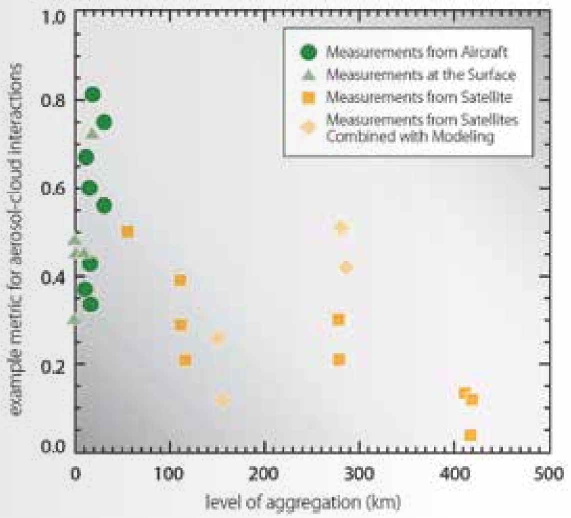
To determine the effect of black carbon and snow grains on heating, researchers generated snow in the laboratory and measured the effects of adding various amounts of black carbon. To learn more about the structure of black carbon, scientists used the Single Particle Soot Photometer, or SP2, one of the few instruments that can quantitatively characterize black carbon down to individual particles. Two of the projects also used observations from a large field measurement campaign funded by DOE, the Carbonaceous Aerosols and Radiative Effects Study (CARES), as the basis for their analyses.

References: Cappa, CD, et al. 2012. "Radiative absorption enhancements due to the mixing state of atmospheric black carbon." *Science* 337:1078, doi:10.1126/science.1223447.

Hadley, OL, and TW Kirchstetter. 2012. "Black-carbon reduction of snow albedo." *Nature Climate Change Letters*: doi:10.1038/NCLIMATE1433.

Sedlacek, AJ, et al. 2012. "Determination of and evidence for non-core-shell structure of particles containing black carbon using the Single-Particle Soot Photometer (SP2)." *Geophysical Research Letters* 39: L06802, doi:10.1029/2012GL050905.

Scale Shows True Weight of Aerosol Effects on Clouds



Differing values. Values derived from aircraft and surface observations, which represent disaggregated data, differ from those derived from satellite-based data, which represent data aggregated at a range of levels. Currently, many climate change models treat the two types of data the same.

Aerosols—tiny airborne particles from sources like pollution or desert dust—can increase the brightness of clouds, changing how much of the sun's energy is reflected or radiated back to space compared to how much is trapped in the atmosphere. Some current climate change estimates are based on models that combine or aggregate aerosol and cloud observations in such a way as to lose important details contained in the observations. Now, researchers have demonstrated that such aggregated data result in computed values, or metrics, of aerosol-cloud interactions that are very different than those derived from disaggregated data. Comparisons of metrics from the two types of data yield a range of values that are often treated as equivalent when, in fact, they may have physically different interpretations.

Disaggregated data represent very specific processes on the fairly small scale of cloud drop formation, while aggregated data represent the full range of processes and feedbacks associated with larger-scale aerosol, cloud, and meteorological conditions. Using this range of metrics in climate models is responsible, in part, for the large uncertainty associated with the impacts of aerosol-cloud interactions on Earth's energy balance. The current research sheds light on oversimplification in the existing range of published metrics and raises the question as to what the range of metrics actually represents.

Based on an understanding of biases revealed in this study, the authors have proposed approaches that combine distributions of small-scale observations, which retain variance in the measured property, with process-scale models. Such approaches include combining multiple available passive and active satellite-based sensors with airborne and ground-based measurements, process-scale modeling, and extrapolating results using disaggregated data. These approaches will lead to more appropriate use of observations in models of future climate, improving the models' accuracy.

To explore the causal relationship between aerosol and cloud properties, the researchers used satellite-based data; ground-based data from the AMF deployment at Pt. Reyes, California; and output from the Weather and Research Forecasting model. As observations became more aggregated, the original range of values was reduced, and the relationship between the aerosol and cloud properties changed. At the fine scale, the specific causal changes were easier to isolate (change x in aerosol equals change y in cloud). However, these causal changes become obscured by many other processes operating at the aggregated scale.

Reference: McComiskey, A, and G Feingold. 2012. "The scale problem in quantifying aerosol indirect effects." *Atmospheric Chemistry and Physics* 12: 1031–1049, doi:10.5194/acp-12-1031-2012.

Infrastructure Achievements

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

Site Operations

Final Recovery Act Milestone Complete

Beginning in 2009, ARM scientists, engineers, operations, and data systems staff worked tirelessly to support the installation and operation of nearly 150 new and upgraded instruments throughout the user facility, the result of Recovery Act funding. In September 2011, ARM received its final three instruments—a radar wind profiler; a micropulse lidar for the Darwin, Australia, site; and a carbon dioxide analyzer for airborne research. Remaining tasks associated with the final calibration of the scanning cloud radars occurred at the fixed and mobile facilities in the first two quarters of FY2012. In total, Recovery Act activities created 138 jobs.

The Darwin site's new Raman lidar (in rear) is housed in a climate-controlled 8'x8'x20' standard shipping container. An additional shelter (in front) houses the water chiller, power supply, and electrical distribution systems that support the lidar.

Flux Measurement Systems

In response to feedback from workshop participants, new flux measurement systems installed at SGP and NSA in FY2012 expanded the measurement capabilities of both sites. Eight new extended facilities came online in Oklahoma and Kansas, centered around the SGP Central Facility. These extended facilities are equipped with a dense network of instruments that measure the exchange of heat, moisture, and carbon dioxide near the ground.

Energy balance Bowen ratio systems (EBBR) are the cornerstone of this network and provide estimates of vertical sensible and latent heat fluxes. For locations where EBBRs are difficult to employ, usually at the north edge of a field of crops, eddy correlation flux measurement systems (ECOR) are installed. The ECOR measures surface turbulent fluxes of momentum, sensible heat, latent heat, and carbon dioxide. Surface energy balance systems (SEBS) are paired with the ECORs for comparing heat fluxes and provide sensor wetness information for data quality purposes. Additional instruments gather radiation and surface meteorological measurements to round out the data obtained at the extended facilities.

In October 2011, the NSA Barrow site welcomed a new ECOR and SEBS, as well as a change to its baseline instrument suite: a methane gas sensor for measurements of greenhouse gases emanating from the surrounding tundra. The addition of the methane instrument to the ECOR adds important information to the measurements submitted to the AmeriFlux archive's central data repository located at the Carbon Dioxide Information Analysis Center (CDIAC).

EBBR systems like the one shown here produce 30-minute estimates of the vertical fluxes of sensible and latent heat at the local surface.

The science and operations team at LANL poses in front of the MAOS Aerosol and Chemistry units.

Aerosol Research Keeps "PACE" with Ecosystem Science

Between December 2011 and April 2012, a research team led by LANL put ARM's new Mobile Aerosol Observing System (MAOS) to the test, and it passed with flying colors. Building upon previous system integration and operational testing during summer 2011, the primary goal of the Pajarito Aerosol Couplings to Ecosystems (PACE) field campaign was to demonstrate routine field operations and improve instrumental and operational performance. The MAOS consists of two large shipping containers that house more than two dozen specialized instruments for measuring aerosol, chemistry, and trace gases.

The combination of aerosol and carbon measurements gathered by the MAOS provided details that allowed scientists to analyze how ecosystems, fires, and pollution influence aerosols, clouds, and rain in the U.S. Southwest, which is experiencing significant drought and vulnerability to climate change.

During the course of the campaign, two researchers associated with the GVAX field campaign in India spent nearly nine weeks with PACE researchers at LANL. The arrangement proved extremely fruitful, as both groups worked together in tuning the MAOS instruments over a range of conditions and in strengthening the scientific collaboration between the two countries.

The Cessna Turbo 206 is hangared at Greenwood Aviation in Ponca City, Oklahoma. This aircraft has been used exclusively by the ARM Facility for more than 10 years for research flights over SGP.

Ongoing Flights Gather Carbon Measurements

The ARM Airborne Carbon Measurements (ARM-ACME) field campaign began at SGP in FY2007 and was renewed in FY2012 by the AAF. ARM-ACME is an ongoing study of atmospheric composition and carbon cycling over SGP. A Cessna Turbo 206 aircraft collects carbon profiles semi-weekly on a series of horizontal legs ranging from 1500–17,500 feet above sea level. The scientific objectives of these measurements are central to carbon-cycle and radiative forcing goals of the U.S. Climate Change Research Program and the North American Carbon Program.

The measurements are designed to improve understanding of the carbon exchange of the SGP domain; how carbon dioxide and associated water and energy fluxes influence radiative forcing, convective processes, and carbon dioxide concentrations over the sample region; and how greenhouse gases are transported on continental scales.

New Organization to Optimize ARM Radar Data

In the past few years, the ARM Facility added 19 new scanning cloud and precipitation radars to its fixed and mobile sites. ARM now operates the world's largest multi-frequency radar network for obtaining measurements of cloud and precipitation properties for climate studies.

To ensure the quality, characterization, calibration, availability, and utility of all the radars and associated higher-order data products, ARM and DOE's ASR program formally established a new ARM Radar Organization in June 2012, with a leadership structure for both science and engineering/operations. Together, these groups will guide the development of radar scan strategies and data products that meet the observational needs of the cloud and climate modeling community, ARM, and the ASR science team.

The primary role of the Radar Science Group is to represent the ASR science team's perspective, recommendations, and priorities and to communicate directly with the Radar Engineering & Operations Group and other groups (such as the ARM Data Quality Office) to ensure the optimal utilization of the ARM radar facilities to meet users' scientific needs. The Radar Science Group consists of ASR scientists and a non-ASR radar scientist, ARM site scientists, translators, and a representative from the ARM Data Quality Office.

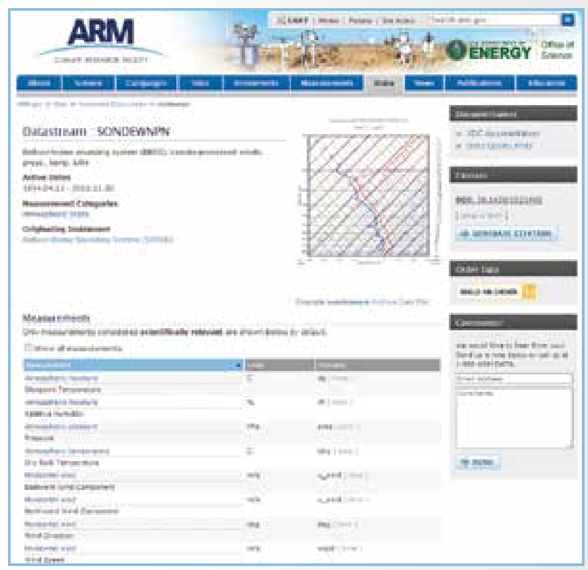
Members of the Radar Engineering & Operations Group gather for a photo at SGP in August 2012.

The Radar Engineering & Operations Group consists of instrument mentors, site operations managers, the Data Quality Office, site scientists, and translators. The members of this group are responsible for the maintenance and performance of ARM radars, including the final rules and processes used to implement standard operational, calibration, and scanning modes for radars at each research site. This group is also responsible for the on-time delivery of high-quality data products to the Data Archive, including the development of innovative VAPs—designed in cooperation with the Radar Science Group—to advance improvements in climate model physics.

Data Advancements

Building Blocks for Discovery: ARM Data Joins DataCite Open Access Registry

Starting with 380 ARM data sets and several hundred more in the queue, the DOE Office of Scientific and Technical Information (OSTI) makes DOE-funded research data sets available through DataCite, a not-for-profit organization that aims to establish easier access to research data and increase their acceptance as legitimate, citable contributions to the scholarly record. ARM Data Archive staff at Oak Ridge National Laboratory worked with OSTI staff and DataCite to establish a stable process for sharing ARM data through "Data Object Identifiers," or DOIs. Once a DOI is assigned to a datastream, it is registered in DataCite and added to a variety of searchable databases.



Datastream pages on the ARM website now display DOI numbers to enable citation of ARM datastreams in scientific publications.

As a scientific user facility serving researchers both in the U.S. and abroad, ARM has amassed one of the largest observational data collections within DOE. The DOI service allows data and information providers to generate globally unique, persistent, and resolvable identifiers for any kind of digital objects. These identifiers can then be used to cite the data in journal articles.

Testbeds Incorporate ARM Data to Facilitate Modeling Improvements

Two new testbeds incorporate a wide range of data, including ARM observations, and provide a platform for modelers to improve climate models.

The Aerosol Modeling Testbed (AMT) collects and organizes a variety of ARM and operational data into a single data set for modelers or any scientist wishing to analyze field campaign data. The CARES testbed case of AMT consists of all the measurements from the CARES field campaign during June 2010 in the vicinity of Sacramento, California. Operational meteorological, air quality, and surface and satellite aerosol optical depth data are included to supplement and enhance the value of the CARES data. To facilitate statistical and graphical evaluation of atmospheric process modules, the software provided with the product extracts model output from the WRF-Chem model in a format and organizational structure consistent with the CARES testbed data. The software can be adapted to read output from other meteorological and chemical transport models. Additional testbed cases from other ARM field campaigns will be added in the future.

The Fast-Physics Testbed developed under the Fast Physics System Testbed and Research (FASTER) project provides a web-based platform for using ARM measurements to evaluate and test parameterizations of cloud-related subgrid processes in global climate models. The current FASTER testbed consists of a single-column model testbed and a numerical weather prediction model testbed. Through these testbeds, researchers can interactively and effectively evaluate and test their parameterizations against the ARM observational data as well as other complementary measurements. In addition to simulations and evaluations with the established models and forcing data, the testbed can also incorporate new parameterization packages and new forcing data products to accelerate the model development-evaluation-improvement cycle.

New Value-Added Products Reach Evaluation Status

Evaluation data are available for the first-ever 4-dimensional ARM data product, called Mapped Moments to a Cartesian Grid (MMCG). The MMCG VAP

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.

In FY2012, six products were moved to the evaluation stage:

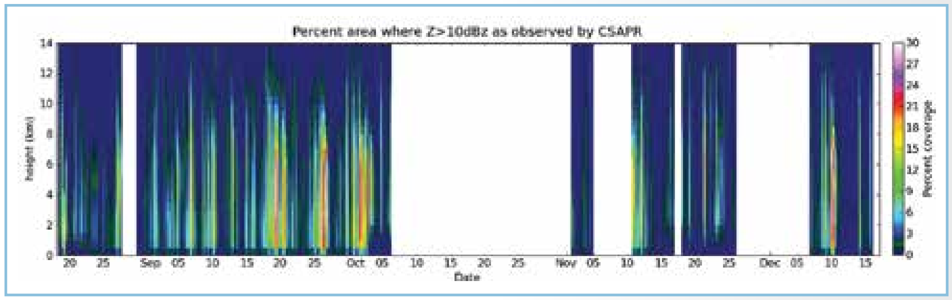
- *Interpolated Sonde (INTERPSONDE)*
- *Ka-band Zenith-Pointing Radar Active Remote Sensing of Clouds (KAZR-ARSCL)*
- *Mapped Moments to a Cartesian Grid (MMCG)*
- *Planetary Boundary Layer Height (PBLHT)*
- *Quality Controlled Eddy Correlation (QCECOR)*
- *Radiatively Important Parameters Best Estimate (RIPBE).*

Six products were moved from evaluation to release:

- *Aerosol Best Estimate (AEROSOLBE)*
- *Aerosol Optical Depth (AOD)*
- *ARM Best Estimate (ARMBE)*
- *Continuous Baseline Microphysical Retrieval (MICROBASE)*
- *Merged Sounding (MERGESONDE)*
- *Raman Lidar Profiles (RLPROF)*

*For more information on any of ARM's VAPs, visit the VAP web page at **http://www.arm.gov/data/vaps**.*

maps raw moment data from the C-band scanning ARM precipitation radar (C-SAPR) on to a model-like, regular Cartesian grid. It produces measurements of raw radar moments in antenna coordinates of range from the antenna and the azimuth and elevation of the antenna. Data are currently available for periods in 2011 corresponding to major events in the AMIE and MC3E field campaigns.

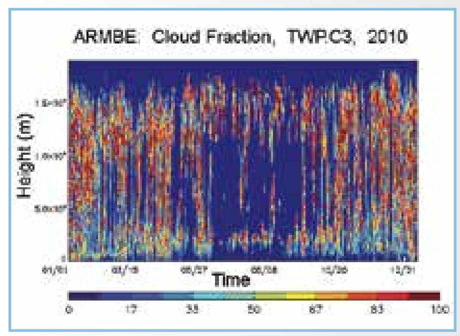


This data plot from the MMCG VAP shows times of data availability for the Manus Island C-SAPR.

The Ka-band ARM zenith radars (KAZRs) replaced the long-serving millimeter-wavelength cloud radars (MMCRs). As a result, the Active Remote Sensing of Clouds (ARSCL) VAP, which is based on MMCR observations, was replaced by a KAZR version, the KAZR-ARSCL VAP. KAZR measurements are combined with observations from multiple instruments to produce two datastreams: one with cloud base and cloud-layer boundaries, and one that also includes best-estimate time-height fields of radar moments. KAZR-ARSCL evaluation data are available for SGP during the Midlatitude Continental Convective Clouds Experiment (MC3E), April to June 2011. Evaluation data are also available for October 2011–February 2012, during AMIE.

Value-Added Products Released Into Production

The ARM showcase data set CMBE, previously an evaluation product, has been released as an ARM production data set and incorporated into the new ARM Best-Estimate (ARMBE) VAP. The new flagship ARMBE product name will represent all ARM best estimate products. Transitioning CMBE to ARMBE required changing the metadata to meet ARM production data standards, but also brings the new release of the ARM Best Estimate Cloud Radiation (ARMBECLDRAD) and ARM Best Estimate Atmospheric Measurements (ARMBEATM) datastreams.



This data plot from the ARMBECLDRAD VAP demonstrates cloud fraction at Darwin for 2010.

These first ARMBE data products consist of best estimates of many ARM measurements, specifically designed for climate modelers to use in the evaluation of global climate models. They contain a best estimate of several cloud, radiation, and atmospheric quantities. Data are averaged over 1-hour time intervals and are available for the SGP Central Facility, NSA Central Facility, and all the TWP sites.

The Aerosol Best Estimate (AEROSOLBE) VAP provides best-estimate time series of total column aerosol optical depth (AOD) and the associated column Angstrom exponent, as well as time/height profiles of aerosol extinction, single-scattering albedo, asymmetry parameter, and Angstrom exponents above the SGP Central Facility. As inputs, AEROSOLBE uses datastreams from several VAPs and instruments.

The Continuous Baseline Microphysical Retrieval (MICROBASE) VAP is a baseline retrieval of cloud microphysical properties. It uses a combination of observations from multiple instruments and VAPs to produce instantaneous vertical profiles of cloud liquid water content (LWC), cloud ice water content (IWC), liquid cloud particle effective radius (LIQRE), and ice cloud particle effective radius (ICERE). Data from April 1998 through December 2009 are now available for the SGP, NSA, and TWP.

Communication and Community Outreach

Attending their first EGU General Assembly, ARM Facility staff shared facility availability information and resources with mostly European scientists, students, and teachers who stopped by the booth.

Outreach Extends to European Geosciences Union

Making its debut at the European Geosciences Union (EGU) General Assembly, the ARM Climate Research Facility "crossed the pond" to attend Europe's leading forum for Earth and space sciences during the week of April 22–27, 2012, in Vienna, Austria. Participating in the meeting for the first time, ARM Facility staff visited with a steady stream of scientists who stopped by the ARM exhibit.

With attendance numbers closing at just over 11,000—11,216, to be exact, from 95 countries— EGU Vice President Gunter Bloschel said this year's meeting was the most successful to date. The 530 scientific sessions included 4,436 oral and 9,092 poster presentations, and ARM data were included in several of these presentations.

Mega Science Festival Draws Mega Crowds

How do you interest kids in science, technology, engineering, and math? Hold the country's largest science fair. Drawing the second biggest crowd in Washington Convention Center history, the second USA Science & Engineering Festival was held in Washington D.C. from April 27–29, 2012. ARM exhibited at all three days of the Festival, including Sneak Peek Friday, attended by nearly 28,000 students, teachers, military families, government officials, and members of the media. More than 150,000 people visited the Festival over the three days.

A visitor to ARM's booth tests the sample "build your own" anemometer.

Professor Polar Bear and the Climate Kids were popular attractions in the ARM booth, with visitors of all ages stopping by to take pictures. Many visitors were interested in ARM's lesson plans for students from kindergarten through high school, and younger attendees received activity books featuring coloring pages, puzzles, and other activities. A sample "build your own" anemometer was on display, along with construction instructions. In total, more than 3,000 exhibits participated in the Festival, including academic institutions, research institutes, government agencies, technology companies, museums, and community organizations.

Collaborations in Atmospheric Science and Observations Discussed in Germany

As part of an effort to enhance collaboration among international climate research activities, ARM personnel visited the University of Cologne in Germany in early June 2012 at the invitation of Susanne Crewell, professor of meteorology at the university. The meeting included a number of thought-provoking discussions and presentations from ARM Facility representatives and the European scientific colleagues. Of great interest to the European attendees were ARM's strategies and approaches for measuring important climate parameters and transforming detailed field data into a form that can be easily used in climate model development.

Further details on collaboration opportunities were discussed at a joint U.S./European workshop held in November 2012. A group of international scientists identified outstanding climate change science questions and the observational strategies for addressing them.

Susanne Crewell (center) is flanked by Jimmy Voyles (left) and Shaocheng Xie (right) during a tour of the Research Center Jülich and the university's Jülich Observatory for Cloud Evolution (JOYCE) site.

ARM Participates in WCRP Open Science Conference

In late October 2011, the ARM Climate Research Facility attended the World Climate Research Programme (WCRP) Open Science conference in Denver as part of the DOE's exhibit organized by the Climate and Environmental Sciences Division (CESD). As a platinum sponsor for the conference focused on climate research in service to society, DOE's display showcased the CESD programs, including the ARM Facility. ARM's Live Data Display was popular with data seekers and led to queries for the AMFs to come to Peru, Honduras, Australia, and the Caribbean.

This first-ever WCRP Open Science Conference was attended by more than 1900 conference participants (of which 523 were students and early-career scientists and 332 scientists were from 86 countries) with more than 1750 posters and 182 papers presented orally. Prominent speakers at the conference included the head of the World Meteorological Organization and members of the Intergovernmental Panel on Climate Change (IPCC) teams in 2007 and 2013. Resulting white papers from the conference will provide strategic input into the IPCC Fifth Assessment Report and identify grand challenges that face the climate research community.

In four days more than 100 visitors, from the interested passerby to the in-depth information gatherer, stopped by the exhibit. Visitors came from many countries, including Japan, Malaysia, Ethiopia, Australia, Hong Kong, Mexico, Jamaica, South Korea, Turkey, and the Netherlands.

Fairbanks Middle Schoolers Enjoy Field Trip to Barrow

In April 2012, the eighth grade class from Watershed School in Fairbanks, Alaska, made the long trek to the North Slope for a week-long field trip filled with science, history, and cultural studies. Their field trip included a visit to the ARM site in Barrow, where NSA Site Manager Mark Ivey, along with Facilities Manager and Alaska native Walter Brower, provided a tour of the site and explained how the instruments are used to obtain measurements for climate studies. Because the Arctic is experiencing the effects of climate change more rapidly than other areas of the world, data from Barrow are very important for scientists studying Earth's climate.

Watershed School's bundled-up eighth grade class and their chaperones stop for a quick photo in front of the U.S. flag near the Arctic sea ice.

The field trip was part of the school's emphasis on "combining science and cultural lessons with outdoor explorations and studies with direct connection to our local community." With its juxtaposition of cutting-edge instrumentation and research located within the largest traditional Eskimo village in Alaska, Barrow was a fitting choice for their field trip.

Madie Houdeshell and David Breedlove each hold a weather balloon data transmitter called a radiosonde.

Science Lesson Starts in the Yard

What began with the discovery of an interesting "white thing" in Madie Houdeshell's yard led to a science assembly for fourth and fifth grade students at Udall Elementary School in Kansas. They learned all about weather balloons, why they are used, and how the sensor package ended up in Madie's yard.

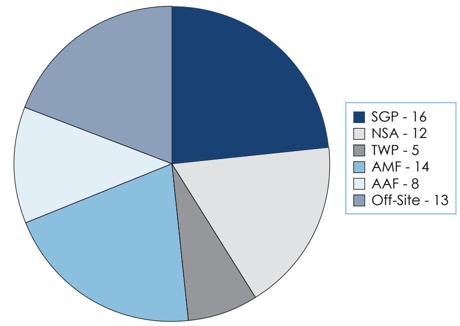
Madie took her discovery to school, where her teacher called the phone number on the device and reached the office of ARM's SGP site near Lamont, Oklahoma. Recognizing an opportunity to engage kids in science, David Breedlove agreed to make a visit to the school. David is the deputy site operations manager for the SGP site and has worked there since 1992.

He joined the curious kids in the school gymnasium, talking with them about his job, the purpose of ARM, and, not least of all, the weather balloons. He explained that the balloons rise very high, collecting data along the way. This data is transmitted to the ground by a device—called a radiosonde—like the one Madie found. The balloons expand as they rise, eventually popping and falling to Earth, along with the radiosonde.

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 FY2012, including these ongoing efforts. The subsequent table summarizes just those campaigns that began in FY2012. For more information, visit the Field Campaign web page at

www.arm.gov/campaigns



Total 2012 Field Campaigns

Dates	Campaign Name	Status	Description
ARM Aerial Facility			
May 2012–July 2012	Two-Column Aerosol Project (TCAP): Ground-Based AOD Measurements	Completed	The 4STAR (Spectrometer for Sky-Scanning, Sun-Tracking Atmospheric Research) instrument flown for the Two-Column Aerosol Project (TCAP) collects AOD measurements that must be anchored by ground-based measurements. This new sun/sky photometer was first calibrated at Mauna Loa Observatory in Hawaii and then used to measure AOD spectra at Barnstable Municipal Airport, Cape Cod, Massachusetts, where the aircraft flying 4STAR was based for TCAP. The ground-based AOD measurements were compared to those measured by 4STAR before takeoff and/or after landing. These comparisons were used to calibrate the AOD measurements made by 4STAR.
July 2012	Two-Column Aerosol Project (TCAP): Airborne HSRL and RSP Measurements	Completed	The NASA Langley High Spectral Resolution Lidar (HSRL) and NASA GISS Research Scanning Polarimeter (RSP) were deployed for airborne measurements of AOD. The focus of this campaign was to relate observations of AOD made from multiple platforms with in situ observations of particle size, composition, and optical properties. Two sets of AOD and related measurements were made from two different aircraft. One aircraft (the DOE G-1) flew near the ground, measuring AOD with an upward-looking instrument, while the second (the NASA Langley King Air) flew at an altitude of about 8 kilometers, measuring AOD with downward-looking HSRL and RSP instruments.
ARM Mobile Facility			
October 2011–March 2012	ARM MJO Investigation Experiment on Gan Island	Completed	In conjunction with the DYNAMO and CINDY2011 campaigns, the AMIE field campaign was designed to test several hypotheses regarding the mechanisms of MJO initiation and propagation in the Indian Ocean area. AMIE included two parallel components: deployment of AMF2 on Gan Island, Maldives (AMIE-Gan), where the MJO initiates and starts its eastward propagation, and the ARM Manus site (AMIE-Manus), in the general area where the MJO usually starts to weaken in climate models. AMIE-Gan provided measurements relevant to improving the representation of MJO initiation in climate models. For more information, see the Featured Field Campaigns section of this report.

January 2012–February 2012	AMIE-Gan Ancillary Disdrometer	Completed	As part of the AMIE-Gan campaign, an ancillary disdrometer for comparison with the ARM two-dimensional video disdrometer and the scanning ARM cloud radar (SACR) and Texas A&M SMART-R C-band radar was fielded. Redundancy in the disdrometer measurements enhanced both the rain droplet measurement capability as well as verifies radar measurements.
July 2012–June 2013	Two-Column Aerosol Project (TCAP)	In Progress	The TCAP field campaign is designed to provide a detailed set of observations with four objectives: (1) perform radiative and cloud condensation nuclei (CCN) closure studies, (2) evaluate a new retrieval algorithm for AOD in the presence of clouds using passive remote sensing, (3) extend a previously developed technique to investigate aerosol indirect effects, and (4) evaluate the performance of a detailed regional-scale model and a more parameterized global-scale model in simulating particle activation and AOD associated with the aging of anthropogenic aerosols. To meet these science objectives, AMF1 and the MAOS have been deployed on Cape Cod, Massachusetts, for a 12-month period beginning summer 2012 to quantify aerosol properties, radiation, and cloud characteristics at a location subject to both clear and cloudy conditions as well as clean and polluted conditions. These observations will be supplemented by two aircraft intensive observation periods. One aircraft observation period was completed in July 2012, with a second to follow in February 2013.
July 2012–October 2012	Two-Column Aerosol Project (TCAP): KASPRR Engineering Tests	Completed	ProSensing is currently developing a Ka-band scanning polarimetric radar/radiometer (KASPRR) with support from the DOE Small Business Innovation Research (SBIR) program. This campaign was the first field deployment of the KASPRR system and focused on engineering issues, including testing the new polarimetric modes and calibration of both the radar and radiometer. Radar calibration was carried out through corner reflector calibration and intercomparison with the existing AMF1 SACR system. Water vapor and liquid water profiles generated by other ARM instruments were used to calibrate the radiometer channel. Intercomparison of sun brightness temperature measured with the KASPRR radiometer channel was compared to sun brightness estimated by the radiometer mode in SACR. These data will be used to assess the relative beam efficiencies of the SACR and KASPRR antennas.
July 2012–August 2012	Two-Column Aerosol Project (TCAP): CU GMAX-DOAS Deployment	Completed	The University of Colorado has developed an innovative passive remote sensor, the CU 2D scanning ground Multi AXis Differential Optical Absorption Spectroscopy (2D-GMAX-DOAS) instrument, that features an azimuth and elevation angle scanning telescope to measure scattered and direct sun light radiance spectra. The CU 2D-GMAX-DOAS and Light Emitting Diode Cavity Enhanced Differential Optical Absorption Spectroscopy (LED-CE-DOAS) instruments were operated during the TCAP intensive operational period (July–August 2012) at Cape Cod, Massachusetts, where ground-based aerosol measurements provide an opportunity for (1) atmospheric radiation closure studies, (2) test retrievals of AOD by 2D-GMAX-DOAS and comparison with measurements from the Cimel sunphotometer and multifilter rotating shadowband radiometer (MFRSR) in the presence and absence of clouds, and (3) the study of secondary organic aerosol (SOA) formation. 2D-GMAX-DOAS column observations provide a bridge between spatial scales probed by in situ sensors and satellites and those predicted by atmospheric models.

July 2012– June 2013	Two-Column Aerosol Project (TCAP): Ground-Based Radiation and Aerosol Validation Using the NOAA Mobile SURFRAD Station	In Progress	In preparation for the upcoming Geostationary Operational Environmental Satellite – R Series (GOES-R) satellite launch in 2015, a mobile field site for ground-based validation of radiation and aerosol products is being developed. The goal of the mobile site is to validate many of the products being developed for GOES-R. This Cape Cod deployment of the NOAA's mobile Surface Radiation (SURFRAD) station concentrates on retrievals of surface radiation budget and aerosol properties including AOD, single-scattering albedo, and asymmetry parameter as a function of the wavelengths measured by the MFRSR.
July 2012– February 2013	Two-Column Aerosol Project (TCAP): Aerodynamic Particle Sizer	In Progress	A total sky imager (TSI) model 3321 aerodynamic particle sizer (APS) is deployed at the primary TCAP ground site on Cape Cod in conjunction with the MAOS. The deployment will greatly improve the accuracy with which mass scattering coefficients and related properties can be evaluated. In turn, this deployment will also provide measurements that, in conjunction with the proposed TCAP modeling studies, will improve understanding of the impact of particles on the Earth's radiation budget.
July 2012– January 2013	Two-Column Aerosol Project (TCAP): Aerosol Light Extinction Measurements	In Progress	This field campaign has deployed LANL's new Cavity Attenuated Phase Shift extinction (CAPS PMex) monitor that measures light extinction by using a visible light-emitting diode (LED) as a light source, a sample cell incorporating two high reflectivity mirrors centered at the wavelength of the LED, and a vacuum photodiode detector. Its efficacy is based on the fact that aerosols are broadband scatterers and absorbers of light.
August 2012– November 2013	Marine ARM GPCI Investigations of Clouds (MAGIC): Bridge Display	In Progress	A laptop computer will be installed on the ship bridge during the MAGIC cruises for the purpose of having a data display, especially meteorological data, for use by the crew and for scientists and technicians. During Leg0 the meteorology computer was on the bridge, and the bridge officers used it continually for the endless weather discussions and as an aid for their regular weather observations. True winds must be calculated by hand.
August 2012– November 2013	Marine ARM GPCI Investigations of Clouds (MAGIC): RH Quality Assurance	In Progress	This campaign provides an independent means of assessing the RH measurement accuracy. RH sensors are notorious for long-term drift and susceptibility to contamination. During the MAGIC deployment, three different RH measurements are gathered by autonomous data acquisition.
August 2012– November 2013	Marine ARM GPCI Investigations of Clouds (MAGIC): Sunshine Pyranometer	In Progress	This campaign consists of the integration of the SPN1 Pyranometer into the AMF2 portable radiation package (PRP) during the MAGIC deployment.
August 2012– November 2013	Marine ARM GPCI Investigations of Clouds (MAGIC): Atmospheric Optical Depth by Microtops	In Progress	The Solar Light Microtops has been proven to provide good measurements of AOD on moving platforms such as ships. This activity will provide valuable support to other AMF2 instrumentation such as the aerosol instrumentation and the rotating shadowband radiometer.

August 2012–November 2013	Marine ARM GPCI Investigations of Clouds (MAGIC): Infrared Seasurface Temperature Autonomous Radiometer (ISAR)	In Progress	Sea surface temperature is an essential measurement for MAGIC. It is generally accepted that SST accuracies of 0.1°C are necessary. ISAR (Infrared Seasurface Temperature Autonomous Radiometer) is the only instrument to provide that.
North Slope of Alaska			
October 2011–May 2012	NSA Snow IOP	Completed	The lack of accurate ice precipitation measurements has been identified as an impediment to efficient improvement of climate models, making the improvement of these measurements a priority for several climate research programs. The deployment of the new X- and Ka/W-band radars in Barrow, Alaska, opened an opportunity for ARM to obtain spatial estimates of snowfall rates using the polarimetric X-band measurements and dual-frequency measurements based on different combinations of the three wavelengths. A preliminary investigation of ice crystal aggregate shapes approximated as ellipsoids was conducted using more than 24,000 individual aggregate images collected with 2D video disdrometers on 39 days. These data included snow events in Boulder, Colorado; Egbert, Ontario; and Helsinki, Finland. These results suggest that combined radar/disdrometer measurements will be needed to make progress on radar estimation of snowfall rates.
April 2012–September 2013	Support for Next-Generation Ecosystem Experiments (NGEE Arctic)	In Progress	Characterized by vast amounts of carbon stored in permafrost and a rapidly evolving landscape, the Arctic has emerged as an important focal point for the study of climate change. These are sensitive systems, yet the mechanisms responsible for those sensitivities are not well understood, and many remain uncertain in terms of their representation in earth system models. Working with the multi-disciplinary teams of the NGEE Arctic and the larger scientific community, this field campaign is developing communication and data management strategies, helping to chart a course for investigations that target improved process understanding and high-resolution model representation of important ecosystem-climate feedbacks in the Arctic.
July 2012–February 2015	Cosmic-Ray Moisture Probe on North Slope of Alaska	In Progress	Soil moisture and snow are critical variables affecting the energy balance at the Earth's surface and are also crucial to Arctic ecosystems and to the carbon cycle. Large amounts of carbon are stored in perennially frozen soils. If the permafrost melts, then carbon can be released, affecting global warming. A new soil moisture/snow monitoring instrument has been installed at NSA to make ongoing measurements of cosmic-ray neutrons as a proxy for soil moisture and snow cover. Depending upon the results achieved, this may lead to a network of probes for installation in the Arctic.

July 2012– June 2013	Barrow Black Carbon Source and Impact Study	In Progress	The goal of this campaign is to characterize emission source contributions to atmospheric and snow-based black carbon, providing data for establishing links between emission source contributions and snow albedo impacts in the Arctic. Deposits of the dark particles on snow and ice decrease albedo, which results in increased melting, forming a positive feedback loop for Arctic warming. The sample campaign at NSA is underway with two atmospheric particulate matter samplers and one optical black carbon instrument that have been set up for a year of air monitoring and sample collection. The campaign includes a combination of air monitoring, snow collection, and the use of radiative measurements, with follow-up chemical analysis in laboratories at Baylor University. The results from the analysis of the collected particulates and snow samples will be used in source apportionment modeling to determine the major source contributions for carbon components in the air and snow at Barrow.
July 2012– December 2015	ARM Radiosondes for NPOESS/NPP Validation - NSA	In Progress	With parallel campaigns at the SGP and TWP sites, this satellite validation project involves the use of radiosonde launches coincident with overpasses of subject satellites. This field campaign employs the same data collection concepts and analysis techniques for the validation of Cross-Track Infrared Microwave Sounder Suite (CrIMSS) and Visible Infrared Imaging Radiometer Suite (VIIRS) products from the National Polar-Orbiting Partnership (NPP) and National Polar-Orbiting Operational Environmental Satellite System (NPOESS) satellite platforms.
July 2012– September 2013	Arctic Cloud Infrared Imaging	In Progress	The third-generation Infrared Cloud Imager (ICI) instrument was deployed near the Great White facility at NSA, where it operates 24 hours a day. The ICI obtains one cloud image at a user-selected interval of approximately 1 minute or more. A high-temporal-resolution mode can acquire one image every few seconds, typically for several tens of minutes. The radiometrically calibrated thermal sky images are processed to remove atmospheric emission. The resulting images allow identification of cloud and no-cloud pixels in each image and estimation of cloud optical depth for each cloudy pixel. These image sequences are processed to produce histograms of cloud fraction by season and month. Noteworthy products of this campaign are separate cloud histograms for daytime and nighttime because of the ICI's unique ability (relative to a visible imager) to obtain measurements with unchanging sensitivity during day and night.
August 2012– July 2014	Barrow In Situ Snow Sampling Study	In Progress	Black carbon (BC) aerosol is proposed to change the albedo of snow via dry deposition and scavenging by precipitation. This study involves analyzing the BC concentration and size distribution in snow using an SP2 and improving the accuracy of this measurement. The analysis requires approximately 10–20 milliliters of water. The data, combined with the ambient BC concentrations measured at the National Oceanic and Atmospheric Administration (NOAA) site, will lead to a more quantitative understanding of BC scavenging in cloud and below cloud.

Off-Site Campaigns			
October 2011–May 2013	Stable Boundary Layer Education (STABLE)	In Progress	The STABLE field campaign deployed instruments in two phases. In Phase 1, the instruments were deployed around the National Weather Center on the University of Oklahoma campus. This allowed students to become familiar with the instruments and associated data, including the measurement theory, data quality protocol, and retrieval theory. These data were incorporated into the various lectures and exercises, providing hands-on experience to a new set of future scientists. In Phase 2, the instruments were relocated to the Kessler Farm field site in Purcell, Oklahoma, for use by a second class. The data collected at this site are being used to investigate the thermodynamic and dynamic structure of the lowest several hundred meters of the boundary layer and how this layer evolves over the diurnal cycle. In particular, the collapse of the daytime convective boundary layer and development of the nocturnal stable layer is emphasized, as well as the role of the low-level jet on the evolution of the nocturnal boundary layer. Students have been carrying out most of the research under the direction of the principal investigators.
November 2011–December 2011	Measure of Coating Mass to Black Carbon Core Mass	Completed	The purpose of these week-long experiments was to conduct a series of proof-of-principle measurements by leveraging recent advances in a new analytical technique using a Centrifugal Particle Mass Analyzer (CPMA) and the SP2 to accurately determine the coating thickness. The use of the CPMA-SP2 system is a novel advancement in BC measurement techniques that provided accurate results without relying on the high-uncertainty assumptions (about particle shape and density) made in mobility sizing methods. The ability to provide direct measurement of the coating mass to BC core mass ratio will lead to more robust BC parameterizations. The calculated coating thicknesses in this method can also be used to investigate the accuracy of coating thickness measurements determined in other studies based only on SP2 incandescence and scattering measurements.
December 2011–April 2012	Pajarito Aerosol Coupling to Ecosystems	Completed	The primary goals of this field campaign were to demonstrate routine MAOS field operations and to improve instrumental and operational performance while providing the MAOS operational team with real field deployment experience. The secondary goal was to leverage LANL's long-term Pinon-Juniper (PJ) woodland site to measure the aerosol life cycle of biogenic (SOA formation from sesquiterpenes) and smoke (light absorption by mixed BC and organics) aerosols. PACE measured changes in biogenic volatile organics from the PJ ecosystem, the meteorological state, and the aerosol properties during the winter-spring transition. Fire and automobile emission interactions with biogenic aerosols were also investigated. MAOS was operated by LANL and used to train Indian scientists under the guidance of the PACE PI and science team working closely with the instrument mentors.

January 2012–February 2012	Aerosol Flow from London to Detling, UK	Completed	To supplement long-term measurements in the Clear Air for London (ClearfLo) study of the London urban atmosphere, a consortium of research groups in this ARM campaign deployed a suite of instruments for an intensive operating period at the study's Detling site, a rural location east of London used for sampling the outflow from the megacity. A particular focus of this study was on understanding the processing of BC particles because the CalNex/CARES campaign in 2010 suggested that understanding of the morphology of coated-BC particles was incomplete. Measuring particulate chemical composition (including organics, inorganics, and BC), size distributions, optical properties, and hygroscopic properties, as well as gas-phase oxidants and aerosol precursors, the instruments at Detling made in situ, quantitative, high time-resolution measurements for the outflow of the megacity during wintertime. These measurements complemented the successful study of megacity outflow from Mexico City during MILAGRO/MCMA 2006.
April 2012–August 2012	SP2 at Boston College-Led Black Carbon (BC3) Study	Completed	This field campaign examined BC optical and microphysical properties. Central to this laboratory-based study was the deployment of the SP2. The study investigated the influence of coated-BC microphysical properties on the optical properties of the coated particle, the most appropriate calibration material for the SP2 and SP-AMS, the most appropriate mixing rule for SOA+BC particle, and the origin of the complex behavior observed when flame-generated BC was coated with sulfuric acid.
September 2012–February 2013	Characterization of Black Carbon Mixing State	In Progress	This measurement campaign is exploring and characterizing the types of BC emissions that result in near-surface BC-containing particles in a region dominated by biomass burning and open pit/stove cooking. Specifically, the campaign is examining two primary BC emission sources in India: an urban setting (with fossil fuel emissions, for example) at the Indian Institute of Science (IISc) in Bangalore and biomass burning from an active fire in the rural area surrounding Bangalore. The differing emissions between the urban environment and rural biomass burning provide the opportunity to examine the BC mixing state more closely.

Southern Great Plains			
October 2011–November 2011	Airborne Optical Autocovariance Wind Lidar	Completed	The Optical Autocovariance Wind Lidar (OAWL) instrument in its pressurized pallet was flown over the ARM site in one or two 30-minutes circles per flight, taking wind measurements that were processed into wind speed and direction profiles. During the same periods, the SGP Doppler Wind Lidar operated in a scanning azimuth mode to profile lower-tropospheric wind profiles, providing ground-based data for comparison.
January 2012–December 2012	Full-Column Greenhouse Gas Sampling	Completed	The SGP site has become a de facto focal point for evaluation of new remote sensing instruments that determine greenhouse gas (GHG) mixing ratios from ground, airborne, and satellite platforms. These activities all require validation against in situ measurements of the vertical profiles of GHG mixing ratios. The GHG sampling in this campaign supports both carbon-cycle science being conducted by the DOE ARM/LBNL Carbon Project and a large component of the other major GHG remote sensing missions concerned with accurate assessment of the radiative forcing derived from atmospheric GHGs.
February 2012–June 2012	AOS Validation of Instrumentation Study	Completed	This campaign provided for operation of the AMF2 Aerosol Observing System (AOS) for an extended period to allow direct comparison between the current and previous generations of AOS instrument suites. While there are nearly identical measurements in the AMF2 AOS and the SGP AOS, the individual systems all differ in age by nearly 20 years. Establishing the relative precision of the resulting data sets significantly added to reliability for investigators using field campaign data from these platforms. The AMF2 AOS functions as a "transfer standard" because it has already been inter-compared with the MAOS during the summer of 2011, so the benefit extends across the entire "next generation" of ARM systems.
March 2012–June 2012	Carbonyl Sulfide for Tracing Carbon Fluxes	Completed	This campaign used a new carbonyl sulfide (COS) eddy flux system at SGP, COS airborne monitoring data, and atmospheric modeling tools to quantify the climate sensitivity of carbon flux processes at the regional scale. The multi-scale analysis provided evidence to demonstrate a new COS technique to the terrestrial ecology community and an understanding of how COS should be incorporated into comprehensive investigations of ecosystem processes.
May 2012–June 2012	Deep Convective Clouds and Chemistry	Completed	The Deep Convective Clouds and Chemistry (DC3) field campaign used extensively instrumented aircraft and ground-based instrumentation to characterize the impact of deep convective systems on the composition and chemistry of the midlatitude upper troposphere and lower stratosphere. Observations were conducted in northeastern Colorado, central Oklahoma, and northern Alabama to gather data on different types of storms and with different boundary layer compositions. Involvement of students from K–12 through graduate school was encouraged throughout the campaign from data collection to improvement of numerical models and reporting of the results to the scientific community.

July 2012–December 2015	ARM Radiosondes for NPOESS/NPP Validation – SGP	In Progress	With parallel campaigns at the NSA and TWP sites, this satellite validation project involves the use of radiosonde launches coincident with overpasses of subject satellites. This field campaign employs the same data collection concepts and analysis techniques for the validation of CrIMSS and VIIRS products from the NPP and NPOESS satellite platforms.
September 2012–November 2012	Lower Atmospheric Boundary Layer Experiment	Completed	Although boundary layer turbulence is an important process that is parameterized in most atmospheric numerical models, few studies have investigated how the vertical turbulence profile changes over short horizontal distances. To investigate those locational differences in vertical turbulence profile and their dependence on wind direction and other variables, this experiment deployed four instruments at the SGP Central Facility: two Doppler wind lidars, a sodar, and a laser scintillometer. The study was primarily sensitive to the surface conditions upwind of these instruments, so the results should better characterize the SGP site in general. Data collected during the experiment were also used to derive water vapor fluxes at the top of the boundary layer and to compare vertical motions observed by multiple types of instruments.
Tropical Western Pacific			
October 2011–March 2012	AMIE (ARM MJO Investigation Experiment): Observations of the Madden-Julian Oscillation for Modeling Studies	Completed	In conjunction with the DYNAMO and CINDY2011 campaigns, the AMIE field campaign was designed to test several hypotheses regarding the mechanisms of MJO initiation and propagation in the Indian Ocean area. For more information, see the Featured Field Campaigns section of this report.
February 2012–January 2013	CROC - Convective Radio Occultations Campaign	In Progress	This campaign at Darwin is acquiring in situ measurements (cloud base; cloud top; and profiles of backscatter, temperature, and water vapor) collocated with the Global Positioning System (GPS) Radio Occultations (ROs) tangent point. These measurements are being taken during convective systems to assess the contribution of atmospheric processes to the variation of the RO bending angle. A deeper knowledge of what affects the RO bending angle will help in understanding the role of convection in the climate changes, the thermal structure and composition of the upper troposphere/lower stratosphere (UTLS), how the GPS RO signal relates to the intensity of a storm, and characterization of the deep convective cloud top.
July 2012–December 2015	ARM Radiosondes for NPOESS/NPP Validation - TWP	In Progress	With parallel campaigns at the NSA and SGP sites, this satellite validation project involves the use of radiosonde launches coincident with overpasses of subject satellites. This field campaign employs the same data collection concepts and analysis techniques for the validation of CrIMSS and VIIRS products from the NPP and NPOESS satellite platforms.

On the inside covers: Graciosa Island, in the Azores, is the site of a new ARM observation facility. The ENA site is scheduled to be operational by the end of 2013.

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