DOE/SC-ARM-11-024

ANNUAL REPORT

ARM
CLIMATE RESEARCH FACILITY

U.S. DEPARTMENT OF ENERGY | Office of Science

2011

Recovery Act **HIGHLIGHTS**

October 2010

- Doppler lidars tested at the Atmospheric Radiation Measurement (ARM) Climate Research Facility's Southern Great Plains (SGP) site.
- Final installation completed for the three X-band scanning ARM precipitation radars (X-SAPRs) at SGP.
- Weighing bucket rain gauge installed at Tropical Western Pacific (TWP) site in Darwin, Australia.

November 2010

- Aerosol chemistry speciation monitor incorporated into the Aerosol Observing System (AOS) at SGP.
- Data communication towers and radio equipment for all SGP radar sites installed.
- First operational Raman lidar in the tropics began gathering data in Darwin.

December 2010

- All three X-SAPRs completed acceptance testing at SGP.
- Ka-band ARM zenith radar (KAZR) replaced millimeter wavelength cloud radar (MMCR) at SGP.
- New atmospheric emitted radiance interferometer (AERI) and Doppler lidar installed at the Darwin site.

January 2011

- High spectral resolution lidar (HSRL) and 3-channel microwave radiometer joined the ARM Mobile Facility (AMF) installation in Steamboat Springs, Colorado.
- New AERI installed at SGP.

February 2011

- C-band SAPR and W/Ka-band scanning ARM cloud radar (SACR) installed at SGP, completing the new suite of five scanning radars.

March 2011

- HSRL and autosonde launcher installed at North Slope of Alaska (NSA) site in Barrow, Alaska.
- Fast-forward scattering probe and fast cloud droplet probe added to the ARM Aerial Facility (AAF) instrument suite.

April 2011

- C-SAPR on Manus Island, Papua New Guinea, installed, representing the first operational precipitation radar in the TWP area.

May 2011

- New KAZR began operation at NSA, representing the final replacement of the original MMCRs throughout the ARM Facility.

June 2011

- Acceptance testing complete for X-SAPR at NSA.
- Dual-frequency W/Ka-band and X/Ka-band SACRs accepted for deployment at Darwin and Manus Island and as part of the AMF.

July/August 2011

- X/Ka-SACR installed in Darwin.
- Three new 3-channel microwave radiometers passed acceptance tests at SGP.

September 2011

- Final Recovery Act instruments received, and infrastructure enhancements complete.

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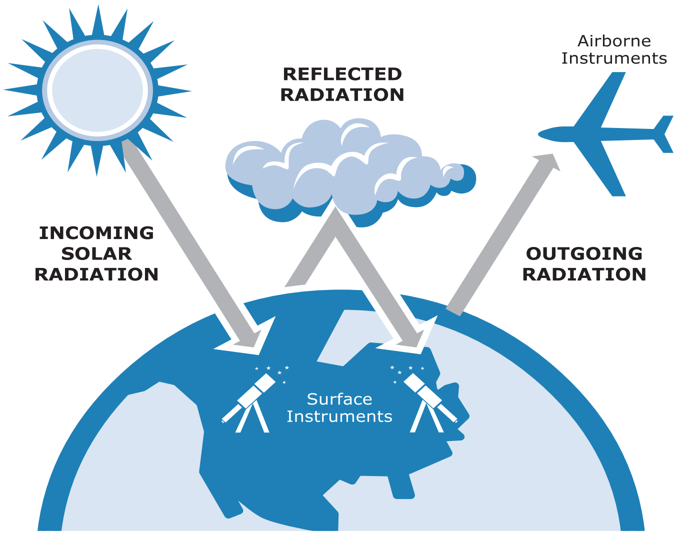
On the cover: During April and May of 2011, the Midlatitude Continental Convective Clouds Experiment took place at the ARM SGP site in central Oklahoma. The goal of this campaign was to document and monitor precipitation, clouds, winds, and moisture in order to provide a holistic view of convective clouds. 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 (GCMs) are the primary tool for quantifying future climate change; however, significant uncertainties remain in the GCM treatment of clouds, aerosol, and their effects on the Earth's energy balance.

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

Designated a national user facility in 2003, the ARM Climate Research Facility (ARM Facility) is a scientific user facility for obtaining long-term measurements of radiative fluxes, cloud and aerosol properties, and related atmospheric characteristics in diverse climate regimes.

The ARM Facility now provides unmatched measurement capabilities that permit the most detailed documentation of cloud characteristics and their evolution ever obtained anywhere in the world and will help scientists reduce the two largest uncertainties in climate models: the roles of clouds and aerosols in climate change.

This report provides an overview of the ARM Facility and a selection of achievements for each in fiscal year (FY) 2011.

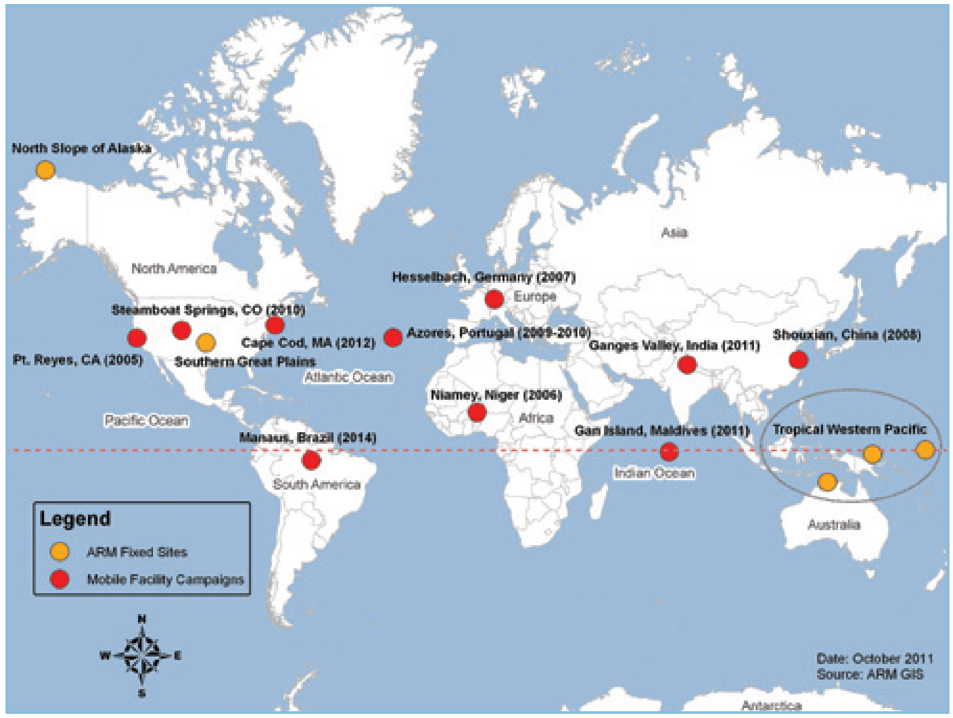
Review panel states ARM Facility "without peer." *Every three years, DOE Office of Science user facilities undergo a review to evaluate their effectiveness in contributing to their respective science areas. The latest ARM Facility review was conducted in mid-February by a six-member review panel. The panel convened in Ponca City, Oklahoma, near ARM's SGP site to conduct their review. Their first agenda item was an SGP site tour, which provided a real-time example of the scope and expertise of site operations and included a demonstration of the site's newly installed precipitation radars. The remainder of the review consisted of technical presentations by Facility management. Notably, in a debriefing following the review, the panel stated that ARM was a "world-class facility without peer."*

GOAmazon 2014 workshop identifies challenges, opportunities. *In July 2011, DOE's Office of Biological and Environmental Research (BER) held a two-day workshop to identify key scientific challenges and opportunities associated with a major field campaign—Green Ocean Amazon 2014, or GOAmazon2014—taking place in Manaus, Brazil. During the campaign, several BER programs, including the ARM Facility, will deploy observational resources to obtain data for studying one of the most complex climate processes on Earth: the atmosphere-cloud-terrestrial tropical systems that drive tropical deep convection in the Amazon.*

More than two dozen process and modeling scientists with expertise in atmospheric and terrestrial ecosystem research participated in the workshop, along with BER program managers and invited speakers. The outcomes of this workshop are summarized in the GOAmazon2014 Workshop Report (DOE/SC-0141), including appendices containing an agenda, participants list, and measurement capabilities collection.

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).

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 (***www.archive.arm.gov***) for use by the atmospheric science community.

Using these data, scientists are studying the effects and interactions of sunlight, radiant energy, and clouds to understand their impact on temperatures, weather, and climate. As part of this effort, ARM personnel analyze and test the data files to create enhanced data products, which are also made available for the science community via the ARM Data Archive 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 directed by **DOE Headquarters**. An **Infrastructure Management Board** coordinates the scientific, operational, data, financial, and administrative functions of the ARM Facility. An 11-member **Facility Science Board**, selected by the ARM Program Director, serves as an independent review body to ensure appropriate scientific use of the ARM Facility.

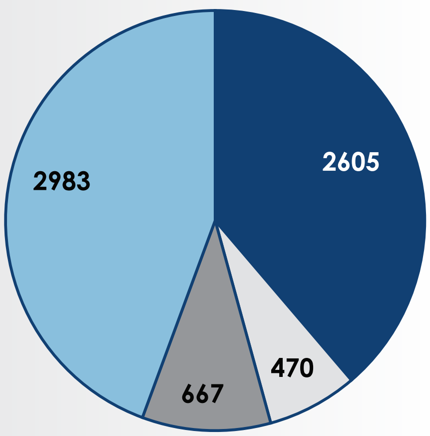
Cloud radar overhauled and renamed. *In mid-December 2010, a new radar began a two-week pre-operational test alongside the ARM MMCR at SGP. This ushers in a new era for the fixed-position cloud data previously acquired by the MMCR. The MMCR (right-hand side) has been retired at all of ARM's permanent research sites in favor of the new KAZR (left-hand side), which is expected to provide significantly improved sensitivity.*

Since it began operating in 1996, the MMCR set the standard for providing data about cloud boundaries, vertical velocity, and reflectivity. Through the Recovery Act, ARM was provided the opportunity to significantly update the radar's technology. As a result, the KAZR is essentially a new radar. Sourced by a different manufacturer, it uses only two of the same components—the antenna and transmitter—as the previous model. Although the user community must familiarize itself with a new instrument name, the ingested data format is as similar as possible to the historical MMCR ingest. In addition, the change should be transparent for researchers who use data from the MMCR through the widely used Active Remote Sensing of Clouds, or ARSCL, value-added product (VAP).

Fiscal Year 2011 Budget Summary and Facility Statistics

FY2011 Budget ($K)	
Infrastructure	*45,694*

Visitor Days by Site



User Statistics for the Period of October 1, 2010–September 30, 2011			
ARM Facility Component	**Unique Scientific Users**	**Unique Non-Scientific Users**	**Totals**
AMF1 (Azores)	19	16	35
AMF2 (Colorado)	156	43	199
NSA	41	40	81
SGP	149	178	327
TWP	34	28	62
Data Management Facility	48	67	115
Archive	770	75	845
Total	**1217**	**447**	**1664**

Operational Statistics for the Period of October 1, 2010–September 30, 2011		
	Data Availability (%)	
SITE	**GOAL**	**ACTUAL**
AMF	0.95	0.77
NSA	0.90	0.90
SGP	0.95	0.93
TWP	0.85	0.94
Site Average	**0.90**	**0.92**

Site average is calculated for fixed sites only.

The AMF did not operate during the fourth quarter of FY2011, so the average is calculated based on data availability during the first three quarters.

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 FY2011. A summary of all ARM Facility campaigns that began in FY2011 is available at the end of this report.

Midlatitude Continental Convective Clouds Experiment

Beginning April 2011, the ARM SGP site in north-central Oklahoma hosted the Midlatitude Continental Convective Clouds Experiment (MC3E), the first major field campaign to take advantage of numerous new radars and other remote sensing instrumentation installed throughout the site with funding from the Recovery Act.

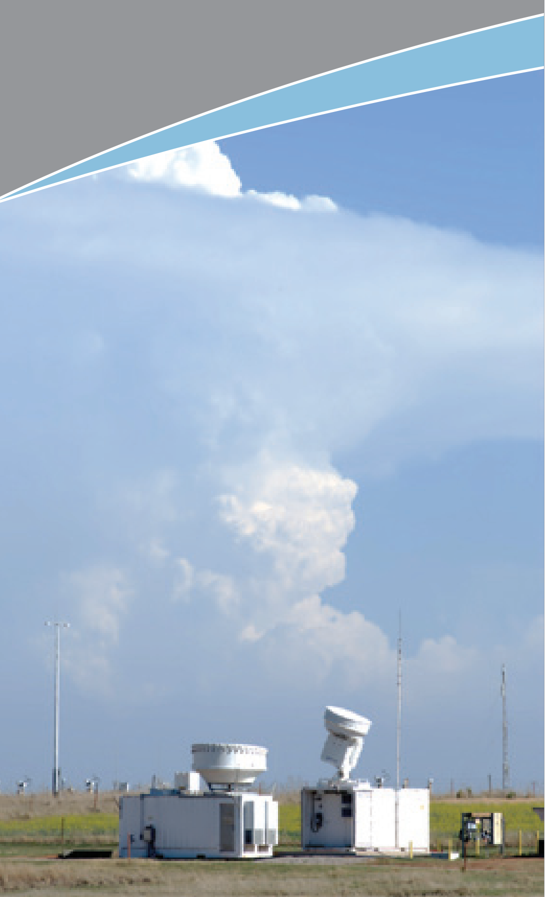
The campaign was highly complex, involving five remote radiosonde sites, supplemental radars, coordinated aircraft, and a dense network of dozens of rain gauges and disdrometers. The National Aeronautics and Space Administration (NASA) also sponsored more than 100 flight hours with two different aircraft: the ER-2 and the University of North Dakota's (UND) Citation. The Citation carried two probes belonging to the AAF and purchased in 2010 through the Recovery Act. By heavily supplementing the routine measurements from the SGP site, the goal of MC3E was to provide the most complete characterization of convective cloud systems and their environment that has ever been obtained, providing details for the representation of cumulus clouds in computer models that have never before been available.

Late spring in the Midwest generated some of the most severe weather ever recorded in the state of Oklahoma and produced a variety of convective cloud conditions. These conditions provided MC3E researchers with ample opportunity to study the comprehensive data set collected by the wide array of instruments throughout the study domain.

As a storm system moved over the SGP Central Facility on May 20, 2011, it was sampled by all the ground-based instruments and radars and sampled from above and within by aircraft flying well-defined cross-sections over the Central Facility. A tornado on May 23, 2011, was observed by the new C-SAPR about 50 kilometers to the northeast of the Central Facility.

On May 24, 2011, another series of storm cells spawned numerous tornadoes that touched down in Oklahoma. One of these tornadoes passed within a quarter-mile of SGP instruments located at a small SGP "extended facility" in El Reno. Although outside of the MC3E radar domain, instrumentation at an Oklahoma Mesonet site collocated with the ARM site at El Reno recorded winds of around 150 miles per hour and an extreme pressure drop as the tornado passed through.

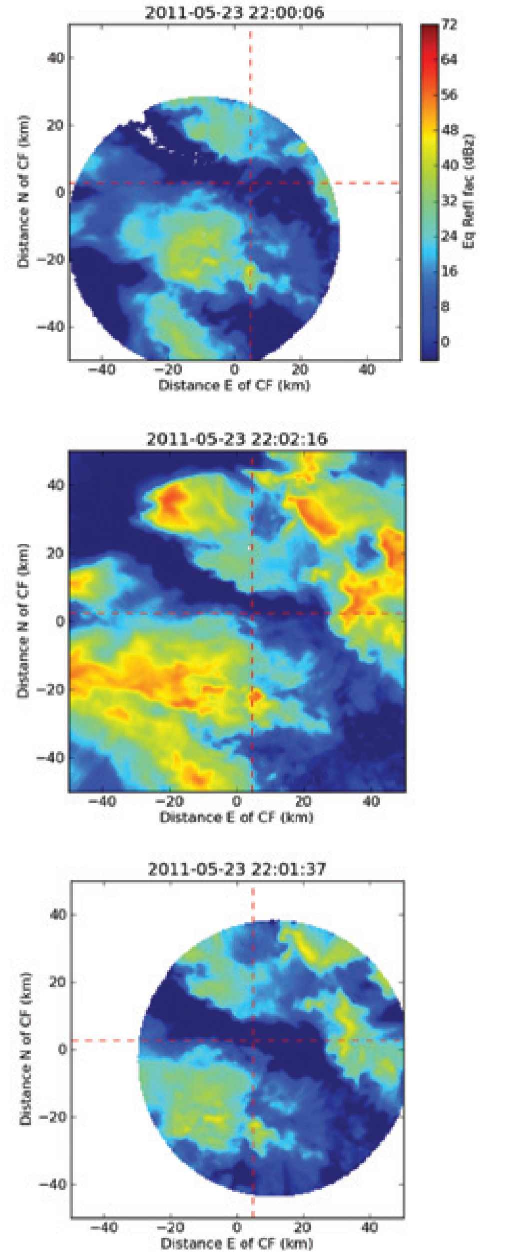
During MC3E, convective clouds like these were measured by NASA research aircraft and numerous radars throughout the SGP site, including ARM's radars at the SGP Central Facility.



Results: Preliminary analysis of the data from the MC3E campaign indicates that a wide variety of cloud and precipitation conditions were sampled, including strong convective lines, isolated convective cells, widespread stratiform rain, elevated weak convection, boundary-layer clouds, and mid- or upper-level clouds. The data collected before, during, and after these events will be used to investigate atmospheric processes important for the parameterization of convective clouds in large-scale atmospheric models. The measurements that will be used for this analysis include:

- Large-scale radiosonde array: More than 25 participants launched 4–8 weather balloons per day from 6 different sites, totaling more than 1400 launches over the course of the six-week field campaign. The profiles of atmospheric state variables will provide important information on the environment in which convective clouds progress through their life cycle. These profiles are also an important input to large-scale atmospheric models.
- New ARM scanning radar systems: These instruments provided new observations on the details of cloud and precipitation systems during all stages of their life cycle. The variety of observations at different wavelengths allowed the observation of a full spectrum of clouds from small non-precipitating clouds to large, organized storm systems, including severe weather.
- Coordinated aircraft observations: The NASA ER-2 and UND Citation flew coordinated flights in many of the different precipitating systems seen during MC3E, providing a view from above the clouds and measurements of the cloud and precipitation microphysics within the clouds.
- Disdrometer network: A network of more than 20 disdrometers provided information on the variability of precipitation drop size distributions at sub-storm size scales and insights into the formation, growth, and break-up processes of the drops.

These cases provide an unprecedented, comprehensive data set for studying cloud and precipitation processes and improving climate models for years to come.



These three radar images show observations of a strong convective system with severe weather that moved through the MC3E domain on the afternoon of May 23, 2011. From top to bottom, data were gathered by the southwest X-SAPR, the C-SAPR, and the southeast X-SAPR.

Storm Peak Lab Cloud Property Validation Experiment

During STORMVEX, the AOS was located at Christie Peak, along with a sign describing the various elements of the study.

From October 2010 through April 2011, a dense collection of remote sensing instruments gathered data from the clouds at four different elevations on Mount Werner in the Steamboat Springs ski area as part of the Storm Peak Lab Cloud Property Validation Experiment (STORMVEX). Scientists will use these data to study how clouds—especially those that produce rain and snow—evolve in mountainous terrain. They will use the data to verify the accuracy of measurements used in computer models of the Earth's climate system.

The goal behind the multiple elevation instrument strategy was to capture a "vertical profile" of the clouds that move across the mountain slopes. To do this, the department deployed AMF2 with nearly two dozen remote sensing instruments to take continuous measurements from three different elevations beneath Storm Peak Lab (SPL), a permanent atmospheric research laboratory at the top of Mount Werner. Several of the instruments deployed during the field campaign were funded by the Recovery Act and had never been deployed before. The campaign also represented the inaugural deployment of ARM's second mobile facility.

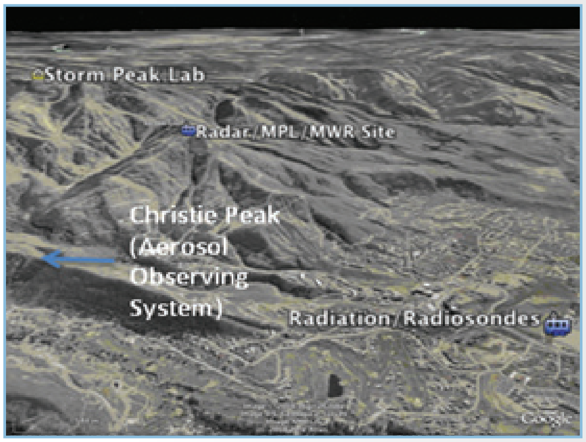
The SWACR gathered cloud properties data outside the Thunderhead Ski Lodge in Steamboat Springs, Colorado.

Because clouds are so dynamic and can contain ice, water, or a mixture of the two, they continue to be one of the hardest components of the climate system for scientists to model accurately. Ground-based instruments provide more geographic and temporal coverage of these cloud systems. Instruments on the ground are typically used to obtain—or "retrieve"—measurements that are related indirectly to important cloud processes. Inferring these cloud processes requires development of mathematical formulas, or algorithms, to convert the measurements into cloud properties. In order to ensure greater accuracy of the ground-based measurements, comparisons are made with more direct airborne measurements. During the experiment, SPL was in-cloud, and their array of measurements served as a proxy for aircraft measurements.

About a dozen instruments were located on the valley floor, near the base of Mount Werner, where researchers also launched weather balloons several times a day. More instruments were located outside Thunderhead Lodge, a main thoroughfare for the ski area. A third instrument collection was located near the Christie Peak Express chairlift. SPL, at the top of the mountain, hosted several instruments in addition to its permanent collection.

In addition, the National Science Foundation-supported Colorado Airborne Multiphase Cloud Study (CAMPS) provided nearly 100 hours of research flight time over the Steamboat area by the University of Wyoming King Air research aircraft. Instruments and support from NASA's Jet Propulsion Lab were also critical elements of STORMVEX.

Results: Understanding the complex microphysical processes that link air motions with the production of frozen precipitation in liquid phase clouds is an important but poorly understood process. STORMVEX benefited from one of the snowiest winters on record in the northern Colorado Rocky Mountains and enjoyed cloud cover exceeding 60 percent. Measurable snow was recorded on more than 75 days of the campaign, with major snowfall exceeding 10 centimeters per day on approximately 20 of those days. Total measurable snowfall exceeded 800 centimeters.



This map of the STORMVEX sites illustrates the various elevations at which measurements were gathered.

During the campaign, AMF2's major assets operated nearly flawlessly with no major downtime of the scanning W-band cloud radar (SWACR). The SWACR collected terabytes of Doppler spectra and volumetric radar reflectivity data from an area extending 10 kilometers in all directions, including the complex terrain of the Park Range mountains.

Radiosondes were launched on a regular schedule from the valley by AMF2 and an intrepid cadre of local volunteers. Simultaneously, aerosol data were collected by the AOS located on Christie Peak and by instruments at SPL. Also at SPL, measurements of cloud droplets, ice crystals, and snowflake particle concentrations were collected. In addition to SPL's regular staff, a team of graduate students from the University of Utah and the University of Washington maintained SPL's instruments in conditions that were often challenging.

Analysis of the data set is just beginning to generate scientific results. Early analysis of the SWACR data is showing a measurable polarimetric signature to snowflake crystal structure. The aerosol data are revealing a unique nucleation process that occurred daily at approximately the same time in the afternoon at both SPL and at Christie Peak. Finally, the SWACR Doppler spectra are displaying a well defined signature of oriented snowflakes as well as depicting a unique distribution of precipitation.

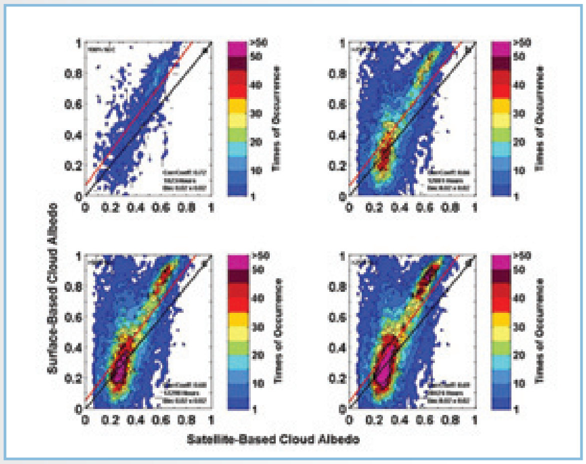
2011 Publications Summary	
Category	**Total**
Abstracts or Presentations	239
Book Chapters	1
Conference Papers	117
Journal Articles	117
Technical Reports	23
Total	380

Research Highlights

Scientists around the world use data from the ARM Facility for their research. In FY2011, ARM data were cited in a total of 380 publications. The following pages feature a selection of ARM research highlights from these publications. For more publications information, search the ARM Publications Database:

www.arm.gov/publications/publist

A New Surface-Based Approach for Determining Cloud Albedo



Comparison of cloud albedo derived from the new surface-based approach and the Geostationary Operational Environmental Satellite (GOES) satellite measurements at SGP. The red and black lines represent the linear fit to all the data points and perfect match, respectively. The different panels account for the different percentage of the occurrence of single-layer clouds.

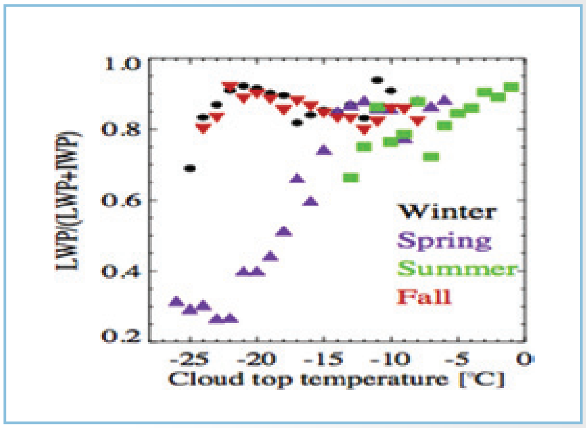
One of the ARM Facility's longest and best measurements is surface-based solar radiation. Within this study, researchers capitalized on long-term and high-resolution radiation measurements to address three outstanding issues related to cloud-radiation interactions. First, it is theoretically shown that relative surface cloud radiative forcing, defined as the difference between clear-sky and all-sky surface downwelling solar radiation normalized by the clear-sky surface downwelling solar radiation, approximately equals cloud fraction times cloud albedo. Second, based on this analytical expression, a new method was developed to estimate cloud albedo from measurements of the relative surface radiative forcing and cloud fraction. The new surface-based method is evaluated by comparison with coincident and collocated satellite measurements. Finally, using the new formulation, high-resolution, decade-long data on relative cloud radiative forcing and cloud albedo are generated from the concurrent surface-based measurements of downwelling shortwave radiation flux and cloud fraction collected at SGP since 1997. These new data are then used to quantify multiscale (diurnal, annual, and inter-annual) variation and co-variation of surface cloud radiative forcing, cloud fraction, and cloud albedo.

This study demonstrates the utility of the concept of relative cloud radiative forcing, its quantitative relationship with cloud fraction and cloud albedo in studying cloud-radiation interactions, and the potential for its application to other ARM-like sites where radiation is routinely measured. A similar framework can be applied to evaluate climate models in terms of parameterization of process coupling, an aspect that has not received sufficient attention.

(Reference: Liu, Y, W Wu, MP Jensen, and T Toto. 2011. "Relationship between cloud radiative forcing, cloud fraction and cloud albedo, and new surface-based approach for determining cloud albedo." *Atmospheric Chemistry and Physics* 11(14): 7155–7170, doi:10.5194/acp-11-7155-2011.)

Ice Generation and Growth in Arctic Mixed-Phase Clouds

In experiencing significant changes in its surface air temperature, sea-ice cover, atmospheric circulation, precipitation, snowfall, biogeochemical cycling, and land surface, the Arctic has proven sensitive to global climate changes. Advanced knowledge of cloud-radiation-dynamics feedbacks is needed to understand these current changes and to reliably forecast future changes. Due to the Arctic's location and unique thermodynamic conditions, knowledge of clouds in the middle latitude cannot be fully applied to it. For example, Arctic clouds are dominated by stratiform mixed-phase clouds, which have a much lower occurrence in the middle latitude. Long-term observations at NSA offer opportunities to understand physical processes controlling these clouds and their roles in the Arctic climate system.



Long-term data show the spring season has distinct ice-liquid mass partition in Arctic mixed-phase clouds.

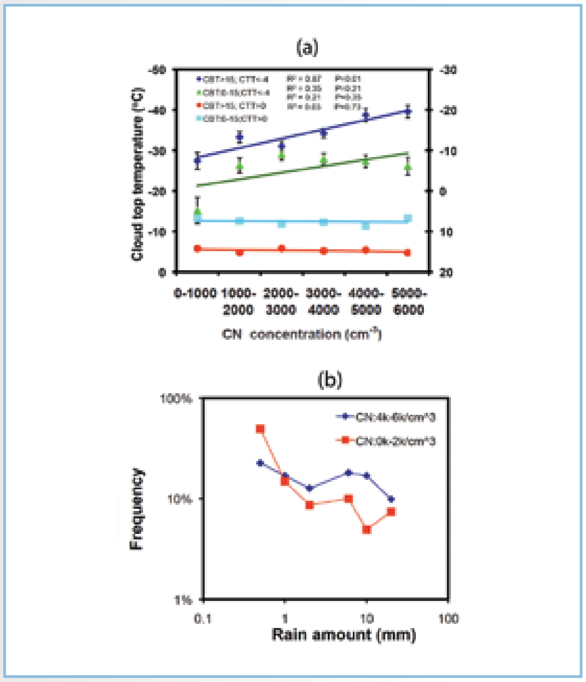
By combining multiple remote sensor measurements, an algorithm was developed to retrieve liquid- and ice-phase properties in these mixed-phase clouds, which offer needed information for process studies. Based on six years (1999 to 2004) of observational and retrieval data at NSA, researchers determined the spring season has distinct ice-liquid mass partition in Arctic mixed-phase clouds. The analyses of surface samplings and lidar depolarization profiles indicated a high occurrence of long-range transported dust aerosols in the spring season, which points to a strong seasonal dust impact on ice generation in Arctic mixed-phase clouds. Due to the Arctic's long winter and low sun elevation angle, these mixed-phase clouds can warm the surface through downward longwave radiation. For moderate, thin mixed-phase clouds, different ice water contents in them can result in up to 9 watts per square meter more downward longwave radiation reaching the surface. This indicates a potential significant aerosol indirect radiative effect in Arctic mixed-phase clouds by changing ice-phase properties.

(References: Zhao, M. 2011. "The arctic clouds from model simulations and long-term observations at Barrow, Alaska." PhD Dissertation, University of Wyoming.

Zhao, M, and Z Wang. 2010. "Comparison of Arctic clouds between European Center for Medium-Range Weather Forecasts simulations and Atmospheric Radiation Measurement Climate Research Facility long-term observations at the North Slope of Alaska Barrow site." *Journal of Geophysical Research* 115: D23202, doi:10.1029/2010JD014285.)

ARM Data Reveal the Strongest Long-Term Net Impact of Aerosols on Clouds and Precipitation

Aerosols—tiny particles in the air, like dust or soot—can affect clouds and precipitation by serving as cloud condensation nuclei (CCN). They can alter cloud microphysics and precipitation processes and modulate radiative and latent energy to change atmospheric dynamics and thermodynamics that dictate cloud development. These effects can either suppress or foster cloud and precipitation processes. Various effects have been studied for individual cases under highly constrained conditions, but little has been done to decipher long-term effects under general conditions.

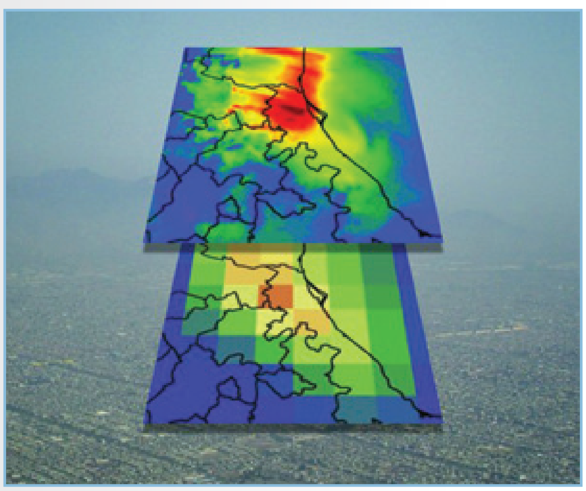


Changes of cloud top temperature (a) and precipitation frequency (b) with aerosol number concentration (CN) measured at SGP for 10 years. Clouds are differentiated by cloud top temperature (CTT), bottom temperature (CBT), and rainfall amount.

Using a 10-year data set of extensive measurements from SGP, the long-term net impact of aerosols on cloud and rainfall frequency is revealed for the first time, and various effects are sorted out under different meteorological and cloud conditions. Cloud-top height and thickness are found to increase—most significantly in summer—with increased aerosol concentration measured near the ground for clouds with warm base (above 15°C) and mixed-phase tops (below -4°C). Few changes are found for clouds with no ice or with high cloud bases. The precipitation frequency increases with aerosols for deep clouds of high liquid water content and decreases for clouds with little water. The observations, successfully reproduced with a cloud-resolving model, have significant implications to understanding anthropogenic influences on water resources, monitoring Earth's climate changes, and sustaining economic development. The drastic changes in cloud vertical development can alter Earth's radiation balance and atmospheric dynamics. Because economic development often is accompanied by increases in aerosol emissions, the findings imply a severe adverse impact on sustainable development, especially over regions vulnerable to extreme meteorological events (e.g., drought or flooding). Increases in aerosol or pollution tend to polarize precipitation, making dry places drier and moist regions wetter, reducing water usage efficiency—a key factor for sustaining life and agriculture.

(Reference: Li, Z, F Niu, J Fan, Y Liu, D Rosenfeld, and Y Ding. 2011. "Long-term overall impact of aerosols on the vertical development of clouds and precipitation." *Nature Geoscience*: doi:10.1038/NGEO1313.)

Looking for Aerosol in All the Right Places



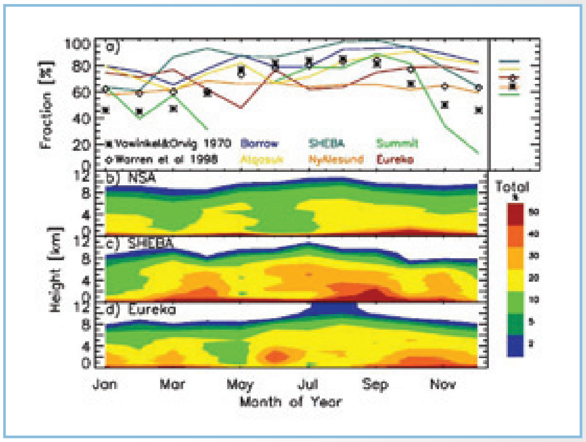
High-resolution simulation for Mexico City (top), shows a more detailed and accurate picture of aerosol pollution compared to representations of a global climate model (bottom). The deep red to light green represents high to low concentrations of aerosol pollution.

Global climate models calculate atmospheric processes at scales close to 100 by 100 kilometers (62 miles across). Aerosols, tiny particles of dust or pollution in the atmosphere, act on much smaller scales and can vary according to local atmospheric or geographic features. Overlooking the small-scale effects of aerosols can have a negative impact on global climate predictions. During a two-week period over Mexico City, researchers found that the difference between their detailed aerosol modeling and the coarse modeling used in modern global climate models was as high as 30 percent. In global climate models, the climate effects of these features are often averaged out over the large-scale grid, distorting the actual effects of the processes. Aerosols, which scatter and absorb sunlight, are known to tip the energy balance toward heating or cooling, depending on the type of particle and its elevation above Earth's surface. The researchers identified small-scale processes that can lead to larger, accumulated errors over time. Using a high-resolution atmospheric meteorology and aerosol model combined with extensive observations of aerosol and the surrounding environment, they found that certain aerosol emissions are likely to cause error due to small-scale fluctuations in atmospheric conditions. This study provides climate scientists with a more accurate account of aerosols on the small scale to help analyze and predict global climate changes.

(Reference: Gustafson Jr., WI, Y Qian, and JD Fast. 2011. "Downscaling aerosols and the impact of neglected subgrid processes on direct aerosol radiative forcing for a representative GCM grid spacing." *Journal of Geophysical Research–Atmospheres* 116: D13303, doi:10.1029/2010JD015480.)

Characterizing Clouds at Arctic Atmospheric Observatories

To better observe the role clouds play in Arctic atmospheric radiation and hydrologic cycles, research scientists assembled cloud observations made over the past decade at six Arctic atmospheric observatories—Barrow and Atqasuk (Alaska), Eureka (Canada), NyAlesund (Norway), Summit (Greenland), and the Beaufort Sea—to investigate many basic cloud characteristics, including occurrence fraction, vertical distribution, persistence in time, diurnal cycle, boundary statistics, and phase distributions.



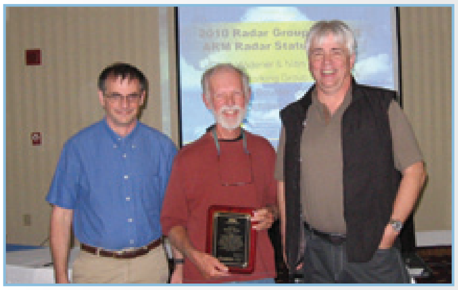
(a) Annual cycles of monthly mean cloud occurrence fraction at six Arctic atmospheric observatories. The average cloud fraction for all sites, equally weighting each site, is given as the black curve with annual averages provided (at right). For comparison, past Arctic cloud fraction climatologies also are provided. Monthly average vertical distributions of cloud occurrence fraction are provided for (b) Barrow, (c) SHEBA, and (d) Eureka.

Continuous ground-based observations, provided via a combination of ground-based cloud lidar, radar, ceilometer, interferometer, microwave radiometer, and/or radiosondes at the sites, reveal annual cloud occurrence fractions ranging from 58 to 83 percent, with clear annual cycle variability where clouds are least frequent in winter and most frequent in late summer and fall (except in Eureka). Importantly, this study has also provided a broader examination of Arctic cloud phase, monthly average total cloudiness at individual locations, median cloud persistence, interannual variability, and cloud phase distributions as a function of atmospheric temperature and relative humidity. Significant inter-site differences do occur in both the frequency of occurrence for clouds of different phases and their annual variability, suggesting that the processes responsible for cloud formation and phase determination are similar across the Arctic while larger-scale meteorology determines the actual distribution of clouds and cloud phase at each specific location. These data are important to both better understand and simulate in numerical models to more accurately predict trends in Arctic climate.

(References: Shupe, MD, VP Walden, E Eloranta, T Uttal, JR Campbell, SM Starkweather, and M Shiobara. 2011. "Clouds at Arctic atmospheric observatories, part I: Occurrence and macrophysical properties." *Journal of Applied Meteorology and Climatology* 50(3): 626–644, doi:10.1175/2010JAMC2467.1.

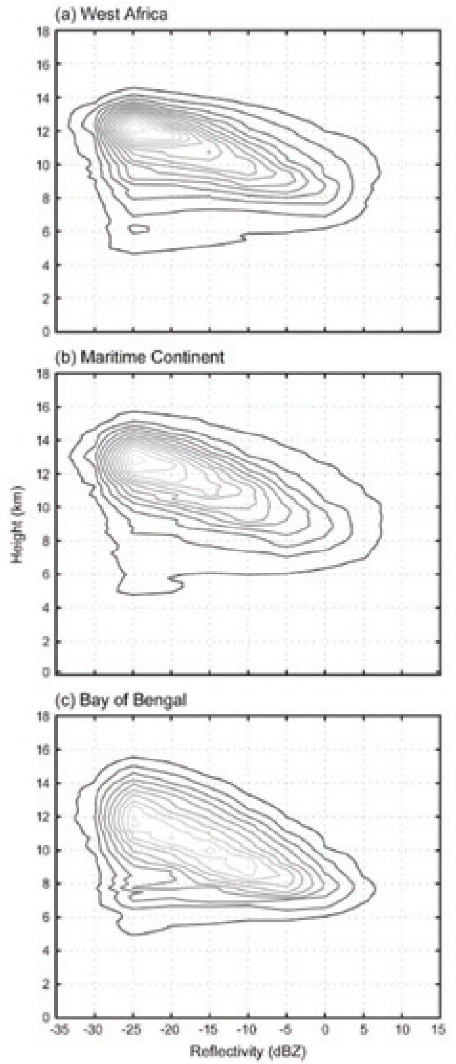
Shupe MD. 2011. "Clouds at Arctic atmospheric observatories, part II: Thermodynamic phase characteristics." *Journal of Applied Meteorology and Climatology* 50(3): 645–661, doi:10.1175/2010JAMC2468.1.)

Developer of the Millimeter Cloud Radar Recognized at the ASR Fall Meeting. *During the Atmospheric System Research Fall Working Group Meeting in October, Dr. Kenneth Moran, National Oceanic and Atmospheric Administration (NOAA), was presented with a plaque in recognition of his 15 years of outstanding contributions to the ARM Program and ARM Climate Research Facility. As the developer of the MMCR, Ken's expertise and professionalism, as well as his subsequent support and maintenance efforts, have been invaluable to ARM's success.*



ARM Technical Director Jim Mather (left) and ARM Radar Group Lead Kevin Widener (right) present a plaque to Kenneth Moran.

Anvil Clouds of Tropical Mesoscale Convective Systems in Monsoon Regions



These contour diagrams show the frequency distribution of CloudSat cloud profiling radar reflectivity as a function of height of thick (>6 kilometers) mesoscale convective system anvils over (a) West Africa, (b) the Maritime Continent, and (c) Bay of Bengal. The contours show bin counts divided by total counts. The contour interval is 0.001, contour values range from 0.001 to 0.018, and bin dimensions are 5 dBZ by 250.

In the tropics, upper-level clouds containing ice and mixtures of ice and liquid water strongly affect the transfer of radiation through the atmosphere and are associated with deep convection. Deep mesoscale convective systems (MCSs), larger than ~100 kilometers, often develop large stratiform precipitation regions and account for a large fraction of tropical precipitation, anvils, and cirrus clouds; produce most of the latent heating in the tropics; and affect radiative heating. This study, which analyzed three locations: the Maritime Continent, Bay of Bengal, and West Africa, constructs a joint climatology of both precipitation structure and anvil characteristics of tropical MCSs to analyze their effect on radiative heating in the tropics.

The MCS precipitation structures were examined using data from the Tropical Rainfall Measuring Mission's (TRMM) Precipitation Radar. CloudSat Cloud Profiling Radar was used for the anvil cloud structures and was verified against the ARM vertically pointing cloud radars (Niamey and Darwin) with a high degree of consistency. The precipitation structures were partitioned into convective and stratiform profiles, and anvil clouds were subdivided by thickness. The data were displayed using Contoured Frequency by Altitude Diagrams (CFADs).

In general, the anvils generated by MCSs in each location have similar statistics, although they are dominated by measurements of the extensive thin portions of MCS anvils. Most of the variation in anvil structure is evident in the thick portions. The West Africa thick anvils CFAD, indicating a broad, flat reflectivity histogram and maximum reflectivity lower in the anvils, contrasts with the Bay of Bengal thick anvils CFAD that shows a sharply peaked distribution of reflectivity at all altitudes with modal values increasing downward monotonically. The Maritime Continent thick anvils reflectivity histogram is intermediate between the other two. The observed differences between the continental and oceanic anvil statistics imply that future parameterizations and representations of anvil clouds in prediction models must account for different anvil physics in the two regions.

(Reference: Cetrone, J, and RA Houze Jr. 2009. "Anvil clouds of tropical mesoscale convective systems in monsoon regions." *Quarterly Journal of the Royal Meteorological Society* 135(639): 305–317, doi:10.1002/qj.389.)

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.

Recovery Act

Doppler Lidars Measure Wind in Three Dimensions

Through the Recovery Act, ARM added three new Doppler lidar systems to its measurement suite. The Doppler lidar operates in a similar fashion as a radar; pulses of energy are transmitted into the atmosphere, and the energy that returns to the transceiver is collected and measured. By detecting the Doppler shift in the returned energy, the Doppler lidar produces height- and time-resolved measurements of vertical air velocity in the lower troposphere. In addition, the new ARM Doppler lidars have full upper-hemispherical scanning capabilities. This enables 3D mapping of turbulence structure and measurement of horizontal wind profiles. The lidars were tested at the SGP site beginning in October 2010. Following the test period, two of the new Doppler lidars were deployed at SGP and TWP Darwin, while one system is currently deployed in India and will travel with AMF1.

Two of the three new Doppler lidars are shown here during testing at SGP in October 2010.

A Giant Lift for Arctic Climate Data

Ushering in the first operational precipitation radar on the U.S. Arctic Coast, engineers completed acceptance testing for the new X-SAPR on June 21, 2011, at its location atop the Barrow Arctic Research Center in Alaska. Data from the radar are transmitted through a wireless connection to the ARM site data system. With the radar up and running, signal returns on June 24, 2011, provided an indication of the radar's coverage over the North Slope, reaching distances of 200–250 kilometers to the north of Barrow over the Arctic Ocean.

A newly installed X-SAPR operates from atop the Barrow Arctic Research Center in Alaska.

The "X-band" refers to the 9.5-gigahertz frequency at which the radar operates. Different frequencies detect different types of cloud particles and also determine how far the radar can detect those particles. The X-band radar is sensitive to precipitating particles, and in the snow and light rain common in Barrow, it can "see" these precipitating systems to great ranges. This dual-polarization Doppler radar provides details about precipitation that allow scientists to more accurately estimate rainfall, classify precipitation types (rain, sleet, snow) and map wind fields.

New Raman Lidar Provides Tropical Remote Sensing Data

The new Raman lidar in Darwin is nearly identical to the lidar that has been in operation at SGP since 1996.

The first operational Raman lidar in the tropics began gathering data at the TWP Darwin site in November 2010. Nearly identical to the long-running Raman lidar at SGP, it is the only active remote sensing instrument at the Darwin site capable of providing simultaneous measurements of water vapor, clouds, and aerosols. It provides a useful complement to data collected by the other instruments at the site.

The Raman lidar (light detection and ranging) uses pulses of laser radiation to probe the atmosphere. A telescope collects the backscattered radiation that returns, and the optics inside the laboratory shelter use that radiation to derive time- and altitude-resolved profiles of atmospheric water vapor, aerosols, clouds, and temperature. The system is housed in two standalone shelters; one serves as a laboratory enclosure, and the other contains support systems such as HVAC services and power conditioning.

Site Operations

New Aircraft Probes in Operation Again

In March, ARM Aerial Facility scientist Jason Tomlinson met with colleagues at the University of North Dakota to assist in the integration of the probes onto the Citation aircraft and to provide training on the operation of the UHSAS-A (back) and HVPS-3 (front) instruments.

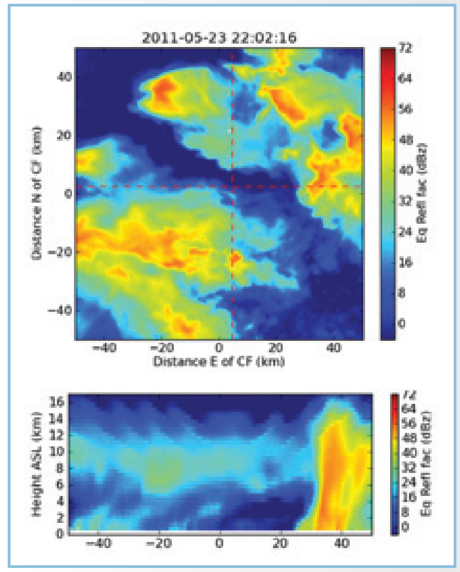
In April, researchers began the MC3E field campaign at SGP. As part of the airborne research portion of the campaign, NASA sponsored the UND Citation aircraft that provided in situ observations of precipitation-sized particles, ice freezing nuclei, and aerosol concentrations. Joining the Citation's instrument payload for the campaign were two new aircraft probes—an airborne ultra-high sensitivity aerosol spectrometer (UHSAS-A) and a "version 3" high-volume precipitation spectrometer (HVPS-3)—purchased in 2010 by the ARM Facility through the Recovery Act. Both probes completed research flights on a Gulfstream-1 (G-1) aircraft for the five-week Calwater campaign in California.

The UHSAS-A has increased resolution for measuring a wider range of aerosol size distributions and concentrations than other instruments of a similar nature. Meanwhile, the HVPS-3 measures the number and size of precipitation particles and provides complete digital images of precipitation particles up to nearly two centimeters in size. In addition, the HVPS-3's new slanted probe tip design and post-processing techniques are expected to result in more representative particle size distributions of the ice in the thunderstorm anvils and within precipitating clouds, as data collected with older probes have been questioned due to the influence of "shattering."

ARM Computing Cluster Accelerates Large-Scale Data Products

Three new systems currently being implemented at the ARM Data Archive will provide data processing, analysis, and visualization capabilities for users. The ARM Analysis and Visualization System will contain data visualization tools for various visualization and small-scale data extraction tasks, allowing users to interact with the large-volume data products gathered by ARM radars and lidars. The system will also be used to produce pre-computed plots for large volumes of scanning data, as well as for software development and evaluation.

The ARM Large-Scale Data Processing system will expedite the creation and evaluation of data products from new large datastreams. A specialized graphics processing unit-based system will also be implemented, allowing intensive computation for vertical velocity measurements. Data output from these systems will be archived on a long-term basis and distributed to users through the ARM Data Archive.

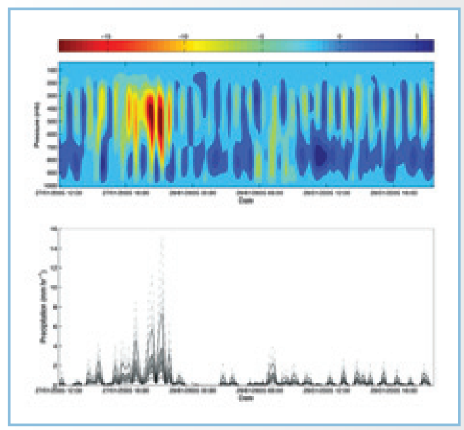


The top plot shows data gathered from a C-SAPR at SGP, and the bottom plot displays a "moment" from that data mapped to a Cartesian grid. These plots were generated using the ARM Analysis and Visualization system, taking about 20 hours and using 8 processors.

Data Delivery

Long-Term, Large-Scale Ensemble Forcing Data Set for Darwin Available

A new data set is available for the ARM TWP Darwin site for long-term, large-scale forcing data. These data were constrained with C-POL radar retrieved rainfall through the variational analysis method (Zhang and Lin 1997) by using the European Centre for Medium-Range Weather Forecasts (ECMWF) analysis. This is an ensemble forcing data set (currently N=100), which was produced by considering potential errors in radar-retrieved rainfall estimate, and covers three wet seasons from 2004 to 2007.

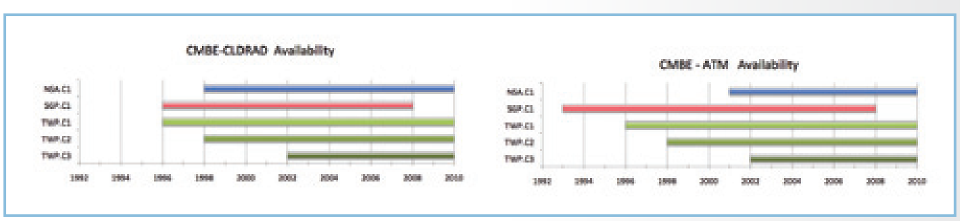


The lower panel shows 100 precipitation time-series derived given potential errors in radar-retrieved rainfall estimate. The upper panel shows the profile of vertical velocity derived using a best-estimate precipitation time-series. Strong rainfall is clearly associated with strong vertical motion in the mid- and upper-levels.

More Climate Modeling Best Estimate Data Available for More Sites

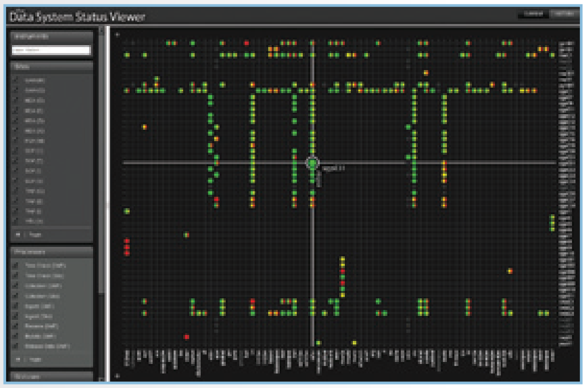
In October 2010, the latest release of the Climate Modeling Best Estimate (CMBE) data set added soundings and surface meteorological measurements in the CMBE-ATM datastream for Barrow, Alaska, and all three TWP sites.
For these four sites, the cloud and radiation datastream, or CMBE-CLDRAD, now includes the most current available source data. In addition, CMBE-CLDRAD has the most recent release of integrated liquid water and water vapor data from the microwave radiometer (MWRRET) data set, which was reprocessed for all sites since the last CMBE release.

Also provided is the statistical summary of the CMBE data for these four ARM sites. It includes both monthly mean and monthly mean diurnal cycle and their climatologies for all the geophysical quantities contained in the CMBE data sets. For most sites, the most current data are from 2010.



Soundings and surface meteorological measurements are now available for five ARM sites in the CMBE data set.

Overhaul of Data System Status Viewer Hits Bull's-eye



This partial window of DSView shows filtering options for various ARM sites on the left. The bull's-eye can be dragged to any spot in the matrix to highlight a specific site/ instrument.

How do you display the operational status of nearly 200 instruments at multiple sites around the world on a single web page? In late June, ARM implemented a major system overhaul of the Data System Status Viewer, or DSView—the interactive database providing operational status information for every instrument at ARM's permanent sites. Now running with Adobe®Flash® software, the complex grid is surprisingly easy to navigate. Using a "bulls-eye" to guide the viewer to the desired instrument and site, the new display also includes options for filtering information, browsing processing logs, and exporting status reports to Excel format.

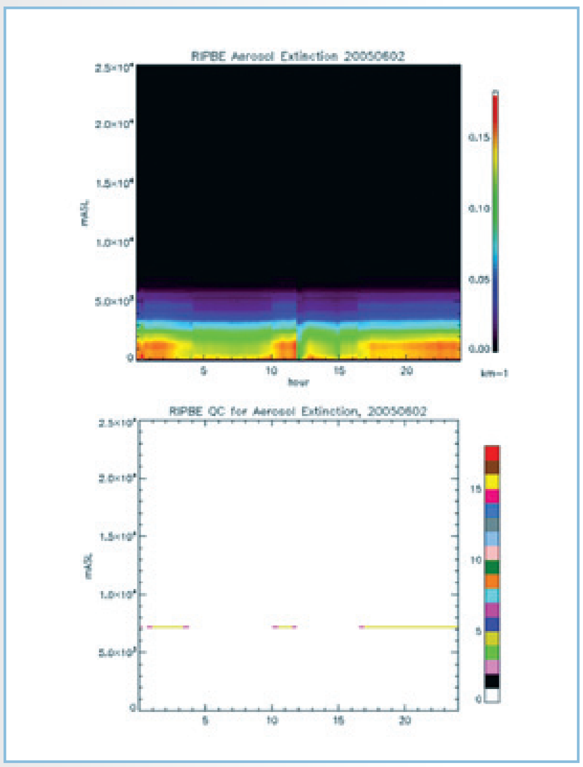
The latest installment of DSView has a totally different look and feel than previous versions, is much faster, and is easily deployed and installed—each site has its own DSView web page displaying only site-relevant information. Because collection, time check, and ingest processes run on both the site and DMF systems, this allows for quick and helpful comparisons. In updating the grid to an integrated process/ data view, the display is refreshed every five minutes while content in the database history is used to display a timeline view of cumulative changes to detect intermittent events.

New Data Evaluation Products

In order to ensure that VAPs meet the high quality standards of the ARM Data Archive, new products progress through an "evaluation" stage before their final release. In FY2011, two new products focusing on cloud properties and radiation moved to the evaluation stage.

The ARM Cloud Retrieval Ensemble Data Set (ACRED) provides a rough estimate of the uncertainties in current retrieved cloud microphysical properties for climate model evaluation and development. It was created by assembling numerous existing ground-based cloud retrievals from the ARM Facility's permanent research sites.

One year of data gathered at SGP is available in the Radiatively Important Parameters Best Estimate (RIPBE) VAP. This product contains a complete set of radiatively important parameters assembled from various instruments on a uniform vertical and temporal grid with quality control and source information.



The upper panel shows the output aerosol extinction field in RIPBE, and the bottom panel shows the quality control (qc) flags on aerosol extinction. Descriptions of the qc flags are given in the netCDF file header. In this case, the gold and pink qc flags on the aerosol extinction indicate periods at the top of the aerosol profile where data were missing in the input file. These data points are marked as indeterminate, and RIPBE either interpolates over the missing data (gold) or uses the closest good value (pink).

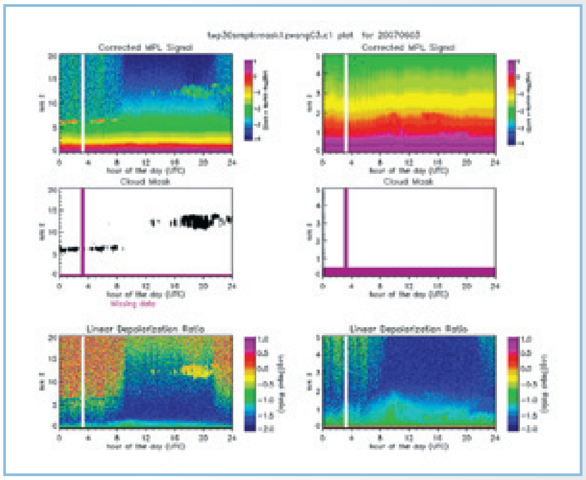
Three Data Products Released for Widespread Use

Three data products moved from "evaluation" to "operational" status, releasing the data to the ARM Data Archive for use by the scientific community. The Surface Spectral Albedo (SURFSPECALB) VAP creates a near-continuous best estimate of broadband and narrowband downwelling irradiance, upwelling irradiances, and surface albedo using the multifilter radiometers (MFRs) on the 10-meter and 60-meter towers and the multifilter rotating shadowband radiometers (MFRSRs) at the SGP Central Facility. The VAP identifies the dominant observed surface type for each day at each tower and then extrapolates the 6-channel narrowband

MFR albedo values to high spectral resolution at one-minute temporal resolution. Data are available for SGP from January 2004 onwards.

The Micropulse Lidar Cloud Mask (MPLCMASK) VAP provides cloud base height, cloud top height, and backscatter coefficient for non-polarized micropulse lidar measurements. In addition, depolarization ratio is computed for polarized and fast-switching micropulse lidar systems. This VAP processes data for the SGP, NSA, TWP, and AMF sites.

Finally, the Microwave Radiometer Retrievals (MWRRET) VAP has data available for the SGP, NSA, and TWP sites, as well as the Black Forest, Germany, deployment of the AMF. Additional AMF deployments will be processed in the next year. The MWRRET VAP retrieves column precipitable water vapor (PWV) and liquid water path (LWP) from the 2-channel microwave radiometers using a physical retrieval methodology that provides improved retrievals over the standard statistical coefficient method.



This sample data plot from MPLCMASK provides several cloud measurements gathered by the MPL.

Communication, Education, and Outreach

ARM Joins User Facility Display at Capitol Hill Exhibition

To become better informed about the research conducted at DOE user facilities, members of Congress extended an invitation for the facilities to take part in a science exhibition on Capitol Hill on April 7, 2011. As one of about 40 user facilities participating in the exhibition, ARM provided content for a poster display in the Rayburn House Office Building and was represented at the event by Jimmy Voyles, ARM Chief Operating Officer. Several congressmen, staffers, and DOE and national laboratory managers stopped by the ARM Facility poster, which provided an overview and images of key features of the Facility, including sites, instruments, data, outreach, demographics, and publications. Voyles answered a variety of questions about ARM's data products, collaborations, and contributions to climate research advances. The poster session was followed by an informal reception with short keynote addresses by invited speakers.

User facility representatives gather in the foyer of the Rayburn House Office Building to set up their posters for the user facility science exhibition held on April 7, 2011.

ARM Data Featured at United Nations Climate Change Conference

At the United Nations Climate Change Conference (COP16) in Cancun, Mexico, in early December 2010, a new global audience got the chance to learn about ARM and how its data are used to improve climate models. Led by the U.S. Department of State, ARM was part of an interagency multimedia demonstration about U.S. climate research efforts that was presented numerous times throughout the conference.

Along with NASA and NOAA, DOE provided information and data that were integrated into the StormCenter Communications, Inc. (SSC) Envirocast® Vision™ TouchTable system. Consisting of a center console with a plasma screen on each side to display supporting videos and animations, the system allows users to access, visualize, and interact with the science data in real-time using touch screen technology and Google Earth™.

Attendees at COP16 gathered in the U.S. Center's "living room" to learn more about climate change research among the federal agencies. (Photo courtesy of the U.S. Department of State.)

The engaging multimedia experience in the U.S. Center "living room" resulted in very positive feedback from the audience, including members of official delegations and non-governmental organizations. Members of the State Department indicated that the United States was presented exactly how they envisioned: a nation that cares about climate change and that is acting to learn more, while using the best science to adapt to the changes that are occurring, mitigate where possible, and offer assistance to other nations that ask for it.

ARM Explores New Frontier with American Association for the Advancement of Science

Numerous scientists and educators at the AAAS 2011 Annual Meeting stopped at the ARM exhibit to learn about the user facility's measurement capabilities and data collections.

Reaching a new audience, the ARM Facility participated for the first time in the annual meeting of the American Association for the Advancement of Science (AAAS) held February 17–21, 2011, in Washington D.C. A total of 8,200 meeting registrants, families, and press attended the event, themed "Science Without Borders" to emphasize the global scale of complex scientific challenges.

Unlike the other scientific conferences that ARM traditionally attends, AAAS held its public "Family Science Days" in the same hall as the scientific exhibits and posters. The resulting crossflow of traffic led many teachers to the ARM exhibit. One teacher expressed interest in using ARM's live data display in her classroom as an example for communicating data, and several science teachers asked about using ARM data for classroom projects. In all, just over 200 visitors stopped at the ARM exhibit to talk or pick up materials during the event. About 300 visitors stopped by the ARM education exhibit, where the lesson plans were well received, and several visitors signed up to receive the biannual education newsletter.

Professor Polar Bear Goes to Washington

One of ARM's Climate Kids debuted at the USA Science & Engineering Festival. Photo courtesy of the Festival.

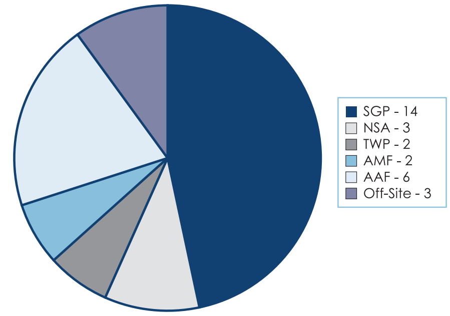
On October 23–24, 2010, ARM participated in the U.S. Department of Energy's exhibit at the USA Science and Engineering Festival on the National Mall in Washington D.C. The new Climate Kid cutout was a big hit, with children and adults alike stopping to take pictures with it and Professor Polar Bear. ARM Education bookmarks, activity booklets, and lesson plans were handed out. A computer showed data from one year ago at ARM's permanent and mobile sites, with explanations of what measurements each data plot showed. A light meter and lamp simulated what happens when clouds pass between the Earth and the sun, and a wind meter tracked the wind speed and plotted it on a chart.

The two-day event was the culmination of a two-week festival, including events in Washington D.C. and across the country. More than 350 organizations participated in the Festival, including academic institutions, research institutes, government agencies, technology companies, museums, and community organizations. As many as 1 million visitors have been reported as attending.

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 FY2011, including these ongoing efforts. The subsequent table summarizes just those campaigns that began in FY2011. For more information, visit the Field Campaign web page at

www.arm.gov/campaigns



Total 2011 Field Campaigns

Dates	Campaign Name	Status	Description
ARM Aerial Facility			
October 2010–September 2012	Airborne Open Polar/Imaging Nephelometer for Ice Particles in Cirrus Clouds and Aerosols	In Progress	A proven laboratory instrument was modified for airborne applications that will measure phase function of ice crystals and aerosol particles without inlet tubes. This O-I-Neph (Open Imaging Nephelometer) will make the first true in situ observations of cirrus cloud phase function and contribute to characterization of aerosol particle properties and remote sensing validation studies. The instrument design uses a narrow-beam laser source and a wide field-of-view imaging camera to capture the entire scattering phase function in one image almost instantaneously. The laboratory instrument's sensitivity allows fully resolved phase functions of gas molecules (Rayleigh scattering) and low concentration background aerosol particles.
October 2010–July 2012	The Maturation and Hardening of the Stabilized Radiometer Platforms	In Progress	Measurements of solar and infrared irradiance by instruments rigidly mounted to an aircraft have historically been plagued by the introduction of offsets and fluctuations into the data that are due solely to the pitch and roll movements of the aircraft. Two Stabilized Radiometer Platforms (STRAPs) were developed to address this problem. As part of the maturation and hardening of the existing STRAP instruments, upgrades were made to the navigational computer hardware components, the platform control software, and the operating system of each of the STRAPs.
October 2010–December 2011	Further Development of the HOLODEC 2 (Holographic Detector for Clouds 2) Instrument	In Progress	The HOLODEC 2 instrument measures ice and cloud particle shape, size, and 3D position via digital inline holography. The sample volume is not dependent on particle size or air speed, but is large enough that size distributions for cloud droplets and small ice particles can be obtained from single holograms. This campaign will harden the HOLODEC 2 instrument to prepare it for regular use in field campaigns through three major activities: (1) design, configure, and test a new data system for HOLODEC 2 capable of reliably recording and storing data recorded in a typical full field campaign, (2) further develop the hologram processing code by developing tools to allow the user to more easily select parameters for hologram processing and ascertain the quality of the results, and (3) refine or reengineer the subsystems of the instrument as required from the initial test flights results to make it fit for regular field campaign work.
October 2010–September 2011	Aircraft Integration and Flight Testing of 4STAR	Completed	The goal of this research effort was to develop and demonstrate an airborne sun-sky spectroradiometer to provide information on aerosols, clouds, and trace gases extending beyond what can be derived from existing airborne sun photometers and to improve compactness, modularity, and versatility. The proposed enhanced instrument was an airborne Spectrometer for Sky-Scanning, Sun-Tracking Atmospheric Research (4STAR-Air) based on the ground prototype (4STAR-Ground) that has been developed and extensively tested over the past several years. The integration effort of the 4STAR and G-1 aircraft included mechanical accommodation as well as electrical and data communication details.

February 2011–March 2011	Calwater Field Campaign	Completed	The goal of this project involved determining how aerosols impact clouds and precipitation patterns in California. Specifically, flights were conducted through precipitating and non-precipitating clouds to determine whether there were chemical or physical differences in the cloud nuclei forming the clouds. The sources of the key cloud seeds were determined using single-particle mass spectrometry. Cloud physics and chemistry were probed in addition to high level meteorological data. Meteorological data were acquired during flights as well as at several ground-level sampling sites. The goal was to unravel the key parameters leading to high levels of rain and snow in California versus sustained cloud cover with very little precipitation.
March 2011–April 2011	MACPEX/SPARTICUS Continued	Completed	In an investigation of properties of cirrus and cirrus anvils, a fast-forward scattering spectrometer probe (FFSSP) and a fast cloud droplet probe (FCDP), installed on the SPEC Learjet, flew in cirrus clouds over SGP in conjunction with the NASA WB-57F in the MACPEX field campaign.
ARM Mobile Facility			
November 2010–April 2011	Storm Peak Lab Cloud Property Validation Experiment (STORMVEX)	Completed	Storm Peak Lab (SPL), located east of Steamboat Springs, Colorado, is a well-established cloud and aerosol research facility operated by the Desert Research Institute. SPL is located 3210 meters above sea level and is above cloud base 25 percent of the time during the winter season. The already extensive instrument suite at SPL was augmented with additional state-of-the-art instruments typically used for airborne cloud research by the Stratton Park Engineering Corporation (SPEC). SPL and SPEC collected in situ cloud and precipitation property measurements while the AMF2 operated at a location approximately 2.4 kilometers west and 2,078 meters in elevation during the winter season.
June 2011–March 2012	Ganges Valley Aerosol Experiment (GVAX)	In Progress	GVAX is using the AMF to measure relevant radiative, cloud, convection, and aerosol optical characteristics over mainland India during an extended period of several months. The aerosols in this region have complex sources, including burning of coal, biomass, and biofuels; automobile emissions; and dust. The extended AMF deployment will enable measurements under different regimes of the climate and aerosol abundance in the wet monsoon period with low aerosol loading; in the dry, hot summer with aerosols dispersed throughout the atmospheric column; and in the cool, dry winter with aerosols mostly confined to the boundary later and mid-troposphere.
North Slope of Alaska			
January 2011–December 2014	Cosmic-Ray Moisture Probe on North Slope of Alaska	In Progress	A new soil moisture/snow monitoring instrument was installed at the Barrow site in the Arctic. This instrument detects 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.
January 2011–December 2013	Sea Ice Effect on Arctic Precipitation-Extension	In Progress	Precipitation samples for each storm that brings about 2 millimeters water of rain (or 2 centimeters of snow) are collected at the Barrow and Atqasuk, Alaska, sites. For a given storm, coastal and inland sites often have a different moisture mix from subtropical versus local sources. By looking at the weather patterns that are responsible to a given storm, scientists will be able to determine what part of the ocean surface contributes to the moisture budget of the storm. The results will be interpreted for the individual influences of the ice-free area of the Arctic, of storm tracks, of atmospheric temperatures at both moisture sources and precipitation sites, and of circulation changes associated with the Arctic Oscillation and/or the North Atlantic Oscillation.

June 2011– May 2021	Atqasuk GPS Base Station	In Progress	A global positioning system base station in Atqasuk provides a local source of geodetic quality differential corrections for GPS data post-processing by scientists and others operating in the Atqasuk area on the Alaskan North Slope. The station is located at the ARM Climate Research Facility, which provides security, power, and Ethernet communications. The station runs continuously, and 15-second sample rate data are archived at the University Navstar Consortium (UNAVCO) and available to the public. All data are available via the internet.
Off-Site Campaigns			
February 2011– November 2014	Four Corners Aerosol Cloud Climate Experiment	In Progress	Four Corners, New Mexico, is one of the largest point sources of nitrogen oxides in the United States from two power plants in the region, in addition to sulfates. This creates acidic aerosols that are transported to downwind regions where they interact with organic emissions (sesquiterpenes) from pine forests in southern Colorado. The deployment will be used to observe boundary-layer heights to provide the dynamical context for a solar tracking Fourier Transform Spectrometer that will measure greenhouse gases, aerosol precursors, and radiation fields on a regional scale (10–100 kilometer).
May 2011– May 2012	915-MHz Wind Profiler for Cloud Forecasting at BNL	In Progress	In support of the installation of a 37 megawatt solar array on the grounds of Brookhaven National Laboratory (BNL), a study of the impacts of clouds on the output of the solar array has been undertaken. Emphasis is on predicting the change in surface solar radiation due to the observed/forecast cloud field on a five-minute time scale. The 915-MHz wind profiler is being operated at BNL to provide information on the vertical profile of winds, especially profiles in the lower troposphere, as an additional input to short-term cloud modeling studies. A secondary focus is on the observation of dynamics and microphysics of precipitation during cold season/winter storms on Long Island.
June 2011– August 2011	Aerosol Life Cycle IOP at BNL	Completed	At BNL, intensive aerosol observations were conducted using the Mobile Aerosol Observing System in a region exposed to anthropogenic, biogenic, and marine emissions with atmospheric processing times depending on air mass trajectories and time of day.
June 2011– November 2011	Evaluation and Upgrades to ARM FFSSP and FCDP	In Progress	Both FCDP and FFSSP probes were acquired by DOE under the Recovery Act procurement program. These are advanced versions of the fast-forward scattering probe (FSSP) and cloud droplet probe (CDP). Both the FCDP and FFSSP incorporate state-of-the-art electronics that process and record particle-by-particle measurements that are used to remove shattered ice particles, coincidence and additional statistical measurements. The FCDP also incorporates a slit-based optical system that is designed to reduce uncertainties in sample volume determination.
Southern Great Plains			
December 2010	IR Cloud Camera Feasibility Study	Completed	During December 2010, a prototype long-wavelength infrared cloud camera system was deployed at the SGP Guest Instrument Facility. The system consisted of a microbolometer camera (~7–15 meters) to capture sky imagery, a blackbody calibration source, and a GPS receiver used to estimate atmospheric column water vapor and constrain atmospheric compensation. The camera system collected calibrated sky radiance images co-incident with the SGP Central Facility with the goal of quantitatively assessing its ability to detect thin cirrus clouds.
January 2011	ARRA AERI Comparison	Completed	The ARM Facility, using Recovery Act funds, acquired a new AERI instrument for the SGP site. This new instrument was run side-by-side with the operational AERI at the SGP Central Facility to evaluate its accuracy and noise performance.

March 2011–April 2011	Middle Latitude Airborne Cirrus Properties Experiment (MACPEX)	Completed	NASA WB57 aircraft flew patterns above the Vance ceiling during April. Aircraft flight plans included stepped horizontal legs and spiral up/down in cirrus.
March 2011–February 2012	PGS Validation 2011	In Progress	A paired treatment control experiment continues at the Agricultural Research Services Southern Plains Range Research Station (SPRRS). The ongoing experiment compares energy and carbon fluxes from a field recently planted to switchgrass (a potential biofuel crop) with fluxes from winter wheat. The ongoing experiment is being conducted in a collaboration that includes SPRRS staff and researchers from the University of Oklahoma.
March 2011–February 2012	Radon Mixing (RAMIX 2011–2012)	In Progress	This collection of radon mixing ratio data from the 60-meter tower has the objective of using the radon measurements to help estimate regional carbon dioxide (and later methane) exchange. The project is being conducted with existing instrumentation already operational at SGP.
March 2011–March 2012	Continuous Light Absorption Photometer (CLAP)	In Progress	The CLAP will be installed at SGP in February of 2011. During a one-year comparison period, aerosol absorption coefficients from the CLAP, particle soot absorption photometer (PSAP), and photo-acoustic absorption photometer (PAAS) will be compared and the CLAP performance evaluated. As part of GVAX, the CLAP will also be installed at the AMF in parallel to the PSAP. The installation in India will give an opportunity to evaluate the CLAP and PSAP under conditions of high organic aerosol loading.
April 2011–April 2014	ReFresh	In Progress	The ReFresh investigation is taking place at two sites: SGP and the Cape Grim site in Tasmania, Australia. The NASA DC-8 is flying above the tops of the weather systems, providing cloud and rainfall profiles from a combination of W-, Ka- and Ku-band radars. A second, lower-altitude, aircraft, the CIRPAS Twin Otter, provides in situ profiles of cloud microphysical and aerosol measurements, ice nuclei concentrations, cloud chemistry, and water isotopic composition in the lower cloud regions.
April 2011–June 2011	Midlatitude Continental Convective Clouds Experiment (MC3E)	Completed	This joint field campaign involving NASA Global Precipitation Measurement Program and ASR investigators was conducted in south-central Oklahoma. The experiment leveraged the unprecedented observing infrastructure available in the central United States, combined with an extensive sounding array. The goal was to provide the most complete characterization of convective cloud systems and their environment that had ever been obtained, providing constraints for model cumulus parameterizations that had never before been available. Several different components of convective processes tangible to the convective parameterization problem were targeted, such as pre-convective environment and convective initiation, updraft/downdraft dynamics, condensate transport and detrainment, precipitation and cloud microphysics, influence on the environment and radiation, and a detailed description of the large-scale forcing.
May 2011–June 2011	Middle Latitude Airborne Cirrus Properties Experiment (MACPEX) Continued	Completed	As a continuation of the Middle Latitude Airborne Cirrus Properties Experiment (MACPEX), the NASA WB57 aircraft was flown in patterns above the Vance ceiling. Aircraft flight plans included stepped horizontal legs and spiral up/down in cirrus.
May 2011–October 2011	Field Test of a High Dynamic Range Sky Imaging System	In Progress	The High Dynamic Range Sky Imaging System (HDR-SIS) will be deployed at the SGP Central Facility for a 4-month period. The HDR-SIS is an innovative digital imager and control system designed for improved imaging of atmospheric conditions and radiance across the full sky dome (including the exposed solar disk) without radiometric saturation or loss of information associated with use of a shading device. Initial tests of the HDR-SIS have been highly successful and suggest promise for applications to quantitative studies of clouds, aerosols and radiation. This field campaign is designed to evaluate this potential.

June 2011– August 2011	Humidity Experiment—Infrared (HUMEX-I)	Completed	This experiment deployed two AERIs at SGP at two of the three X-band radar sites for an extended period of time to help characterize the horizontal inhomogeneities in the water vapor field over the SGP domain. These data will be used to characterize the vertical and horizontal distribution of water vapor in the boundary layer, especially for pre-convective environments, to better understand the connection between inhomogeneities in the water vapor field and convective initiation.
July 2011– August 2011	Humidity Experiment 2011 (HUMEX)	Completed	Thermodynamic parameters, including water vapor and temperature, are highly variable in space and time. Therefore, it is important to observe water vapor and temperature profiles with high vertical, horizontal, and temporal resolution. Remote sensing instruments, including microwave radiometers and Raman lidars, can provide water vapor and temperature profiles. This field experiment measures these atmospheric parameters with a vertical resolution of 50–100 meters in the lowest 3 kilometers of the troposphere with high temporal resolution.
September 2011– October 2011	2011 Full-Column Greenhouse Gas Sampling	In Progress	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 the ground, airborne, and satellite platforms. These activities all require validation against in situ measurements of the vertical profiles of GHG mixing ratios. This campaign directly supports both carbon cycle science being conducted by the joint ARM/Lawrence Berkley National Laboratory 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.

On the inside covers: New and enhanced radars at SGP provide enhanced measurements of cloud properties and wind speed.

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