DOE/SC-ARM-10-032

ANNUAL REPORT

ARM

CLIMATE RESEARCH FACILITY

U.S. DEPARTMENT OF ENERGY | Office of Science

2010

Recovery Act **HIGHLIGHTS**

September 2009

- One hundred percent of allocated funding from the American Recovery and Reinvestment Act of 2009 released to the Atmospheric Radiation Measurement (ARM) Climate Research Facility.

October 2009

- Preliminary design reviews successfully completed for new solar spectrometer and Data Management Facility (DMF) upgrades.

December 2009

- Preliminary design reviews successfully completed for 18 new radars and upgrades to existing radars.

January 2010

- Design reviews completed for DMF, radars, and shipborne radar wind profiler.
- Installation and integration of new equipment in process for the ARM Data Archive and aircraft infrastructure, data systems, and instrument systems.

February 2010

- Preliminary design review successfully completed for high-spectral resolution lidar.
- Contracts in place for 100 percent of instrument procurements, with 36 instrument systems received.

March 2010

- Design review for C-band radar successfully completed.

April 2010

- New ceilometer deployed to Southern Great Plains (SGP) site, representing the first ground-based instrument procured through the Recovery Act to begin collecting routine ARM data.
- Forty-six instrument systems received.

May 2010

- Construction underway for X-band radar at SGP.
- Equipment upgrades to DMF installed and under acceptance testing.

June 2010

- DMF acceptance testing complete.
- Ultra-high sensitivity aerosol spectrometer completed testing and installed on the Gulfstream-1 aircraft.
- New ceilometer installed at the North Slope of Alaska (NSA) site.

July 2010

- Newly upgraded micropulse lidar began sending routine data from SGP to ARM Data Archive.
- New ceilometer installed with ARM Mobile Facility deployed on Graciosa Island.

August 2010

- One hundred percent of Recovery Act procurements in place.
- First X-band scanning ARM precipitation radar installed at SGP.

September 2010

- Numerous Recovery Act instruments deployed with the second ARM Mobile Facility at Steamboat Springs, Colorado.
- Second X-band scanning ARM precipitation radar installed at SGP.

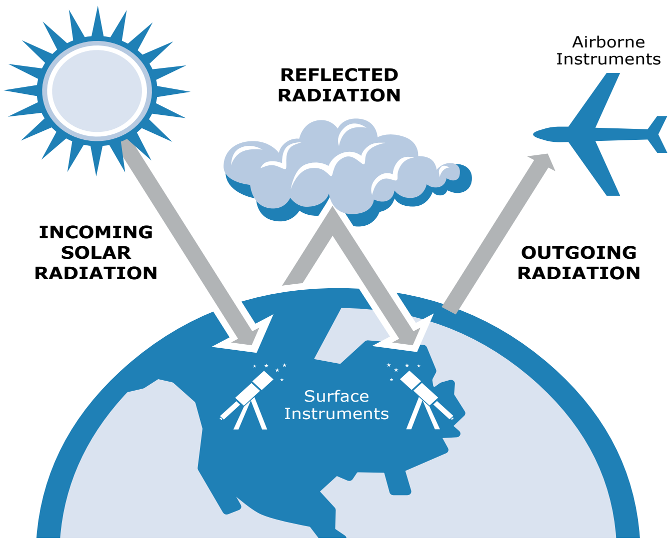
Table of CONTENTS

On the cover: From May 2009 through December 2010, the ARM Mobile Facility operated on Graciosa Island in the Azores to obtain data for the Clouds, Aerosol, and Precipitation in the Marine Boundary Layer field campaign. Data from this prolonged deployment represent the first climatology of the detailed vertical structure of cloud and precipitation properties of low clouds at a remote subtropical marine site. 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 aerosols and how those 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 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.

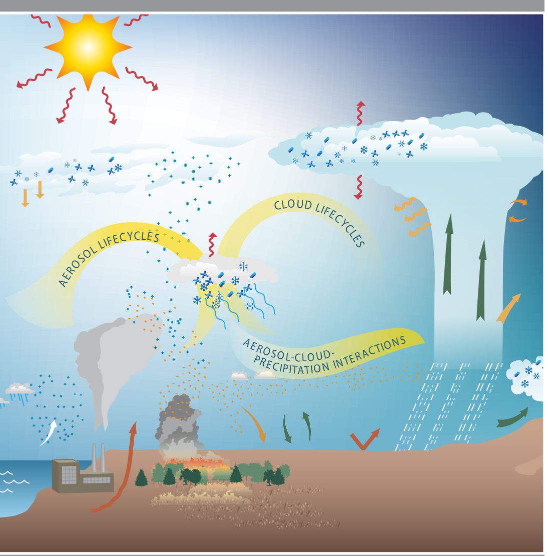
This report provides an overview of each of these components and a sample of achievements for each in fiscal year (FY) 2010.

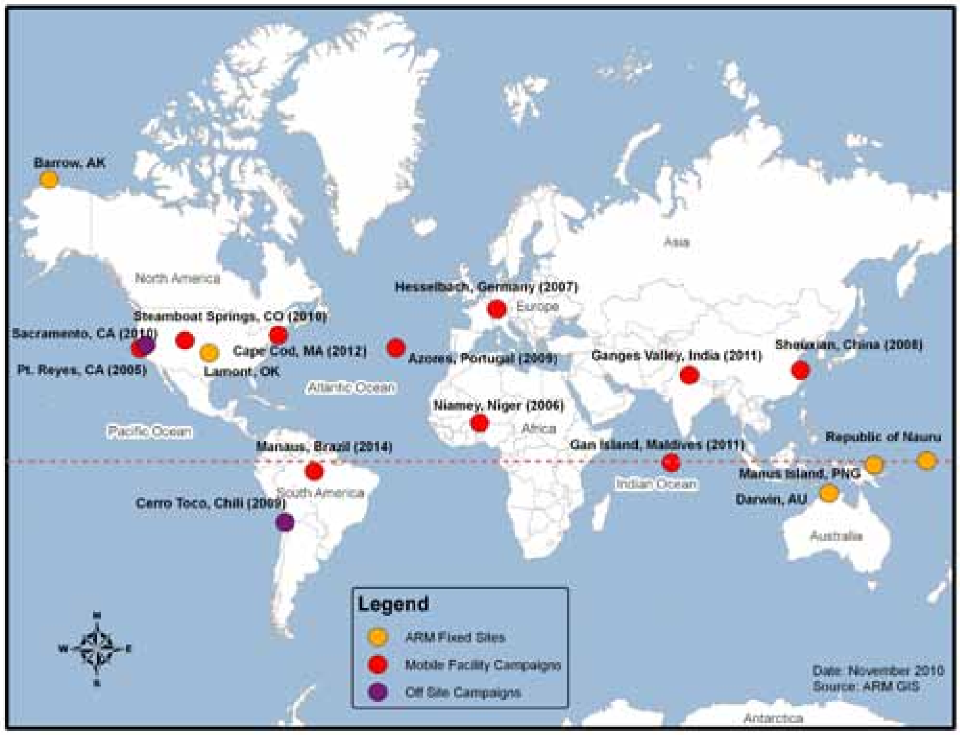
New atmospheric research program created. *Effective October 1, 2009, a new DOE research program—Atmospheric System Research—was initiated. This new program is a merger of the former DOE Atmospheric Science Program and ARM Science components. In partnership with the ARM Facility, the aim of this new research program is to quantify the interactions among aerosols, clouds, precipitation, radiation, dynamics, and thermodynamics, with the ultimate goal of reducing the uncertainty in global and regional climate simulations and projections.*

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:

Science plan provides overview of ASR. *In January 2010, the ASR Science and Program plan was published. This document outlines ASR's structure and science goals and lists the ways that ASR scientists will use the ARM Facility. The science plan can be found on ASR's website,* ***asr.science.energy.gov.***





- **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 two frequencies of millimeter wavelength cloud radar, Raman lidar, infrared interferometers, aerosol observing systems, and several frequencies of microwave radiometers, among others. These 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 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 (***www.archive.arm.gov***) to aid in further research.

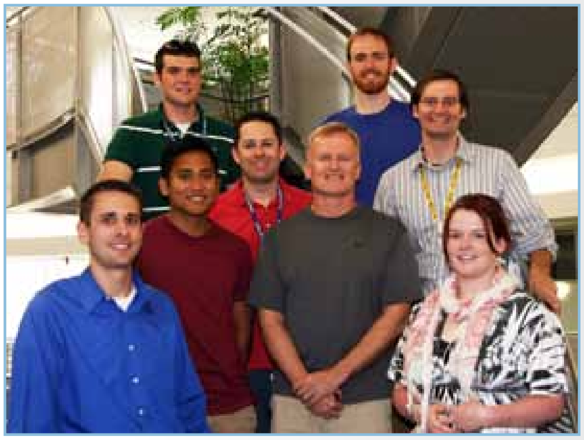
Enhancements from the American Recovery and Reinvestment Act of 2009. *The ARM Facility received $60 million from the Recovery Act to purchase and deploy new and upgraded instrumentation, equipment, and infrastructure. Some of the instruments—particularly new scanning radars, enhanced lidar technologies, aerosol observing systems, and in situ aircraft probes—will provide unprecedented data sets for improving and validating Earth System Models.*

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. The **Science and Infrastructure Steering Committee** and periodic workshops provide input to the Facility on the state of the science, including identifying data products, measurement systems, and needed model improvements. 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.

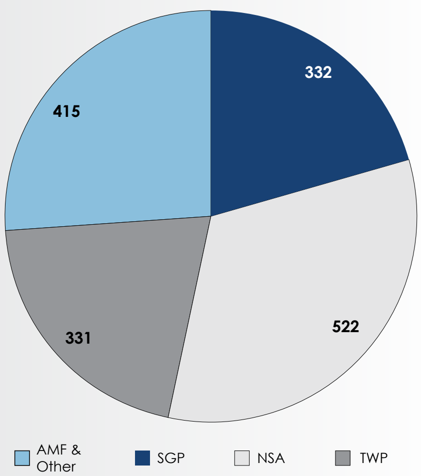
ARM Data Quality Office turns ten. *The ARM Data Quality (DQ) Office celebrated its 10-year anniversary in June 2010. Staffed by personnel from the University of Oklahoma, the DQ Office ensures that quality data are collected by field instrumentation located at ARM's sites around the world. The DQ Office reviews more than 5,000 datastreams each week and identifies any data anomalies they see using quality control procedures and tools established with the help of instrument mentors. Once identified, problems are recorded into the ARM problem reporting systems and tracked by the DQ Office and ARM's site scientists to resolution. These data quality assessment reports are shared with site operations and instrument mentors to assist in the corrective maintenance of the instruments.*



Budget Summary and Facility Statistics

FY 2010 Budget ($K)	
Infrastructure	*41,688*

Visitor Days by Site



User Statistics for the Period of October 1, 2009 – September 30, 2010			
ARM Facility Component	**Unique Scientific Users**	**Unique Non-Scientific Users**	**Totals**
AMF1 (Azores)	16	13	29
AMF2 (Colorado)	14	3	17
Off-Site Campaigns	2	4	6
NSA	33	38	71
SGP	60	63	123
TWP	22	21	43
Data Management Facility	27	56	83
Archive	744	69	813
Total	**918**	**267**	**1185**

Operational Statistics for the Period of October 1, 2009 – September 30, 2010		
	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**

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 FY 2010. A summary of all ARM Facility campaigns that began in FY 2010 is available at the end of this report.

Clouds, Aerosol, and Precipitation in the Marine Boundary Layer

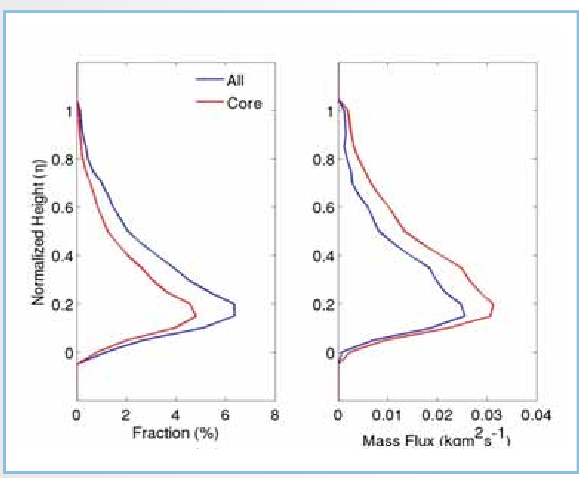
Microwave radiometers deployed in the Azores gathered measurements of marine boundary-layer cloud properties, such as water vapor and liquid water content.

In the longest AMF deployment to date, the first mobile facility (AMF1) spent 20 months on Graciosa Island in the Azores. Scientists involved in the Clouds, Aerosol, and Precipitation in the Marine Boundary Layer (CAP-MBL) field campaign used AMF1, a portable climate observatory, to study low-level clouds and aerosol in a marine environment.

Marine boundary-layer clouds are particularly important in the global climate system, not only as passive modulators of solar energy, but as interactive systems that influence and modulate sea surface temperature and the strength of the trade winds on seasonal-interannual timescales. Their microphysical properties are important, strongly sensitive to manmade aerosol, and poorly understood, especially over remote oceans.

Due to its location on the edge of the climatological subtropical and midlatitude belts, Graciosa experiences a wide variety of meteorological, cloud, and aerosol conditions. It experiences long-range transport of pollutants from both North America and Europe, but also periods of extremely clean air masses that have been over the ocean for several days.

During CAP-MBL, investigators focused on the interactions between clouds, aerosols, and precipitation at Graciosa using state-of-the-art sensors. Data from this prolonged AMF deployment will provide important new information about the structure and variability of the remote marine boundary-layer system and the factors that influence it.

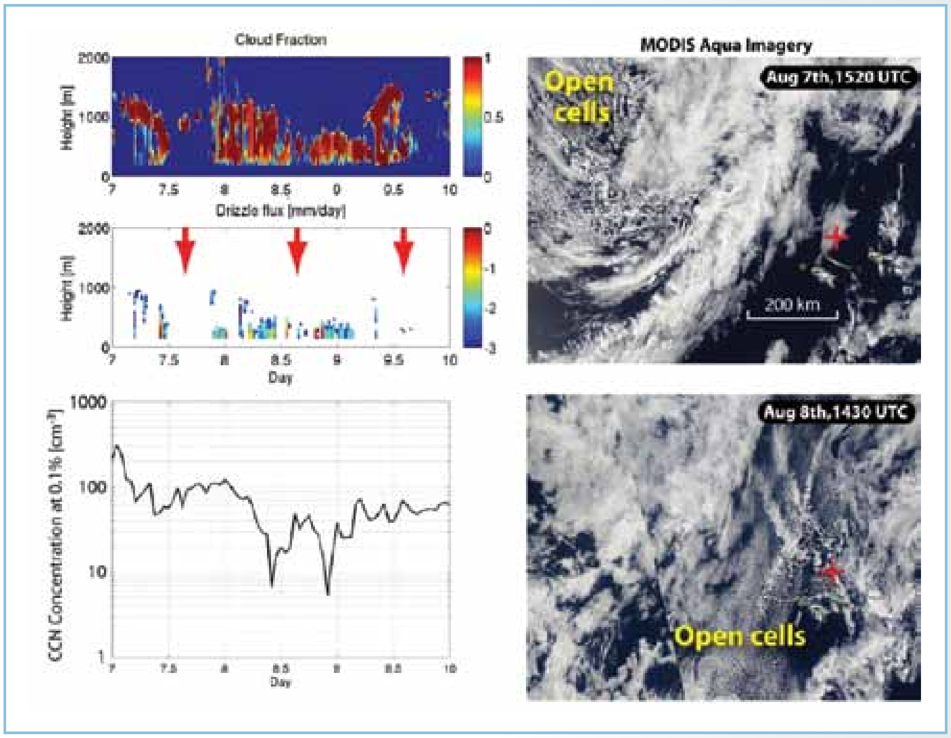


Profiles of cloud fraction (left) and vertical mass-flux (right) for 557 individual trade cumulus clouds (114 hours), derived from the 94-GHz vertically pointing radar during the CAP-MBL campaign. Profiles from vertically moving core regions (red) and for the entire cloud (blue) are shown.

A supplementary campaign, the Above-Cloud Radiation Budget Near Graciosa Island campaign, took place on nearby Pico Island from April to September 2010. The difference between the measurements at Pico and those on the surface of Graciosa Island reflect the impact of the marine clouds on radiation transmission through the lower atmosphere. Collaborators from the Regional Directorate of Science and Technology of the Government of Azores, the University of the Azores, and the Portuguese Meteorological Institute provided crucial logistical and operations support for the entire Azores deployment.

Results: A focus area of CAP-MBL was the mechanisms by which drizzle precipitation is produced in warm, low clouds, including the extent to which this precipitation can be modified by aerosols and the degree to which the drizzle can impact the low clouds themselves.

Data gathered during the campaign illustrate the impact of drizzle on low clouds. At times, strongly drizzling open-cell convection across Graciosa resulted in the near-complete removal of cloud-forming nuclei. These "extreme drizzle" events have been documented elsewhere, but little is known about the interactions between clouds and aerosols in these events or the impact that the feedback between aerosols and precipitation has on the susceptibility of clouds to anthropogenic aerosols.

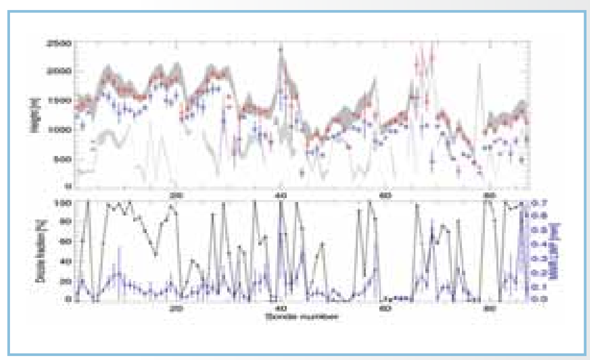


Time-height sections of cloud (top left), drizzle (center left), and cloud condensation nuclei (CCN) concentration (lower left) during August 7–10, 2009. Two MODIS images (right) show the passage of a region of open cells across the island on August 8. The passage coincides with near-complete depletion of cloud-forming nuclei (note the log scale on lower left panel), indicating the presence of an ultra-clean marine boundary layer most likely caused by the strong drizzle associated with open cells.

Preliminary analysis of the available data also identified more than 20 days with typical stratocumulus conditions (single cloud layer, very high cloud fraction, and the presence of thermodynamic inversion). These time periods were examined using a variety of instruments to gather measurements.

- A vertically pointing W-band ARM cloud radar (WACR) was used to extract the cloud-top boundary and detect the presence of drizzle.
- The ceilometer was used to extract the visible cloud base.
- The microwave radiometer (MWR) was used to extract the integrated liquid water path (LWP).
- Available soundings were used to describe the thermodynamic structure of the boundary layer, as well as investigate the presence of a transition layer in the sub-cloud layer and the physical height and thickness of the inversion.

Other data from CAP-MBL show new measurements of the vertical dynamical structure of trade cumulus clouds observed with the state-of-the-art AMF radar. The extended period of the deployment allows many hours of sampling and creates a data set of high statistical significance compared to previous field studies. These unique data are invaluable for constraining process models and will be critical for developing new parameterizations for climate models.



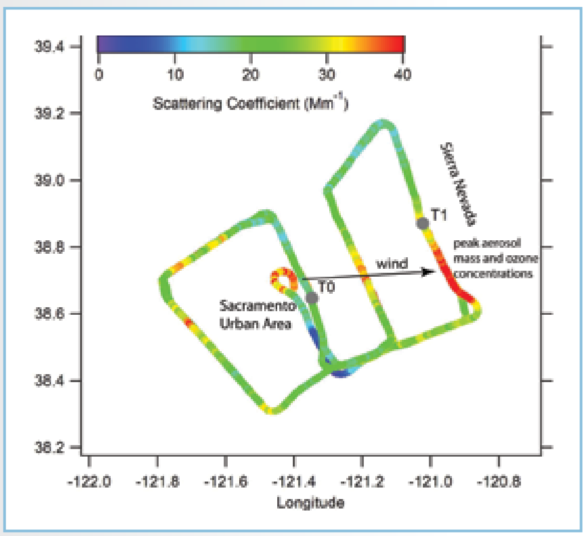
The upper panel shows cloud boundaries (base from the ceilometer [blue] and top from the WACR [red]) averaged over 2 hours surrounding sounding times, superimposed on the soundings inversion and transition layers (dark and light shadings, respectively). The lower panel shows the fraction of the 2 hours that experienced drizzle (black) and the 2-hourly averaged LWP from the MWR (blue). In both panels, vertical lines represent the 2-hourly standard deviations of the measurements.

Carbonaceous Aerosol and Radiative Effects Study

AAF Technical Director Beat Schmid, left, and Operations Lead Jason Tomlinson, right behind the probe, adjust the cloud aerosol and precipitation spectrometer on the G-1.

In June 2010, the month-long Carbonaceous Aerosol and Radiative Effects Study (CARES) took place in Sacramento, California. The campaign gathered aerosol data using more than 50 instruments at 2 ground sites and on 2 aircraft. The campaign's purpose was to sample air from the Sacramento "urban plume"—air that becomes distinct from the surrounding air as it passes over and mixes with material from an urban area. During summer, the transport of Sacramento's urban plume is controlled by regular wind patterns that draw polluted air to the northeast, over oak and pine trees in the Sierra Nevada's Blodgett Forest area, by late afternoon.

The AAF coordinated 21 science flights by the Gulfstream-1 (G-1) aircraft, obtaining aerosol data from 67.4 research hours over the study region to obtain vertically resolved remote sensing measurements of aerosol optical properties, useful for identifying aerosol plume extent and vertical structure. The National Aeronautics and Space Administration (NASA) flew a King Air B-200 in coordination with the G-1 for almost every flight and also sampled areas outside of the G-1's primary domain to supplement the data set. In addition, the National Oceanic and Atmospheric Administration (NOAA) Twin Otter shifted its California Nexus (CALNEX) operations to Sacramento from June 15 through 28 to further enhance the collaborative data set of urban aerosols.



Spatial distribution of aerosol light-scattering coefficient for the 500 nanometers (green) wavelength on the afternoon of June 28, 2010, showing the presence of the Sacramento aerosol plume in the Sierra Nevada foothills area to east of the urban source region. The measurements were taken aboard the G-1 aircraft. The locations of the two ground sites, T0 and T1, are also featured.

Instruments at the two ground sites gathered a nearly identical set of trace gas measurements, aerosol microphysical and chemical properties, plus solar radiation and meteorological variables. American River College (T0) is approximately 14 kilometers northeast of downtown Sacramento, and Northside School (T1), a K-8 school located in Cool, California, is approximately 52 kilometers northeast of downtown Sacramento.

During CARES, the G-1 carried several instruments purchased through the Recovery Act. The ultra-high sensitivity aerosol spectrometer measures aerosol number and size. Two other instruments, the single particle soot photometer and the photo-acoustic soot spectrometer, gathered measurements about black carbon, including mass, size, composition, and absorption of light by aerosols. At the ground sites, a new humidigraph, a Cloud Condensation Nuclei (CCN) counter, a scanning mobility particle sizer, and an upgraded 915-megahertz wind profiling radar were deployed to gather additional information about the aerosols' ability to take up water and to form cloud droplets.

Results: The campaign began with unusually cool and cloudy weather conditions in the Central Valley, likely due to the lingering effects of the moderate El Niño in early 2010. The strong northwesterly flow into the Central Valley and precipitation events during late May, coupled with cool temperatures and reduced photochemical activity, resulted in an unusually low regional aerosol concentrations at the start of the campaign. The boundary-layer height was also relatively deep during the first 2 weeks of the campaign, which led to increased dilution of emissions. The weather pattern transitioned to more summer-like conditions during the second half of the campaign, which resulted in some of the highest polluted days. Observations across the clean and polluted periods will give the scientists an exceptional opportunity to examine aerosol formation and evolution processes in the same region under a range of environmental conditions.

- Trace gas observations were made for key species, including carbon monoxide, nitric oxide, nitrogen dioxide, total odd nitrogen species, ozone, sulfur dioxide, and several non-methane hydrocarbons of both anthropogenic and biogenic origin, some of which are precursors of secondary organic aerosols.

- Aerosol microphysical and chemical observations consisted of particle-size distribution (from 10 to 10,000 nanometers); total number concentrations (>10 nanometers); and multiple measures of particle composition, including bulk, size-resolved, and single-particle, and of the volatility of aerosol species as a function of temperature. Filter samples were also collected onboard the aircraft and at both the ground sites for offline characterization of particle morphology, very high-resolution mass spectrometry, and radioisotope analysis.

- Aerosol properties observations consisted of multiple measures of light scattering, absorption, and extinction, as well as the concentrations of CCN that are needed for studies of direct and indirect radiative forcing of aerosols.

- Radiative observations at the ground sites included broadband solar fluxes as well as multifilter rotating shadowband radiometer measurements of downwelling visible and near-infrared solar irradiance, which provide information needed to estimate aerosol optical depth.

- Atmospheric state observations were made for wind speed and direction, pressure, temperature, and relative humidity.

The CARES campaign enabled comprehensive sampling of aerosols under a range of environmental conditions. The resulting detailed picture for the evolution of different types of carbonaceous aerosols and their optical and CCN activation properties will help improve the key aerosol process and property modules that are used in regional and global climate models.

The campaign data will also be used to inter-compare different analytical techniques used to measure the same set of aerosol chemical and optical properties. This comparison is an essential exercise for assessing uncertainty in the measurements and increasing the confidence in the analyses for climate studies.

The G-1 aircraft prepares for takeoff at McClellan Airport in Sacramento, California, for one of its 21 research flights for CARES.

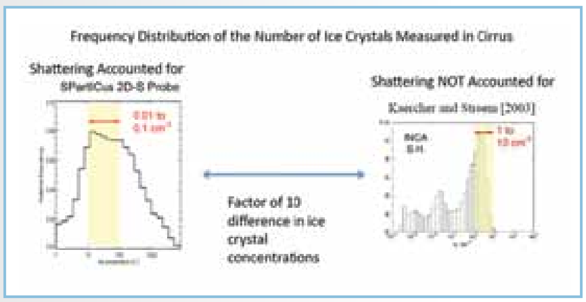
Small Particles in Cirrus

The SPEC Learjet 25 collected data over the ARM SGP site.

Between January and June 2010, the Small Particles in Cirrus (SPARTICUS) field campaign collected 150 hours of concurrent data from cirrus clouds over the ARM SGP site using a broad array of both ground-based and aircraft-mounted instruments. To obtain the airborne data, the AAF coordinated flights by the SPEC Learjet 25, provided and flown by the Stratton Park Engineering Company, Inc.

Cirrus clouds exert significant controls on the Earth's radiation budget, both reflecting solar radiation (the albedo effect) and reducing radiative heat loss through the atmosphere (the greenhouse effect). Quantifying cirrus albedo and greenhouse effects is an important factor in building accurate GCMs.

High-altitude cirrus clouds are primarily composed of ice crystals in various sizes, shapes, and densities. These clouds have traditionally been difficult to understand, partly because of their location more than 5 miles above the Earth's surface and partly because of the complicated physical processes that govern ice crystals at these cold temperatures and low pressures.



The data plot on the left shows the frequency distributions of ice crystal concentrations measured during SPARTICUS compared to similar statistics in earlier campaigns, shown on the right.

Discrepancies in how different instruments measure cirrus properties contribute a large degree of uncertainty in scientific knowledge of these clouds. Some of these discrepancies may be due to the shattering of larger ice crystals on aircraft and probe surfaces during airborne sampling efforts.

The SPARTICUS campaign sought to answer the following questions:

- How do small particles contribute to the mass and radiative properties of midlatitude cirrus clouds?
- How do cloud-scale dynamical processes control the evolution of cirrus properties through nucleation, particle growth, and sublimation?
- What degree of complexity is required in cloud property retrieval algorithms, and what minimal set of algorithms can be used to rigorously describe cirrus microphysical properties using ground-based ARM data?

Results: SPARTICUS flights sampled a wide range of cloud conditions from winter to summer, including cirrus with both high and low particle concentrations. Preliminary results suggest that ice crystal concentration measurements in previous aircraft field campaigns have been influenced by shattering artifacts. Typical particle concentrations measured in midlatitude cirrus clouds during SPARTICUS are on the order of 0.1 or less per cubic centimeter, while earlier data sets suggested that typical particle concentrations are in excess of 1 per cubic centimeter.

Scientists will continue to analyze data gathered from SPARTICUS and use the measurements to develop and validate cloud property retrieval algorithms. Data will also be used to improve model parameterizations.

Research Highlights

Scientists around the world use data from the ARM Facility for their research. In FY 2010, ARM data were cited in a total of 500 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

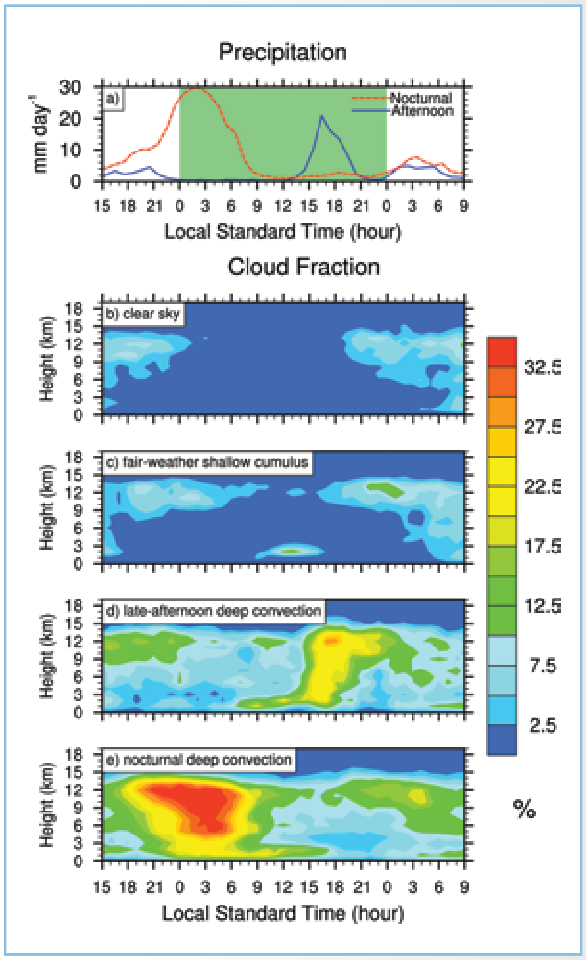
2010 Publications Summary	
Category	**Total**
Abstracts or Presentations	271
Book Chapters	2
Conference Papers	14
Journal Articles	192
Technical Reports	21
Total	500

Mechanisms Affecting the Transition from Shallow to Deep Convection Over Land

The simulation of the diurnal cycle is an important measure of a climate model's performance. A well-known problem is that climate models usually cannot produce the observed afternoon convective rainfall peak over land. In this study, 11 years of summertime observations at the ARM SGP site were used to categorize the diurnal cycle into different convection regimes. Environmental parameters between two regimes were compared—the days with fair-weather shallow cumulus and the days with afternoon deep convection—to reveal the mechanisms controlling the transition from shallow to deep convection.

A few hours before rain events begin on afternoons deep with convection, higher relative humidity is found in and above the boundary layer, especially between the levels of 2 to 4 kilometers above the surface. Compared to days of fair-weather shallow cumulus, greater instability, stronger inhomogeneity in boundary-layer temperature, less wind shear between 600 and 850 hectopascals (atmospheric pressure), and weaker subsidence are found preceding afternoon rain events. With greater relative humidity at 2 to 4 kilometers, rain starts earlier and lasts longer. Boundary-layer inhomogeneity, the 600-to-850-hectopascals westerly wind component, and the 2-to-4 kilometers lapse rate are positively correlated with total rain and maximum rain rate; furthermore, these environmental parameters are correlated with each other. In the early stage of precipitation, boundary-layer temperature and wind variability slightly lag precipitation by up to 1 hour.

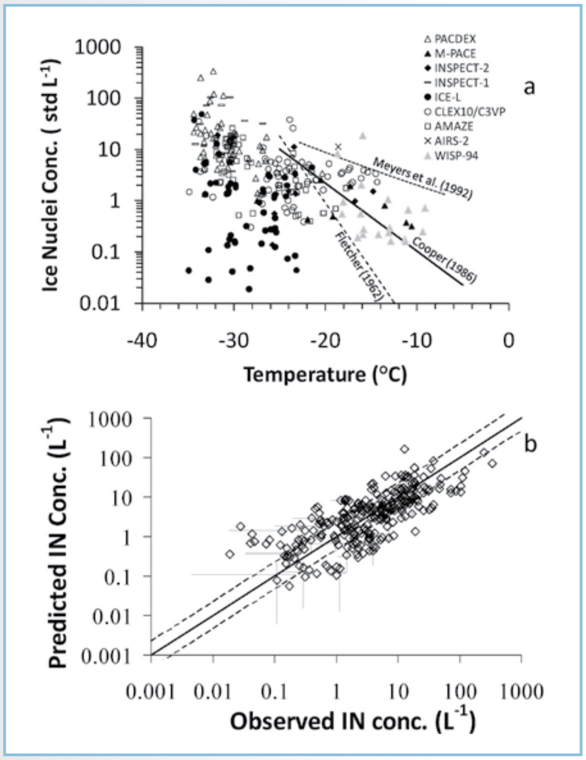
These observations provide partial support to parameterizations focusing on the ability of boundary-layer air parcels to penetrate the level of free convection. Moreover, the observations are encouraging for the nascent efforts to parameterize mesoscale boundary-layer inhomogeneity and its role in the transition from shallow to deep convection.



Diurnal composites of surface precipitation (a) and cloud fraction for days with: clear-sky (b), fair-weather shallow cumulus (c), late-afternoon deep convection (d), and nighttime deep convection (e). In (a), the blue line denotes rain rate for late afternoon deep convection days. The red line is for nighttime deep convection days. The green shaded area in (a) signifies the diurnal cycle of interest.

(Reference: Zhang Y and SA Klein. 2010. "Mechanisms affecting the transition from shallow to deep convection over land: Inferences from observations of the diurnal cycle collected at the ARM Southern Great Plains site." *Journal of the Atmospheric Sciences*, 67(9), 2943-2959.)

Ice Nucleation Link to Aerosols for Global Models



(a) IN number concentration for mixed-phase cloud conditions versus temperature from nine studies. Data points are 5–30-minute averaged data. Single variable (T, RH) parameterizations are labeled and plotted over the data. (b) Relation between observed IN from panel (a) to IN predicted by the new parameterization linking temperature and aerosol concentrations larger than 0.5 microns. Dashed lines indicate observations (62%) within a factor of 2 of 1:1 line.

The formation of ice in clouds is of vital importance to life on Earth, because ice formation is one of the elemental processes for precipitation initiation. Natural and human impacts on ice nucleation can alter energy and hydrological cycles. This study addressed the urgent need for descriptions of complex ice formation processes that encapsulate the environmental dependencies of ice formation, but also include a link to aerosol properties. This study also describes an observationally based, yet simple parameterization of ice nuclei (IN) number concentrations active for mixed-phase cloud conditions as a function of temperature and aerosol number concentrations.

Ice nuclei number concentration data from the Colorado State University continuous flow diffusion chamber for activation conditions in mixed-phase clouds were assembled from nine field studies taking place from the Arctic through the midlatitudes to the Amazon. Simultaneous measurements of total ambient aerosol size distributions showed that a correlation exists between observed IN concentrations and the number concentrations of (non-sea-salt) particles larger than 0.5 micron in diameter. This correlation reduces the spread of potential errors in predicting IN concentrations as a function of temperature to less than a factor of 10 and predicts about two-thirds of values within a factor of 2. The developed parameterization significantly improves constraint and representation of aerosol impacts on cold clouds for immediate use in global climate simulations. Based on presented modeling studies, it appears just as important to properly simulate the lack of available IN as it is to simulate the presence of IN.

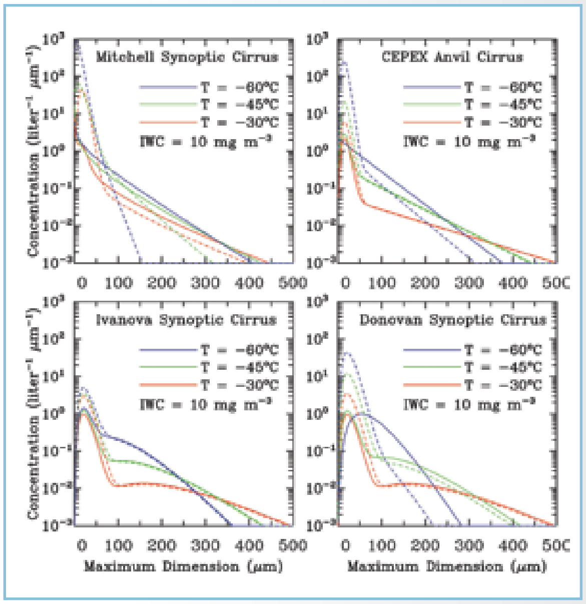
(Reference: DeMott PJ, AJ Prenni, X Liu, SM Kreidenweis, MD Petters, CH Twohy, MS Richardson, T Eidhammer, and DC Rogers. 2010. "Predicting global atmospheric ice nuclei distributions and their impacts on climate." *Proceedings of the National Academy of Sciences*, 107(25), doi:10.1073/pnas.0910818107.)

Estimating Cirrus Size Distributions with Help from Satellites

Historical measurements of ice particle size distributions (PSDs) in cirrus clouds have been plagued with uncertainties regarding the concentration of small ($D < 60$ microns) ice crystals, resulting in large uncertainties in PSD mass flux-weighted fall velocities (Vf), cirrus cloud coverage, and estimates of climate sensitivity in GCMs. One way to address this problem is to use radiance measurements to characterize the relative concentrations of small ice crystals. By developing and applying new theoretical insights regarding absorption by ice crystals at 11- and 12-micron wavelengths, satellite remote sensing can be used to evaluate the relative concentration of ice crystals less than approximately 60 microns. Earlier studies interpreted the absorption difference between these wavelengths as due to changes in the imaginary part of the refractive index for ice. This study shows it is due to the real part that produces different contributions from wave resonance or photon tunneling. These differences in absorption contributions are only apparent when ice particle sizes are less than approximately 60 microns, making tunneling an ideal signal for the detection of small ice crystals.

An average cirrus emissivity relationship between 12 and 11 microns was developed using the Moderate Resolution Imaging Spectroratiometer (MODIS) satellite instrument. The relationship, to a first approximation, is the absorption optical depth ratio, or β. This is used to "retrieve" the PSD, based on five different temperature-dependent PSD schemes. The PSDs from the in situ measurement-based PSD schemes are compared to corresponding retrieved PSDs to evaluate differences in small ice crystal concentrations. The retrieved PSDs had lower concentrations of small ice particles, with total number concentration N independent of temperature. The degree of PSD bimodality increased with increasing temperature. In addition, the retrieved temperature dependence of the PSD effective diameter (De) and Vf was compared with those calculated from the corresponding PSD scheme. These retrieved properties exhibited less variability for a given temperature due to the correction for small ice crystals. Improved estimates of the ice particle mass- and projected area-dimension relationships have also improved estimates of De and Vf. Because this ensemble temperature dependence for De and Vf has climatological significance, it should be helpful in producing better estimates of climate sensitivity in GCM simulations.

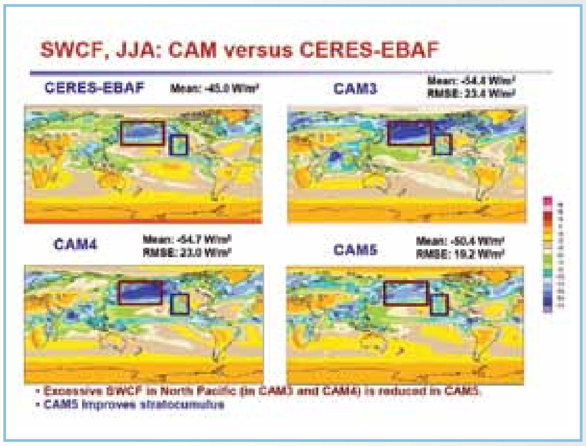
(Reference: Mitchell DL, RP d'Entremont, and RP Lawson. 2010. "Inferring cirrus size distributions through satellite remote sensing and microphysical databases." *Journal of the Atmospheric Sciences*, 67(4), doi:10.1175/2009JAS3150.1.)



The retrieved mean effective β was found to be 1.065 for thin cirrus having temperatures < -35 Celsius. Based on this value, PSD were retrieved (solid) and compared with corresponding PSD given by the original PSD scheme (dashed). The retrieved PSD have lower concentrations of small ice crystals, with bimodality increasing with increasing temperature.

Adoption of RRTMG in the NCAR CAM5 and CESM1 Global Climate Models

Improving cloud, aerosol, and radiative processes in GCMs is one of ASR's continuing objectives. RRTMG, a broadband, longwave, and shortwave rapid radiation model for GCM applications developed at Atmospheric & Environmental Research, Inc. with DOE support, has been formally adopted as the radiation code in the National Center for Atmospheric Research (NCAR) Community Atmosphere Model (CAM5) and the Community Earth System Model (CESM1) with the public release of these GCMs on June 25, 2010. The NCAR Model Working Group development team, in conjunction with substantial changes to the climate model physics, completed the application of RRTMG to CAM5 and CESM1. These include modifications and new approaches for treating the planetary boundary layer, cloud microphysics and macrophysics, shallow convection, and aerosols (including representation of the aerosol indirect effect for the first time). These changes provide a greater degree of consistency among the various physics packages, making it possible to investigate new research directions. The integrated effect of these modifications has notably altered the climate simulated by these global models.

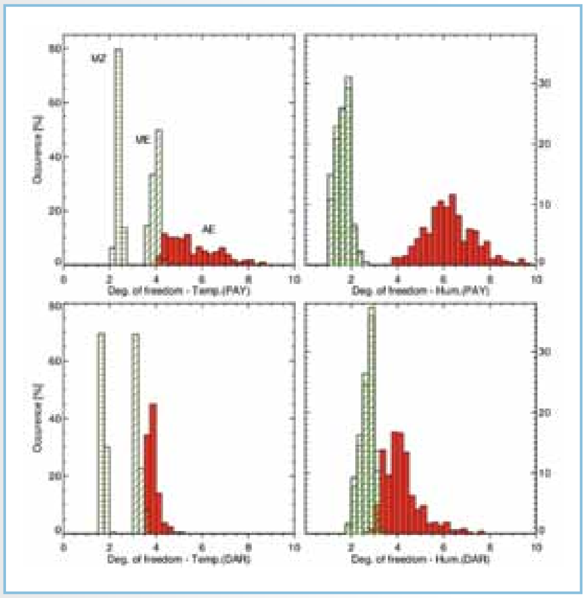


Shortwave cloud forcing for three versions of the NCAR Community Atmosphere Model (CAM) with CERES observations at upper left for June–August 2010. The latest model, CAM5 (at lower right), shows improvement in both mean error and root mean square error (RMSE), with notable improvement in the tropics, the North Pacific, and the stratocumulus region over the Eastern Pacific. Figure courtesy of NCAR.

In the atmospheric model (CAM5), shortwave cloud forcing is improved in the tropics and other regions, and tropical precipitation is better represented. The clear-sky outgoing longwave radiation and longwave cloud forcing agree less well with observations, and the model is too moist overall. The bias in clear-sky outgoing longwave radiation is most likely due to discrepancies in the simulated vertical distributions of temperature and water vapor, because RRTMG has been extensively validated independently. The mean climate in the coupled model (CESM1) is improved over its predecessors, CCSM3 and CCSM4, with notable reductions in root mean square errors in global mean precipitation and sea surface temperature relative to observations. The latest coupled model also retains many positive features of the CCSM4 climate, including its ability to simulate El Niño variability.

(Submitters: MJ Iacono, WD Collins, A Conley, R Neale, P Rasch, E Mlawer, C Hannay, and R Pincus.)

Quantifying the Number of Independent Pieces of Information in Profiles



The degrees of freedom of signal in the microwave (zenith observations only [MZ] and zenith plus elevation scanning [ME]) and infrared (AE) observations from Payerne and Darwin sites, with temperature shown in the left-hand panels and humidity in the right-hand panels. The use of the elevation scans doubled the information content in the microwave retrievals. In most cases, the infrared retrievals have much larger information content than the microwave retrievals.

Remotely sensed profiles of temperature and water vapor appeal to the atmospheric research community because the temporal resolution of the remote sensors is typically much higher than is achieved with radiosonde and other traditional methods. There is also a desire to profile the liquid water content in clouds, because the distribution of liquid water with height is important for a variety of studies, including characterizing the radiative impact of the cloud and predicting the impact of the entrainment of aerosols into the cloud. However, these profiles must be retrieved from the passive remote sensing observations, and these algorithms use a priori information in the retrieval process to constrain the inversion of the radiative transfer equation. These studies investigated the "information content" of the observations to derive the number of independent pieces of input in both the remote sensing observations and the a priori information for the verticle profile.

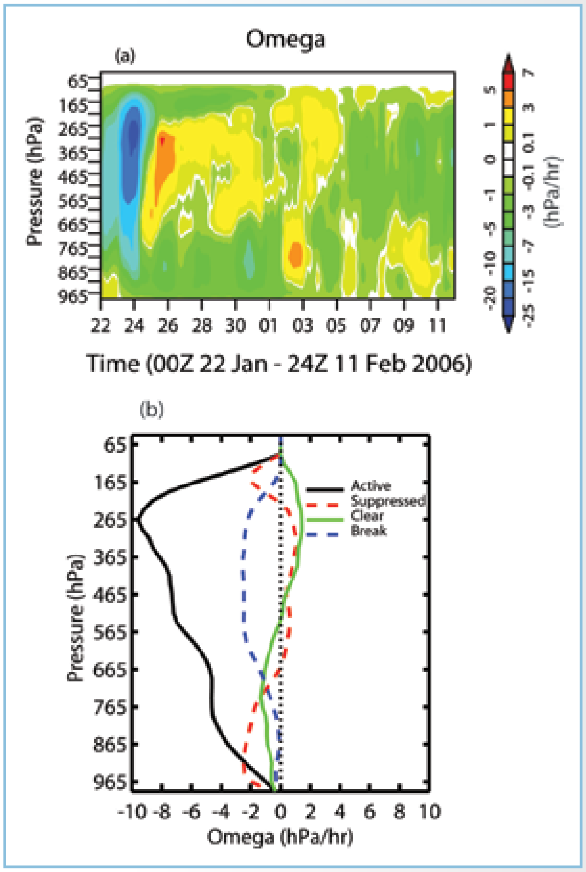
High-spectral-resolution microwave and infrared observations contain information on the vertical profile of temperature and water vapor. This study analyzed the information content (i.e., degrees of freedom of signal) of both approaches using a consistent data set that included clear-sky data from midlatitude (Payerne, Switzerland) and tropical (Darwin, Australia) sites to span a large range of precipitable water vapor (PWV). In virtually all cases, the spectral infrared data have a larger number of independent pieces of information in both the temperature and humidity profile than the spectral microwave data. These two studies, and the follow-up efforts underway, illustrate the power of information content analysis to understand how much information resides in the remote sensing observations versus in the in situ data used in the retrieval. Characterizing the retrieval algorithms in this way prevents the misuse of the retrieved data and provides a strong statement on how the retrieved data should be used in future analyses.

(References: Lohnert U, DD Turner, and S Crewell. 2009. "Ground-based temperature and humidity profiling using spectral infrared and microwave observations. Part I: Simulated retrieval performance in clear-sky conditions." *Journal of Applied Meteorology and Climatology*, 48(5), 1017-1032.

Crewell S, K Ebell, U Loehnert, and DD Turner. 2009. "Can liquid water profiles be retrieved from passive microwave zenith observations?" *Geophysical Research Letters*, 36, L06803, doi:10.1029/2008GL036934.)

Large-Scale Structures and Diabatic Heating and Drying Profiles Revealed by TWP-ICE

Large-scale dynamic and thermodynamic structures play an important role in destabilizing the tropical atmosphere by initiating and maintaining deep convection. On the other hand, latent heating released from tropical convective systems is a major energy source to the large-scale circulation. Documenting these structures of tropical convective cloud systems from observations is a key step to understand how cumulus convection interacts with its large-scale environment. This study documented the characteristics of the large-scale structures and diabatic heating and drying profiles observed during the ARM Tropical Warm Pool-International Cloud Experiment (TWP-ICE), which was conducted in January–February 2006 in Darwin during the northern Australian monsoon season. The examined profiles exhibit significant variations between four distinct synoptic regimes observed during the experiment: (1) the active monsoon period, (2) the suppressed period, (3) the clear period, and (4) the break period.



Analyzed vertical velocity (omega): (a) temporal evolution; (b) averaged profiles for different periods. Significant variations between the four distinct synoptic regimes are shown in the vertical velocity profiles observed during TWP-ICE.

The active monsoon period is characterized by strong upward motion and large advective cooling and moistening throughout the entire troposphere, while the suppressed and clear periods are dominated by moderate mid-level subsidence and significant low- to mid-level drying through horizontal advection. During the break period, upward motion and advective cooling and moistening are located primarily at mid-levels. Strong diabatic heating and drying are seen throughout the troposphere during the active monsoon period, while they are moderate and only occur above 700 hectopascals during the break period. The diabatic heating and drying tend to have their highest values at low-levels during the suppressed periods.

Convection during the monsoon period was weak during the day, increased rapidly in the evening, and reached its maximum intensity in the early morning hours. Convection over the mainland and Tiwi Islands regions during the break period was initiated primarily by the sea-breeze circulation and confined in the lower troposphere in the mid-morning and then quickly developed into deep convection and reached its maximum intensity in the afternoon. The monsoon systems featured upward motion throughout the day with the maximum ascending level in the upper troposphere at 0300 local standard time due to the nocturnal deep convection. In contrast, the mainland and island systems showed an afternoon maximum in vertical velocity in the mid- to upper-troposphere. At their initial system development stages (around 0900–1000 local standard time), the mainland and island systems developed in an environment with an ascending layer near the surface due to the sea-breeze circulation and a subsidence layer above, especially for the island systems. The subsidence layer contributes to limiting the mainland and island convective systems to low levels at their initial stages and focusing convection along sea breeze convergence lines later in the day.

(Reference: Xie S, T Hume, C Jakob, SA Klein, RB McCoy, and M Zhang. 2009. "Observed large-scale structures and diabatic heating and drying profiles during TWP-ICE." *Journal of Climate*, 23(1), 57-79.)

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 maintain effective operations, keep up with technology developments, deliver high-quality data, and provide outreach to a global audience.

Recovery Act

New Cloud Droplet Probe

Newer aircraft probes were designed to potentially minimize the shattering effect that previously resulted in a disproportionate amount of smaller particles being measured by the sensor beam.

In October 2009, a new cloud droplet probe (CDP) arrived at the AAF, the first of many new aircraft research instruments made possible by the Recovery Act. Designed to measure the size distribution of cloud particles, the new probe incorporates an upgraded design and electronics to minimize the effects of "forward scattering," or shattering of ice crystals, that scientists believe may be causing erroneous measurements. The new probe was installed on the SPEC Learjet 25 and used as part of the SPARTICUS field campaign.

Chosen not only for its measurement capabilities but also flexibility, the new probe was incorporated into a combined instrument, the cloud spectrometer and impactor (CSI). While the CDP measures the size distribution of particles, the impactor component measures the total water content—both liquid and ice—of the particles. When used together, the combined CSI instrument provides more complete information about cloud properties.

First Deployment of Recovery Act Ground-Based Instruments

After a 3-day period of side-by-side operations and acceptance testing, the new CL31 ceilometer (foreground) officially replaced the older CT25K model on April 16, 2010, at the SGP site.

In April 2010, a new ceilometer was deployed at the ARM SGP Central Facility, leading the charge for an influx of more than 100 new ground-based instruments slated for installation throughout the user facility. The ceilometer is designed to measure cloud-base height at up to three levels and potential backscatter signals by aerosols. It works by transmitting near-infrared pulses of light into the sky. The receiver detects the light scattered back by clouds and precipitation.

In use since 1994, the CT25K model installed throughout the user facility was discontinued by the vendor in 2007. The new CL31 provides increased spatial and temporal resolution, improved algorithms for cloud amount and mixing-layer height, and a modular design for easy field servicing. It has been configured to optimize the performance for aerosol and boundary-layer detection.

Site Operations

Mobile Facility Completes First Test at Sea

In mid-June, the second mobile facility (AMF2) faced its first test on the open seas off the coast of Cape Cod, Massachusetts. Led by Rich Coulter, AMF2 site scientist from Argonne National Laboratory, the AMF2 team installed a subset of instruments on the *RV Connecticut* to test their operation in a marine environment and experience the potential problems likely to be encountered during a long-term shipboard deployment.

Designed for deployment flexibility—particularly for obtaining atmospheric data over the ocean—AMF2 consists of a number of separate instrument modules containing one or more instruments and their supporting electronics systems. The modules, which are climate-controlled and built of stainless steel, can be deployed together or separately, with wireless data communications.

Wireless communications will significantly reduce the infrastructure congestion and set-up time for the facility. Strategically placed radio-frequency antennas eliminate the need for cables to connect the instruments to the data collection system, which is a "mini" ARM data system. However, the heart of the AMF2 marine capability is a small, innocuous-looking box called the IMU, or inertial measurement unit.

The IMU, located near the center of the ship, records the exact longitude, latitude, and motion (pitch, roll, speed, surge, sway, etc.) of the ship every 0.02 seconds. A global positioning system (GPS), located conveniently within sight of satellites, is part of the system. Combined data from the IMU and GPS will be used to provide a "ship disposition" datastream containing the needed correction information to adjust for these motion variables in several critical instrument measurements that rely on vertical-pointing and air motion data.

Another key component for AMF2 shipboard deployments is the stable platform, which moves in opposition to the ship's movement—if the ship tilts in one direction, the platform is programmed to tilt in the opposite direction. Control software uses information from the IMU to keep the platform level and in the correct orientation.

The stabilized platform can support a relatively large payload—several hundred pounds. In general, the instruments placed on the platform require shading from the sun or need to point vertically. During testing in June, the platform hosted a microwave radiometer, a multifilter rotating shadowband radiometer, and a total sky imager.

Other instruments deployed throughout the ship included a micropulse lidar, upward- and downward-looking infrared thermometers, and two non-standard ARM instruments that do not require stabilization: a portable radiation package and another radiometer to measure total and diffuse radiation.

New aerosol measurement capabilities. *With funding from the Recovery Act, the ARM Facility invested in a new generation of aerosol observing systems (AOS). These systems provide an array of measurements about aerosol concentrations and optical properties to better understand how particles interact with solar radiation and influence the Earth's radiation balance. The Recovery Act provided for three new AOS units: one for the Darwin site, another for the AMF2, and a third stand-alone Mobile AOS composed of separate 20-foot containers—one for aerosol and one for chemistry measurements.*

Rich Coulter, AMF2 site scientist, and Brad Orr, AMF2 site manager, install instruments on the bow of the *RV Connecticut* for operational testing in June.

New Database Tracks Instrument Calibration Information

The Common Calibration Database provides a quick way to view calibration information associated with an instrument and its subcomponents.

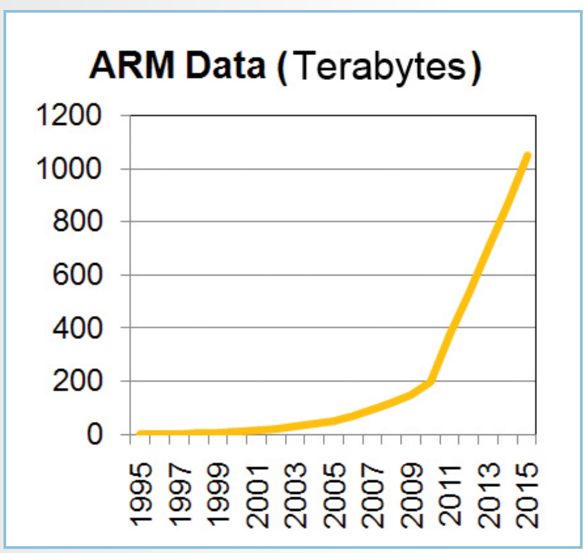
The ARM Facility has research sites around the globe, each with a suite of instruments that must be maintained and calibrated to deliver the best possible climate measurements. To capture timely calibration statistics from the various sites, ARM Operations staff designed and released the Common Calibration Database (CCDB), which provides a central location to store calibration information for all ARM instruments. The CCDB is part of the Operations Status System, the database that tracks the states of various instrument and computer systems and components at each ARM site.

Fields in the database contain the instrument name and/or instrument subcomponent, serial number, date of calibration or calibration check, who performed the calibration or calibration check, the result, and the date of the next calibration or calibration check. Advanced search functionality allows users to search on any of those fields. The database also allows users to upload supporting documentation, such as calibration procedures or a calibration certificate.

Previously, instrument calibration information was stored in a variety of formats in many different locations. The lack of a centralized storage system made it difficult for users to access the data they needed. The new database will make it more efficient for users to update and search for instrument maintenance and calibration information.

Data Delivery

Archive Upgrade



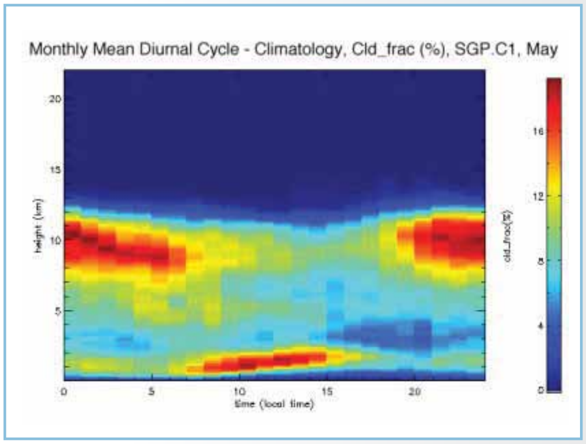
With the addition of new instruments, the growth rate of data in the ARM Data Archive is expected to increase by more than 20 percent, resulting in over 1,000 terabytes of data by 2015.

New instruments from the Recovery Act are expected to increase the growth rate in the number of ARM data files by 20 percent and create 4 to 7 times as much data volume. For example, each new cloud and precipitation radar can produce up to 15 gigabytes of data per day. Fortunately, a portion of the Recovery Act funding was dedicated to increasing the capacity of the data systems.

Procurement of replacement computers for the Archive was complete by January 2010. Installation, evaluation, and implementation of new hardware continued throughout FY 2010. New hardware purchased for the Archive is 3 to 7 times faster than the old systems, with 10 to 20 times more capacity. The current data systems provide the required capacity for near-term data flows at the Archive. As the Archive attains experience with the data flows from the new Recovery Act instruments, tuning and optimization of the system configurations and Archive software will continue.

New Addition to the Climate Modeling Best Estimate Data Set

The Climate Modeling Best Estimate (CMBE) data set is specifically tailored for use in evaluating GCMs and includes long-term best estimates from selected ARM measurements for cloud fraction, total cloud cover, shortwave and longwave radiation fluxes, liquid water path, and precipitable water vapor. A new addition to the CMBE data set was released this year, comprising a statistical summary of the CMBE data. It includes both monthly mean and monthly mean diurnal cycle and their climatologies for all the geophysical quantities contained in these data sets.



A quick-look plot of the new statistical summary files available for the CMBE data product.

The new summary data sets are designed to reduce uncertainty in data caused by gaps in the original CMBE data set. Due to missing gaps in the original data set, statistics generated from CMBE by different groups may be slightly different, depending on how they treat those missing data points. The summary data sets provide a best estimate of these statistics based on the original CMBE data. Significant quality control checks exclude the outliers suspected to be mainly due to missing data.

Data Management Facility Completes Upgrades from Recovery Act Funding

The DMF is the initial collection point for raw data from all the ARM sites. In June, the DMF completed installing and testing $643,000 of new computers and equipment purchased through the Recovery Act. These upgrades increase the DMF processing and storage capacity by 6 to 10 times to support current and future demand for ARM computing power.

The new bank of computers in the front two cabinets will replace the older systems and increase the DMF processing and storage capacity up to 10 times.

Data arriving at the DMF are processed once an hour, every day, 365 days a year. This processing activity includes routine monitoring for readability and usability before the data are transferred to the ARM Data Archive. In addition, the DMF provides computational resources for scientists to develop "value-added products"—physical models that use ARM data as inputs to fulfill unmet measurement needs and to improve the quality of existing ARM measurements.

With the influx of funds from the Recovery Act, new and upgraded instruments throughout the user facility will result in a large increase in data flowing through the DMF, as well as increased downstream processing for data products. The recent upgrades and new equipment improve not only the performance and reliability of the DMF services, but also provide increased computing capability for scientists to develop and run algorithms for new data products.

Tandem Differential Mobility Analyzer Data Available at the ARM Data Archive

Dry samples are collected by the aerosol stack and transferred inside the aerosol observation system structure to the TDMA where they are exposed to humidity for growth rate sampling.

Over 4 years of data from the tandem differential mobility analyzer (TDMA), including an external value-added product, became available online at the ARM Data Archive in FY 2010. Data from the TDMA, located at the ARM Facility's SGP site, measure aerosol dry-size distribution and size-resolved hygroscopic growth rate factors (i.e., relative growth of dry aerosol particles of a given size when exposed to a relative humidity of 85%).

Installation of the TDMA began in October 2005 with data collected and delivered in batches to the Archive as field campaign data. Recent reprocessing of the data as an ARM-standardized datastream makes the TDMA a part of the ARM instrument suite. In addition, data from a value-added product of aerosol properties derived from the TDMA measurements are provided by Don Collins of Texas A&M University, as part of the TDMA data collection at the Data Archive. These data provide CCN measurements using a process developed by Collins.

Communication, Education, and Outreach

YouTube™ Channel and Flickr® Added to Outreach Tools

Flickr now hosts ARM's Image Library, featuring more than 1000 images dating back over 15 years.

During the summer of 2010, the ARM Communications Team moved ARM photo and video content into both Flickr and YouTube, respectively. These popular and cost-effective social media outlets join ARM's existing Facebook and Twitter accounts, providing additional options for sharing information with users and the public. All four sites can be accessed from the new social media bar on the ARM home page.

ARM's former image library was phased out due to its outdated host server, and Flickr was identified as its replacement based on its reputation for efficiently storing large image collections. The ARM image collection on Flickr is organized in numerous ways, including by site, year, field campaign, and measurement categories, enabling users to quickly find images they are interested in. Meanwhile, YouTube offers a free and convenient space for sharing videos longer than 1.5 minutes, which is the current limitation on Flickr.

Both ARM's YouTube channel and Flickr collection have material spanning the two decades of the program's history.

ARM Kiosk Joins International Science Exhibit in Germany

Joining prestigious company overseas, the ARM kiosk was on display at the Isle of Mainau in Germany as part of an international exhibit of science and technology from May 20 through August 29. The "Discoveries 2010: Energy" exhibit was featured during the 60th Lindau Nobel Laureate Meeting, which took place June 27 to July 2, 2010, in Lindau, Germany. The exhibition charted the course of human energy use and showcased future methods for sustainable energy production.

Outdoor pavilions on the Isle of Mainau in Germany featured energy-related science and technology exhibits from May through August 2010. The ARM kiosk was included in the DOE exhibit.

A solar-powered ship brought the laureates to the island on July 2 for a tour of the exhibits, contained in numerous outdoor pavilions. Participating countries provided interactive displays that communicate research and scientific discoveries that tie into the overarching theme of energy and the environment. The ARM kiosk, selected to participate with the DOE exhibit, is a menu-driven multimedia program that provides an overview of the ARM Facility, including its sites, instruments, data, field campaigns, and outreach components.

ARM Shares Information at State of the Arctic Conference in Miami

Representatives from the ARM Facility joined more than 430 students, scientists, and policymakers in Miami at the first State of the Arctic Conference from March 16–19, 2010. The conference location in Florida was considered a "green" choice by meeting organizers for reducing attendees' carbon travel footprints and being a recycle-friendly facility. Organized by the National Science Foundation's Arctic Research Consortium of the United States (ARCUS) and sponsored by 14 additional agencies including ARM's sponsor, DOE's Office of Biological and Environmental Research (OBER), the conference's main goal was to review the understanding of the Arctic system in a time of rapid environmental change.

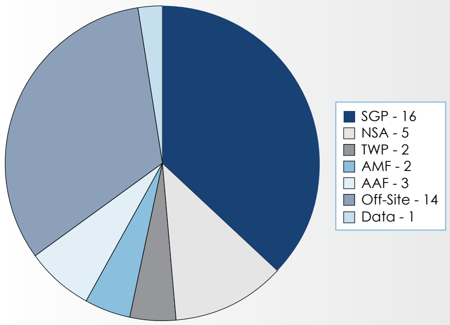
DOE's display table featured ARM's NSA site, as well as an Arctic climate change movie and OBER handouts.

More than 215 posters were presented during sessions on two nights of the conference. During the poster sessions, ARM participated in the display area sponsored by DOE's OBER. As one of DOE's key participants in Arctic research, ARM's NSA site was featured with the NSA live data kiosk, NSA field campaign backgrounders, education materials, and the 2008 and 2009 ARM annual reports. ARM data were also highlighted in the Regional and Global Climate Modeling's movie demonstrating animations of modeling results—a key draw to the display. Information materials were also provided for other DOE OBER divisions and programs, including Carbon Cycling and Biosequestration: Integrating Biology and Climate Through Systems Science. Poster participants expressed their enthusiasm for DOE's participation and support.

Field Campaign **SUMMARY**

The ARM Facility routinely hosts field campaigns at all its sites, as well as 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 FY 2010, including these ongoing efforts. The subsequent table summarizes just those campaigns that began in FY 2010. For more information, visit the Field Campaign web pages:

www.arm.gov/campaigns



Total 2010 Field Campaigns

Dates	Campaign Name	Status	Description
ARM Aerial Facility			
January 2010–June 2010	Small Particles in Cirrus (SPARTICUS)	Completed	An instrumented aircraft obtained the most comprehensive set of measurements of ice crystals in cirrus clouds to date. In conjunction with concurrent data from the ARM SGP site, SPARTICUS will help resolve discrepancies between both ground-based and in situ measurements. SPARTICUS used new probes designed to minimize potential problems with shattering of larger crystals on the inlets of the older probes. By using both new and old probes to obtain the airborne data, scientists hope to balance the new information against legacy measurements and evaluate past data sets. Ultimately, this will lead to a better understanding of the radiative effects of cirrus clouds on global climate.
May 2010–July 2010	Carbonaceous Aerosol and Radiative Effects Study (CARES) - Surface Meteorological Sounding	Completed	The primary objective of CARES was to study the evolution of carbonaceous aerosols and their optical and hygroscopic properties in the Sacramento urban plume as it is advected to the northeast. Carbonaceous aerosols, which include black carbon (BC), urban primary organic aerosols (POA), biomass burning aerosols (BBA), and secondary organic aerosols (SOA) from both urban and biogenic precursors, play a major role in the direct and indirect radiative forcing of climate. However, significant knowledge gaps and uncertainties still exist in the process-level understanding of SOA formation, BC mixing state evolution, and the optical and hygroscopic properties of fresh and aged carbonaceous aerosols. This campaign's ground-based instruments provided essential meteorological information about atmospheric structure and transport.
June 2010	Carbonaceous Aerosol and Radiative Effects Study (CARES)	Completed	The primary objective of CARES was to investigate the evolution of carbonaceous aerosols of different types and their optical and hygroscopic properties in central California, with a focus on the Sacramento urban plume. In addition to obtaining new observation-based understanding from the anticipated field data, the CARES campaign strategy was centered on using the data in various focused model evaluation exercises, so the resulting new knowledge could be integrated into regional and global climate chemistry models. The sampling strategy during CARES was coordinated, to the extent possible, with CALNEX 2010, a major field campaign in California in 2010 by the California Air Resources Board, NOAA, and the California Energy Commission.
ARM Mobile Facility			
April 2010–September 2010	Azores: Above-Cloud Radiation Budget near Graciosa Island	Completed	The scientific focus of this campaign was to measure the cloud-top downwelling radiative fluxes in coincidence with trace gas measurements made at Pico Observatory, Pico Island, Azores. To enhance measurement capabilities in the vicinity of Graciosa and to take advantage of a unique opportunity to measure cloud transmittance in the marine environment, broadband longwave and shortwave radiometers and a shadowband radiometer associated with the ARM Ancillary Facility were deployed at the Pico Observatory.

North Slope of Alaska			
December 2009–November 2011	National Science Foundation (NSF) Advanced Cyber-Infrastructure	In Progress	In response to recent developments in sensor technology and Transmission Control Protocol/Internet Protocol (TCP/IP) wireless communications, a prototype Open Geospatial Consortium standards-based Arctic climatology sensor network has been constructed. This consortium is responsible for creating the standards for sensor web enablement, enabling developers to make all types of sensors, transducers, and sensor data repositories discoverable, accessible, and useable via the web. These standards also enable increased interoperability, scalability, and extensibility for geospatial information at reduced cost. The approach for the prototype is to integrate established technologies to create geographic information networks. A variety of meteorological, soil, and image sensors were linked to wide-area wireless networks in Barrow, Alaska, at the NSF's Barrow Arctic Research Center via the ARM Facility's NSA site. The network allows for global connectivity at remote research stations and on Arctic ice breakers.
Off-Site Campaigns			
October 2009–May 2010	Passive Cavity Aerosol Spectrometry Probe (PCASP) Calibration	Completed	The 2008 VAMOS Ocean-Cloud-Atmosphere Land Study (VOCALS) campaign deployed the AAF G-1 research aircraft to study marine stratus clouds off the coasts of Chile and Peru. Two identical PCASPs measured interstial aerosol particles below, in, and above the marine stratus clouds. Analysis of the results from the two PCASP's indicates some discrepancies with G-1 differential mobility analyzer (DMA) results in their overlapping aerosol particles size ranges. To resolve the DMA/PCASP discrepancies, the PCASPs will be recalibrated in this campaign with respect to aerosol size and, more importantly, aerosol particle concentration. One PCASP was recalibrated in October 2009 and the other about April 2010. A new PCASP calibration with respect to aerosol particle size and concentration was generated.
December 2009–December 2011	Darwin ARM Representativeness Experiment (DARE)	In Progress	A small radiometer system will be deployed at the Gunn Point C-POL radar site, located about 25 kilometers northeast of the TWP Darwin site. The radiation measurements, as well as cloud and cloud-effect retrievals using the Radiative Flux Analysis methodology, will be compared to similar data from the ARM Darwin site over the course of 1–2 years in an effort to quantify local influences and variability that affect the Darwin site measurements. The length of the deployment is expected to last at least 1 year to capture one annual cycle. However, it may be extended for up to another year, depending on analyses of the results at about the 9-month mark, and to allow for factors such as data continuity and possible data losses through equipment malfunctions. The goal is to collect enough data for robust statistical analyses.
April 2010–October 2014	Lidar Support for ICECAPS at Summit, Greenland	In Progress	The Integrated Characterization of Energy, Clouds, Atmospheric State, and Precipitation over Summit (ICECAPS) project, funded through the NSF's Arctic Observing Network, is deploying a suite of remote sensors at Summit, Greenland, for 4 years. ARM is contributing a micropulse lidar and Vaisala ceilometer to gather information about optically thin clouds commonly found above the Summit site. Combined measurements from these sensors and instruments will result in a comprehensive data set of cloud properties, atmospheric state, precipitation, and radiation. The resulting ICECAPS datastreams will be made available in the ARM Data Archive.

April 2010– July 2010	Carbonaceous Aerosol and Radiative Effects Study (CARES) Ground-Based Instruments	Completed	New Recovery Act-funded ARM instruments were deployed at specified ground sites during CARES. The use of CCN counters and humidified tandem differential mobility analyzers provided aerosol hygroscopicity and drop activation measurements for CARES. These new instruments and their future performance greatly benefited from testing and inter-comparison in a rigorous field setting.
May 2010– June 2010	Carbonaceous Aerosol and Radiation Effects Study (CARES) Photo-Acoustic Aerosol Light Absorption and Scattering	Completed	Photo-acoustic aerosol light absorption and scattering measurements collected during CARES focused on interaction of light with secondary organic aerosols and black carbon.
May 2010– July 2010	Carbonaceous Aerosol and Radiative Effects Study (CARES): SMPS and CCN Counter Deployment During CARES/CALNEX	Completed	The simultaneous CARES and CALNEX campaigns offered a unique opportunity to examine the CCN activity of representative organic aerosols within the boundary layer. By combining a scanning mobility particle sizer and a dual-column CCN counter, the size-resolved CCN concentrations were measured. This allowed the characterization of the cloud activation properties of major organic aerosols.
June 2010– August 2010	Time Response of DOE Cloud Imaging Probe	Completed	The time response of the DOE Cloud Imaging Probe (CIP) was evaluated at SPEC Inc. using calibration equipment (i.e., a high-speed spinning disk) owned by Durag Umbh in Germany. This equipment was loaned to SPEC Inc. during the summer 2010. The resulting characterization of the time response of the CIP was transmitted to the ARM Data Archive.
August 2010– April 2011	Columbia Basin Wind Energy Study	In Progress	The primary focus of this study is to obtain a multi-season data set that can be used to evaluate the performance of regional-scale models in a geographic area that has complex terrain and is used for wind power production. This data set will be used to test boundary-layer parameterizations and forecasts of low-level winds in numerical models of the atmosphere.
Southern Great Plains			
October 2009– March 2010	Sun and Aureole Measurement Support for the Small Particles in Cirrus Field Campaign	Completed	This support project for the SPARTICUS field campaign sought to contribute additional measurements of small particles (<50 micrometers in diameter) to determine how these particles contribute to the mass and radiative properties of midlatitude cirrus. Measurements of cirrus particles in this size range were collected using data from a ground-based imaging sun and aureole photometer. Operating at 670 nanometers, this instrument measured the solar irradiance and aureole radiance profiles.
March 2010– February 2011	Radon Measurements of Atmospheric Mixing (RAMIX 2010–2011)	In Progress	Existing instrumentation at the ARM SGP site is collecting radon mixing ratio data from the 60-meter tower with the objective of using the radon measurements to help estimate regional CO_2 (and later CH_4) exchange.
March 2010– February 2011	Precision Gas Sampler Validation 2010	In Progress	This campaign continues a paired treatment control experiment at the Agricultural Research Services Southern Plains Range Research Station. The ongoing experiment is comparing energy and carbon fluxes from a field recently planted to switchgrass (a potential biofuel crop) with fluxes from winter wheat.

May 2010– June 2010	Verification of the Origins of Rotation in Tornadoes Experiment 2 (VORTEX2)	Completed	This field campaign aimed to improve the understanding and forecasting of thunderstorms and tornados, and thereby mitigate the threats they pose to life and property. The specific aims of the soundings component of VORTEX2 were to assess how tornadic and non-tornadic thunderstorms interact with their surrounding environments and improve storm-scale numerical weather predication through an understanding of the importance of environmental variability in the vicinity of storms.
May 2010– June 2010	Deep Convective Clouds and Chemistry (DC3)	Completed	The DC3 campaign sought to understand the influence of convection on the upper troposphere, which will lead to better understanding of radiative forcing and chemical oxidation. These goals directly relate to the physical, chemical, and biological processes that regulate the Earth system, the changes occurring in the Earth system and environment, and how these changes are influenced by human actions. The DC3 field campaign used heavily instrumented aircraft platforms and ground-based instrumentation to characterize the impact of deep convective systems on the composition and chemistry of the mid-latitude 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. The data will be analyzed using models over a range of scales, from 0-D box and cloud-scale models to global models.
July 2010	Near Earth Hyperspectral Imaging (NEHI) Checkout Flights	Completed	NEHI is a newly modified hyperspectral sensor that has been developed in collaboration between the DOE and Department of Defense. NEHI made airborne hyperspectral measurements over fixed targets deployed at the SGP Central Facility. This series of tests was the initial flight of the system and will be used to evaluate the initial performance of the sensor and drive potential modifications to be incorporated in future missions.
August 2010– August 2013	COSMOS Network	In Progress	The goal of this effort is to install and operate one or more cosmic-ray soil moisture probes. The probe will measure soil moisture in the area circa 350 meters around it. The raw data (neutron counts, pressure, temperature, battery and instrument voltages, and miscellaneous data) will be integrated and transmitted hourly to a server, where it will be processed and converted to higher-level data.
September 2010– October 2010	Northern Oklahoma CO_2 Attribution with Tracers Study	Completed	The primary goal of this experiment was the investigation of CO_2 attribution techniques using measurements of atmospheric trace signatures of CO_2 sources. Full attribution studies require measurements focused on the carbon cycle and biogenic sources and sinks in addition to measurements targeted at anthropogenic sources.

On the inside covers: Thanks to the Recovery Act, X-band scanning ARM precipitation radars were installed at the SGP site during FY 2010.

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