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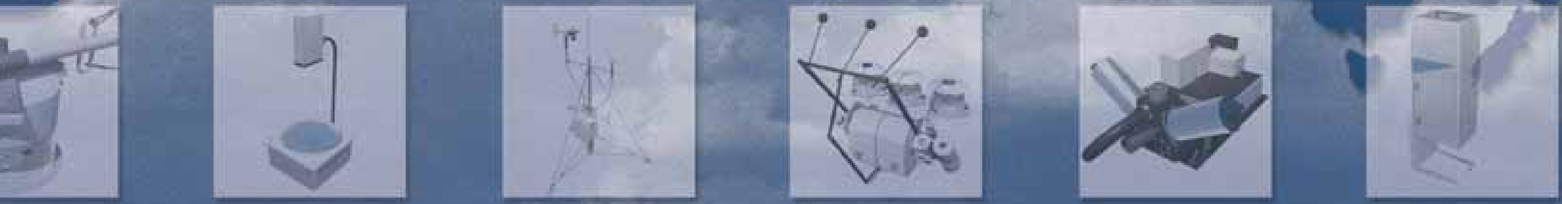
Atmospheric Radiation Measurement Climate Research Facility

U.S. Department of Energy

annual report 2004



Department of Energy
Washington, DC 20585

December 1, 2004

Subject: Annual Report for the Atmospheric Radiation Measurement Program and Climate Research Facility

In 1989, DOE established the Atmospheric Radiation Measurement (ARM) Program to improve the treatment of clouds and radiation processes in global climate models. Research efforts progressed during the following decade, and the Program succeeded in establishing the infrastructure and scientific collaborations needed to conduct cutting-edge cloud and radiation investigations. As a result, three instrumented locations – in Oklahoma, Alaska, and the tropics – now provide continuous measurements of atmospheric properties from a variety of climatic conditions. Because of the potential for this infrastructure to contribute to the study of climate change among the broader national and international scientific community, DOE designated the ARM infrastructure as a national user facility in 2003.

To promote the ARM Climate Research Facility (ACRF) to a broader set of users while continuing to serve ARM research needs, 2004 represented a year of significant challenge and change:

- ARM Mobile Facility – completed engineering and development of a new facility with the same capabilities as the fixed research sites, but with the added benefit of portability.
- ACRF Science Board – established an 11-member panel of experts from the ARM Program and the external scientific community to review proposals for use of the Facility to ensure scientific merit.
- Field Campaigns – developed a new, easier process for researchers to submit field campaign proposals via the website, as well as related planning, tracking, and documentation tools.
- Website Overhaul – completely restructured the aging website design and incorporated ACRF information into new structure, including a review of nomenclature to ease understanding through more common terminology in online and print documentation.

In addition to these achievements, ARM investigators published their research in approximately 150 journal articles this year, and the ARM Science Plan was updated. Reflecting the maturity of the ARM science program, this guiding document briefly describes the scientific accomplishments achieved since the outset of the Program, and provides a direction and plan for future ARM research activities.

With the achievements of 2004, the ACRF is well positioned to contribute to continuing ARM advances in cloud and radiation research, as well as broader climate change research efforts throughout the world.

Thank you for your interest in and support of DOE's ongoing climate research efforts.

Wanda R Ferrell

Wanda R. Ferrell, Ph.D.
ARM Program Manager
Climate Change Research Division

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Program Overview

The Role of Clouds in Climate

Like a rock that slowly wears away beneath the pressure of a waterfall, planet earth's climate is almost imperceptibly changing. Glaciers are getting smaller, droughts are lasting longer, and "extreme weather events" like fires, floods, and tornadoes are occurring with greater frequency. Why? Part of the answer is clouds and the amount of solar radiation they reflect or absorb. These two factors—clouds and radiative transfer—represent the greatest source of error and uncertainty in the current generation of general circulation models used for climate research and simulation.

Previous research has shown that cloud radiative forcing and feedbacks are one of the major sources of uncertainty in simulations of climate change over the next century. The ARM Program focuses on obtaining continuous field measurements of atmospheric properties and processes, and from these measurements, developing data products that promote the advancement of climate models.

The U.S. Global Change Research Act of 1990 established an interagency program within the Executive Office of the President to coordinate U.S. agency-sponsored scientific research designed to monitor, understand, and predict changes in the global environment. To address the need for new research on clouds and radiation, the U.S. Department of Energy (DOE) established the **Atmospheric Radiation Measurement (ARM) Program**. As part of the DOE's overall Climate Change Science Program, a primary objective of the ARM Program is improved scientific understanding of the fundamental physics related to interactions between clouds and radiative feedback processes in the atmosphere.

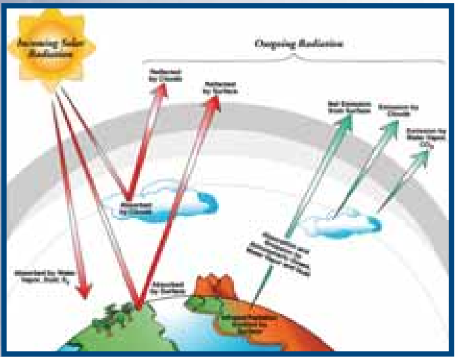
ARM Science Goals

One of the DOE's major goals is to develop global climate models capable of simulating the timing and magnitude of greenhouse gas-induced global warming and the regional effects of such warming. Therefore, the goal of the ARM Program is to improve the treatment of clouds and radiation processes in global climate models.

ARM's goal is addressed through a combination of continuous ground-based observations, data analysis, modeling of local and regional physics, and development of parameterizations for global models. Through these activities, the ARM Program seeks the answers to two principal questions:

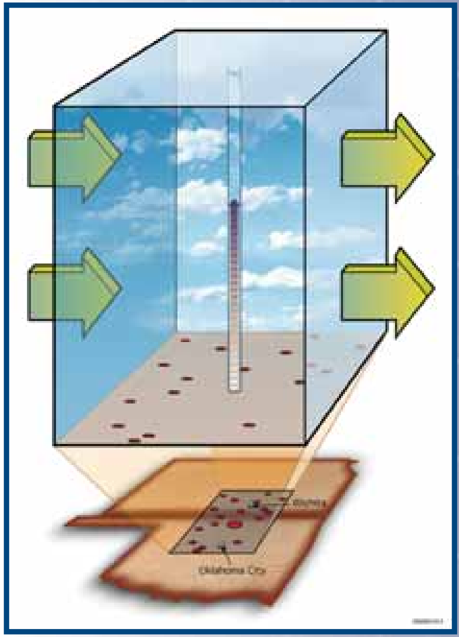
- How accurate are both longwave and shortwave radiative transfer calculations for any given column of the atmosphere?
- How well can cloud properties in a column of the atmosphere be predicted from knowledge of larger scale atmospheric properties?

Because of the complexity and global scope of the research involved in answering these questions, the ARM Program collaborates extensively with other laboratories, agencies, universities, and private firms in gathering and sharing data. This collaborative approach allows ARM to leverage its investment in **research sites, instruments, data, and science** to gain the knowledge necessary to improve the accuracy of the computer models used to simulate global and regional climate changes.



ARM researchers are studying the natural phenomena that occur in clouds, and how those cloud conditions affect the sun's incoming and outgoing energy and, in the longer term, our climate.

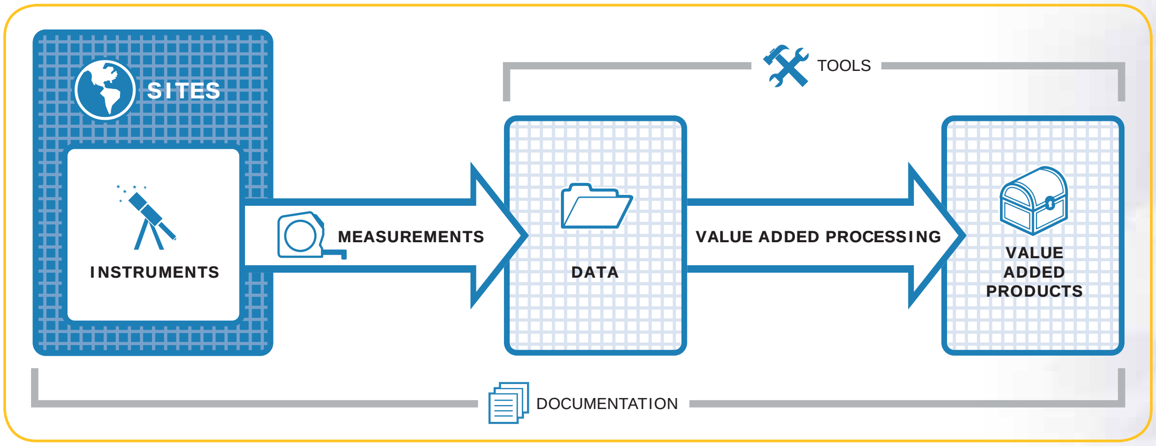
ARM Climate Research Facility: Successful Science Program Leads to User Facility Designation



The dynamic nature of clouds presents a difficult challenge in applying properties in a single column of the atmosphere to larger scale scenarios.

Through the ARM Program, the DOE funded the development of several 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. This scientific infrastructure, and resultant data archive, is a valuable national and international asset for advancing scientific knowledge of Earth systems. In fiscal year (FY) 2003, the DOE designated the ARM sites as a national scientific user facility: the **ARM Climate Research Facility (ACRF)**. The ACRF has enormous potential to contribute to a wide range of interdisciplinary science in areas such as meteorology, atmospheric aerosols, hydrology, biogeochemical cycling, and satellite validation, to name only a few.

Three primary locations—the Southern Great Plains (SGP), Tropical Western Pacific (TWP), and North Slope of Alaska (NSA)—and the portable ARM Mobile Facility are heavily instrumented to collect massive amounts of atmospheric measurements needed to create data files. Using these data, ARM 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 scientists and ACRF infrastructure staff provide value-added processing to the data files to create new data streams called value-added products. Software tools are then provided to help open and analyze these products. Program documentation, from setting up the sites to developing the value-added products, is available for each step in this process.



Sites Around the World Enable Real Observations

A central feature of the ACRF is a set of instrumented field research locales for measuring atmospheric radiation and the properties controlling this radiation, such as the distribution of clouds and water vapor. To obtain the most useful climate data, three locales were chosen that represent a broad range of weather conditions.

The SGP site in Oklahoma provides a wide variability of climate cloud type and surface flux properties, and large seasonal variation in temperature and specific humidity.

Southern Great Plains

The SGP site was the first field measurement site established by ARM. The SGP experiences a wide variety of cloud types and surface flux properties, as well as large seasonal variations in temperature and specific humidity. The site consists of a highly instrumented Central Facility near Lamont, Oklahoma, and smaller facilities scattered over approximately 142,450 square kilometers in north-central Oklahoma and south-central Kansas. Cooperative partnerships have evolved with a variety of government laboratories and agencies, and also with universities, permitting collaborative use of several state-of-the-science radar and climate observing systems and networks. Collection of continuous measurements at this location began in 1994, with a complete suite of instruments operating since 1996. This site is now the largest and most extensive climate research field site in the world.

Climate Research Milestone: *In 2004, the SGP celebrated its 10-year anniversary as the world's largest and most extensive climate research field site for studying the effects of clouds and solar radiation on earth's atmosphere. More than 30 specialized in situ and remote-sensing instrument clusters for measuring surface and atmospheric properties are located at facilities throughout the site. The complete suite of permanent instruments at the SGP site provides a 10-year collection of unprecedented data for the scientific community as they investigate the causes and effects of global climate change.*

Due to the consistently warmest sea surface temperatures on the planet, the TWP locale plays an important role in the interannual variability observed in the global climate system.

Tropical Western Pacific

The TWP locale spans an area roughly between 10°N to 10°S of the equator from Indonesia to the dateline. This area—referred to as the Pacific "warm pool"—is characterized by warm sea temperatures, deep and frequent atmospheric convection, high rain rates, strong coupling between the atmosphere and ocean, and substantial variability associated with El Niño. Three instrumented sites operate in the TWP locale. The first of these sites was established in 1996 on Manus Island, Papua New Guinea. Site operations on Manus are conducted in collaboration with the Papua New Guinea National Weather Service. The second TWP site was established on Nauru Island in 1998. Nauru operations are performed with the cooperation of the Nauru Department of Island Development and Industry. A third TWP facility began operating in April 2002 at Darwin, Australia, in partnership with the Australian Bureau of Meteorology. This facility collects data typical of tropical land convection and monsoon circulations.

Early Results of Nauru Island Effect Study: *Low-level cloud plumes—shallow, cumulus clouds induced by islands that are conveyed by wind—have little effect on the total radiation budget in the tropics, but do have the potential to bias cloud and radiation measurements. To identify the occurrence of island-induced clouds and to quantify their effect on measurements at the TWP, researchers conducted a study at the TWP Nauru Island site. Principal findings showed that the island increased the amount of low cloud on the leeward side of the island from about 20% cloud cover to 30% cloud cover; the amount of middle and high cloud was not affected. This study enabled ARM scientists to develop analysis techniques to detect when an island influence is occurring and how surface measurements may be affected by the island-induced clouds. The study is also allowing scientists to quantify the extent of the island influence on cloud statistics and the impact on surface radiation. This information is important for the ARM Program, as well as for other programs that maintain small island measurement sites.*

North Slope of Alaska

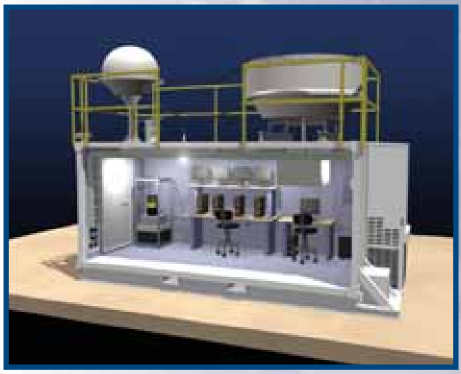
The NSA locale is situated on the edge of the Arctic Ocean. This area provides important information for ARM research because fundamentally different climate processes—such as planetary heat loss from the poles and extensive sheets of ice that affect solar absorption and sea level—occur at high latitudes. Due to generally cold temperatures, atmospheric water vapor concentrations in the Arctic are quite low, allowing heat energy from the surface to escape through the atmosphere more easily than in other regions. The NSA's principal instrumented facility was installed near Barrow in 1997, followed by a smaller remote site at Atqasuk in 1999. Routine operations at these sites are conducted in partnership with employees of Ukpeagvik Iñupiat Corporation/Science Division.

The NSA provides data about cloud and radiative processes in the Arctic, which has been identified as one of the regions most sensitive to climate change.

Arctic Cloud Properties on CD: *In two separate CD collections, ARM Program collaborators at the National Oceanic and Atmospheric Administration (NOAA) have produced a compendium of cloud microphysical properties from research conducted in the Arctic. The two collections include (1) Cloud Microphysical Properties from Barrow, Alaska, Version 1 (August 2003), a 3-CD series that covers data retrieved in 2000, 2001, and 2002; and (2) Cloud Microphysical Properties from the Surface Heat Budget of the Arctic Ocean (SHEBA) Project, Version 2 (January 2004). ARM data sets and retrieval products from different retrieval techniques were used in both efforts.*

ARM Mobile Facility

The ARM Mobile Facility (AMF) was developed to address science questions beyond those addressed by the "fixed" measurement sites. The AMF is similar to the permanent ARM sites in that it contains many of the same instruments and data systems, but it is designed to be deployed around the world for campaigns lasting up to 18 months. The AMF consists of a minimum of two lightweight shelters, a baseline suite of instruments, data communications, and data systems. Designed to collaborate with other agency experiments (particularly those with aircraft), it also has the ability to host instruments other than the baseline collection. Data streams produced by the AMF will be available to the atmospheric community for use in testing and improving parameterizations in global climate models.



Portability and flexibility are key elements of the Mobile Facility, designed to further enhance ARM's ability to measure different climate regions.

First Deployment Scheduled for 2005: *The first deployment of the AMF is planned to occur at Point Reyes, on the California coast north of San Francisco, in spring 2005. As part of a field campaign to study the microphysical characteristics of marine stratus and, in particular, marine stratus drizzle processes, the AMF will provide a mature instrument system to help fill information gaps in the existing limited surveys of marine stratus microphysical structure. Marine stratus clouds are known to be susceptible to the by-products of fossil fuel consumption, a multi-agency climate change priority.*

State-of-the-Art Instrumentation Yields Comprehensive Data Sets

ARM's approach to instrument development and procurement began with a fundamentally new idea in mind: carry out continuous and simultaneous ground-based observations of the atmospheric column using a suite of passive and active sensors. Previously, most sensors used to investigate atmospheric properties and compositions were strictly research instruments and, in many cases, inadequately understood

Through the development of a broad range of retrieval techniques using single and multiple data streams, the ARM Program made key advances in the areas of radiation and aerosol parameterizations, cloud properties algorithms, and cloud modeling/parameterizations versus observations and data analysis.

To study the effects and interactions of sunlight, radiant energy, and clouds on temperatures, weather, and climate, ARM scientists collect and analyze data obtained over extended periods of time from large arrays of instruments located around the world.

A record-breaking 315 people attended the 2004 ARM Science Team Meeting in Albuquerque, New Mexico.

and calibrated. The goal of ARM's instrument development initiative was to bring existing research instrumentation to the advanced state of development required to allow routine, highly accurate operation in remote areas of the world, and to develop new instrumentation as required.

Because side-by-side comparisons and calibration techniques are critical to instrument understanding, the ACRF routinely sponsors and hosts field campaigns focused on this subject. As a result, the new generation of ground-based remote sensing instruments include millimeter-wave cloud radar, Raman lidar, infrared interferometers using electronic coolers (instead of cryogens), and updated sky imagers, among others. These instrument arrays represent some of the most sophisticated tools available for conducting atmospheric research.

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

Science Team Approach Encourages Collaboration

ARM's Science Team is a unique collaboration of laboratory, university, agency, and private partners from around the globe. From the United States and abroad, cloud and radiation scientists ranging from senior scientists to post-docs and students comprise the team. Though diverse in geographic location, these science representatives provide the most direct channel through which ARM research results can affect development and evaluation of global climate models. Key support is provided by software and hardware engineers who maintain the infrastructure necessary for advancing ARM Science Team research.

One of the strengths of the Science Team concept is the interaction and information exchange among Science Team members. This occurs primarily through **Working Group** meetings, where focused research plans and assignments are discussed, and the annual **Science Team Meeting**, where everyone comes together to review research progress and the scientific direction of the Program.

Working Groups Provide Leadership, Focus on Specific Problems

To enable focused research on the various pieces of the cloud physics puzzle, the ARM Program divides its research into key areas, or Working Groups. These groups are the principal organizational structure within the ARM Science Team. Each Working Group concentrates on a specific set of issues related to climate modeling. The Working Groups include:

- **Aerosols** - relate observations of radiative fluxes and radiances to atmospheric composition, and uses these relationships to develop and test parameterizations to accurately predict atmospheric radiative properties

- **Cloud Parameterization and Modeling** - relate observations and data analysis to climate model development and evaluation to improve cloud parameterizations in global climate models
- **Cloud Properties** - develop and implement algorithms that characterize the physical state of the cloudy atmosphere, including cloud occurrence, cloud condensed water amount, and cloud optical properties
- **Instantaneous Radiative Flux** - test radiation parameterizations, particularly for shortwave radiation and cloudy-sky conditions, at the accuracy required for climate studies.

Members of the Instantaneous Radiative Flux Working Group met in October 2003 to review progress and discuss research objectives for the coming year.

Sometimes, the Science Team identifies an area of research that needs focused attention for a limited time to provide specific information to one or more of the "standing" Working Groups. In these cases, an "ad-hoc" working group is formed. In 2004, the **Clouds with Low Optical (Water) Depths Working Group** was formed to determine the best strategy for accurately measuring clouds with low optical depths and low liquid water paths (below approximately 100 g m-2) at ACRF locales.

Focused by sub-discipline, the Working Groups provide a forum for ARM scientists to help shape the program direction and collaborate with each other. Each group includes an infrastructure translator and a science leader to ensure program completeness.

Oversight Ensures Relevant Science, Promotes Facility Use

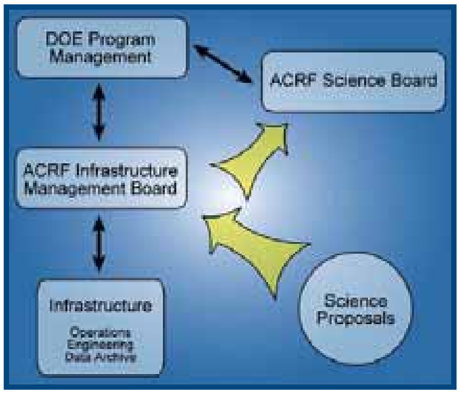
Oversight of the ACRF is provided by the DOE ARM Program Manager, representing the advisory committee for the DOE's Office of Biological and Environmental Research. In addition, a DOE-appointed Science Board reviews research proposals and recommends priorities for increasing the utility of the ACRF. The Science Board coordinates with the ACRF Infrastructure Management Board (IMB) to assess the availability and resource requirements of the proposed facility usage.

The objective of the IMB is to provide fair and equitable distribution of available funds between the fixed site facility infrastructure costs, field campaigns (also known as intensive operational periods, or IOPs) and special projects. An important part of their function is to increase external (non-ARM) use of the ACRF without inhibiting the achievement of ARM scientific progress.

Recommendations for future development of the facility are developed annually by the IMB and include input from the Science Board. These recommendations are presented to the DOE Program Manager for consideration and potential inclusion in budget and spending plans.

ACRF Science Board - *The 11-member ACRF Science Board is chaired by a respected scientist in the field of climate science or a related science. The Chair is appointed by the DOE Program Manager. In addition to the Chair, the Science Board includes five members from the ARM Science Team Executive Committee who represent the interests of the ARM Program, and five members who represent the interests of the broader scientific community, including the DOE Atmospheric Science Program. The DOE Program Manager approves Board membership, and is assisted by the ACRF Science Liaison in coordinating meetings and reviews with the Science Board.*

ACRF Infrastructure Management Board - *The IMB consists of a Technical Coordinator, Operations Manager, Data Archive Manager, Support Administrator, and the ACRF Science Liaison, who serves as a link between the IMB and the ACRF Science Board. The IMB coordinates the screening of science requests for use of the ACRF. Once a request has been sent to the Science Board for evaluation, the IMB provides to the Science Board detailed information regarding costs, resource use, and potential impacts to ARM Program needs at the ACRF.*



Global Program Managed by Many

Eight national laboratories and numerous government agencies, universities, private companies, and foreign organizations are involved in the ARM Program and ACRF. Each entity serves a vital role in managing and conducting the research, operations, and administration of the science program and user facility. Representatives of the ARM Program make up the majority of ACRF users.

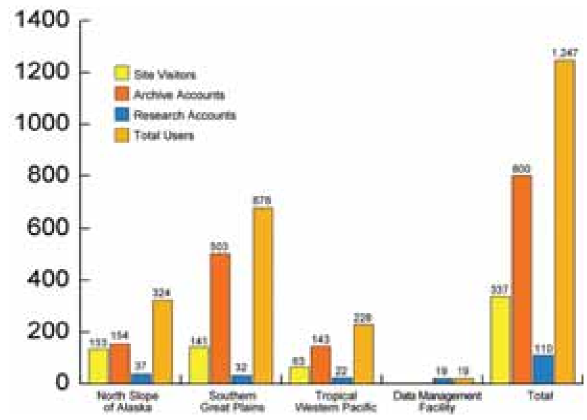
For ARM Program science activities, direction and oversight is the responsibility of **DOE Headquarters**. A **Science Team Executive Committee** reviews scientific progress and provides recommendations for future research. **Working Group** representatives coordinate and modify the ARM research agenda as appropriate. The site infrastructure that enables ARM science is managed through the ACRF.

The ACRF is also directed by **DOE Headquarters**. An **Infrastructure Management Board** coordinates the scientific, operational, data, financial, and adminstrative function of the ACRF. An 11-member **Science Board**, selected by the DOE Program Manager, serves as an independent review body to ensure appropriate scientific use of the ACRF.

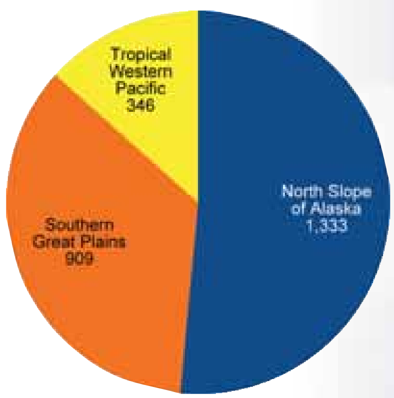
Fiscal Year 2004 Budget Summary and User Statistics

Atmospheric Radiation Measurement Program FY2004 Budget ($K)	
Total ARM Program	44,625
ARM Climate Research Facility	30,907
Technical Coordination	10,696
Operations	15,602
Data Archive	2,027
Capital Equipment	2,582
ARM Chief Scientist	3,100
DOE Science Grants	10,618

User Statistics for the Period of October 1, 2003- September 30, 2004



User Summary



Visitor Days by Site

Operational Statistics for the Period October 1, 2003 - September 30, 2004		
	Data Availability	
SITE	GOAL	ACTUAL
NSA	0.90	0.91
SGP	0.95	0.96
TWP	0.85	0.86
Site Average	0.90	0.91

Key Accomplishments

The following pages highlight a selection of research results, field campaigns, and infrastructure achievements from FY 2004 (October 2003 through September 2004). A complete list of FY 2004 field campaigns and publications is provided in the back of this report. More detailed information can be found on the following web pages:

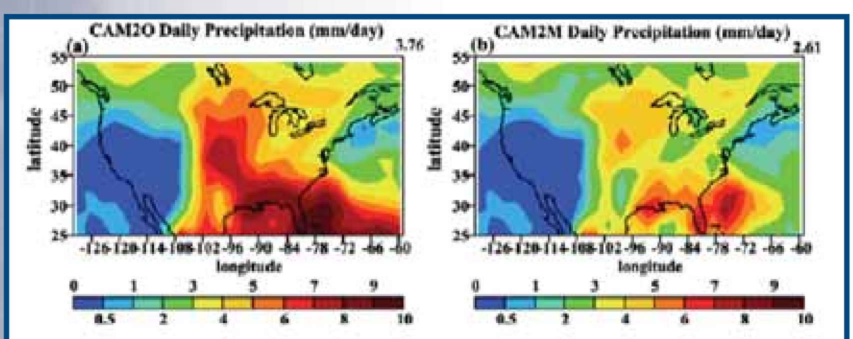
- *http://www.arm.gov/publications/pub_database.stm* for Publications
- *http://www.db.arm.gov/cgi-bin/IOP/iops.pl* for Field Campaigns
- *http://www.arm.gov/acrf/updates.stm* for Operations Updates

Research Highlights

Members of ARM's Science Team publish an average of 150 refereed journal articles per year, and ARM data are used in many studies published by other scientific organizations. In addition, ARM investigators present their research at key conferences each year. These documented research efforts represent tangible evidence of ARM's contribution to advances in almost all areas of atmospheric radiation and cloud research.

Weather Prediction and Climate Simulation: A Meeting of the Models

To improve models used to project climate change, ARM researchers borrowed a technique from the weather prediction community to identify and isolate model errors. ARM researchers implemented an improved convective triggering mechanism—based on ARM observations and single-column model tests—in the National Center for Atmospheric Research Community Atmosphere Model (CAM2) to correct the model tendency to produce excessive warm season daytime precipitation over land. This problem, related to the triggering function used in the model's deep convection scheme, assumes that convection is triggered whenever there is positive convective available potential energy, or CAPE. The new triggering mechanism assumes that convection occurs only when large-scale dynamic forcing makes a positive contribution to the existing positive CAPE.



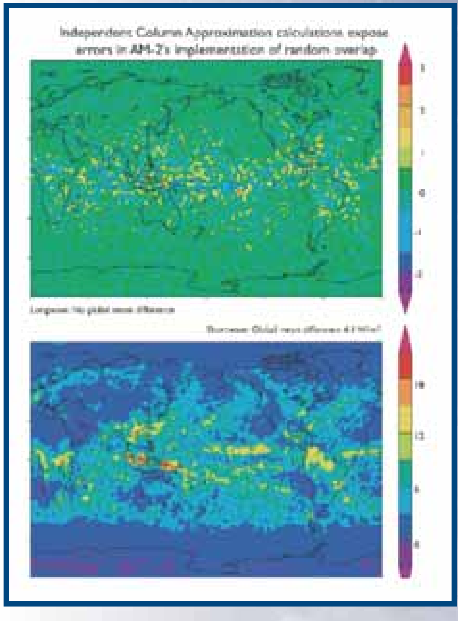
Distribution of a 20-day mean precipitation forecast throughout the continental United States shows much better agreement from the original climate model (CAM2O) to the adjusted CAM2M model.

Based on this assumption, the new triggering mechanism links cumulus convection directly to the large-scale dynamic processes, such as large-scale lower-level convergence. ARM researchers examined the impact of the new convective trigger on the CAM2 simulation using the Climate Change Prediction Program-ARM Parameterization Testbed (CAPT) framework. With the new triggering mechanism, the revised model reduced the impact of the daily cycle of solar radiation on initiating convection. This led to considerable improvements in the simulation of precipitation, temperature, moisture, clouds, radiations, surface temperature, and surface sensible and latent heat fluxes when compared against data collected from the ACRF SGP site. Improved precipitation simulation was also seen in regions surrounding the continental United States.

The CAPT, based at the Program for Climate Model Diagnosis and Intercomparison at the Lawrence Livermore National Laboratory, is a useful framework that allows specific parameterization deficiencies to be identified before the the compensation of multiple errors masks the deficiencies, as can occur in model climate simulation. (Reference: Xie. S., M. Zhang, J.S. Boyle, R.T. Cederwall, G.L. Potter, and W. Lin, (2004), Impact of a revised convective triggering mechanism on CAM2 model simulations: results from short-range weather forecasts, *J. Geophys Res.*, 109, D14102, doi: 10.1029/2004JD004692.)

Out With the Old, In With the New: McICA to Replace Traditional Cloud Overlap Assumptions

Current methods used to simulate radiative transfer through the atmosphere are inflexible and require a large amount of computer resources. These methods also include assumptions regarding the nature and properties of clouds that can lead to bias and error. A team of international researchers led by DOE's ARM Program developed the Monte Carlo Independent Column Approximation (McICA), which uses a complex statistical technique to more efficiently incorporate into radiation transfer calculations the complexity of cloud properties and their effects on the sun's rays. This code is more accurate because it does many radiative transfer calculations using actual cloud distributions instead of relying on assumptions.



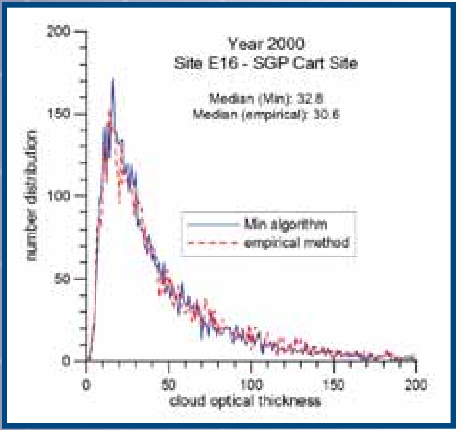
The standard way (AM2, top panel) of mixing solar reflection and transmission differs systematically from the Independent Column Approximation approach (bottom panel).

In 2004, ARM researchers incorporated the new McICA scheme into the National Aeronautics and Space Administration's (NASA) Geophysical Fluid Dynamics Laboratory's (GFDL) atmospheric climate model (AM2) to gauge its effectiveness in improving the accuracy of cloud-radiation interactions. The McICA code demonstrated a significant improvement in solar radiation at the top of the atmosphere of about 4 W/m^2.

The McICA scheme provides a flexible and more accurate way to compare model output with satellite data, and dramatically reduces computational time, making the approach affordable. These advantages will greatly benefit the GFDL as they develop a new cloud scheme for dealing with small-scale cloud variability. (Reference: Pincus, R., H.W. Barker, and J.J. Morcrette, (2003). A fast, flexible approximate technique for computing radiative transfer in inhomogenous cloud fields, *J. Geophys. Res.*,Vol. 108, No. D13, 4376, doi:10.1029/2002JD003322)

For Estimates of Cloud Optical Thickness, Simple Equation is Good Enough

Studies of shortwave cloud optical thickness play an important role in determining how clouds affect climate. This involves satellite and ground-based measurements that gather cloud optical thickness from measurements of solar radiation transmission. Transmitted solar radiation forms the basis of several important algorithms used to calculate cloud optical thickness. Transmission-based algorithms, such as that of Min and Harrison (1996) use spectral or broadband irradiance measurements to infer cloud optical thickness. Though the Min spectral radiance algorithm runs relatively quickly on a desktop computer, the specific wavelength measurements it uses as input are not widely available, limiting its usefulness on a global scale. On



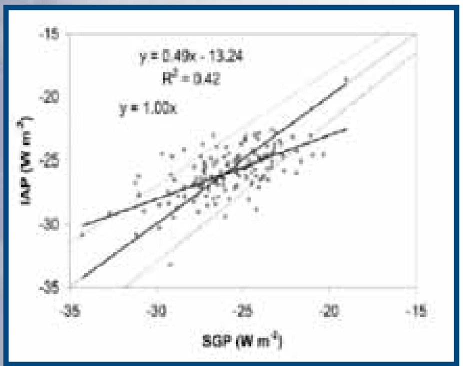
Using 2000 data from the ACRF SGP site, this distribution of cloud optical thickness reveals that the empirical method (red-dashed line) closely replicates the Min algorithm (blue-solid line).

the other hand, shortwave broadband irradiances are commonly measured, but the associated algorithms to infer cloud optical thickness require complex data about atmospheric state, not to mention considerable computer time to perform the calculations.

ARM researchers developed a simple empirical expression that gives cloud optical thickness as a function of surface albedo, broadband diffuse irradiance, and broadband "clear-sky" total irradiance. Using the Min algorithm and empirical method, the researchers calculated cloud optical thicknesses for data from 2000 for several ACRF sites. Medians of the empirical and Min-derived distributions of cloud optical thickness were within 10% of one another, and the shape of the distributions was very similar.

The empirical equation retains the flexibility of using widely available broadband measurements, and virtually eliminates the computational time consideration. However, the price for its simplicity comes with several caveats, the most important being the equation should be used only when "routine" measurements of cloud optical thickness are needed. Because long-term statistics of cloud properties are more relevant to climate studies than point-by-point comparisons at an instant of time, the empirical formula does an adequate job for these purposes. (Reference: Barnard, J.C., and C.N. Long, (2004). A simple empirical equation to calculate cloud optical thickness using shortwave broadband measurement, *J. Appl. Met.*, 43, 1057-1066.)

ARM Program Surface Measurements for Aerosol Profiles Shown to Represent Integrated Column Measurements



A comparison of forcing calculated from aircraft and SGP surface measurements suggest that integrated surface measurements are representative of the column above. Dashed lines indicated 10% difference from 1-to-1 line; solid black lines are linear regression fit.

Data from surface measurements of aerosol optical properties are used to estimate the aerosol effect on radiative forcing. How useful these calculations are depends on how well the surface measurements represent the aerosol properties in an atmospheric column. To address this problem, ARM researchers conducted an experiment to collect a data set of in situ measurements of the vertical distribution of aerosol properties (e.g., light scattering and absorption) over ACRF's highly instrumented SGP site.

Between March 2000 and March 2002, the data were obtained by an aircraft carrying instruments similar to the suite of ground-based instruments operating at the SGP site. The aircraft flew 253 vertical profile flights over the 2-year period at altitudes ranging from 500–3,500 m. These flights captured changes in hourly and daily timescales and obtained a statistically representative data set of in situ aerosol vertical profiles. In addition to comparing surface and flight measurements of the aerosol properties obtained using identical in situ instruments, the researchers also compared aerosol optical depth (AOD) calculated from the in situ flight data with AOD measured from ground-based radiation instruments at the SGP site. Comparisons of AOD calculated from the vertical profiles with other measurements of AOD made at the SGP site showed fair correlation.

The results from this experiment showed that long-term surface aerosol measurements of properties at the SGP site statistically capture the medium column aerosol properties, but may not be as representative of day-to-day variations in the column. Forcing calculations made using surface measurements were also typically within 10% of forcing values calculated using all nine levels of the profile data. The researchers concluded that surface measurements can be a reasonable substitute for integrated column measurements. These findings are important in evaluating the seasonal effects of aerosol optical properties, and the role they play in climate modeling. (References: Andrews, E., P.J. Sheridan, J.A. Ogren, and R. Ferrare (2004), In situ aerosol profiles over the Southern Great Plains cloud and radiation test bed site: 1. Aerosol optical properties, *J. Geophys. Res.*, 109, D06208, doi:10.1029/2003JD004025, and Delle Monache, L., K. D. Perry, R.T. Cederwall, and J.A. Ogren (2004), In situ aerosol profiles over the Southern Great Plains cloud and radiation test bed site: 2. Effects of mixing height on aerosol properties, *J. Geophys. Res.*, 109, D06209, doi:10.1029/2003JD004024.)

In 2004, ACRF established a new system to ease the process—especially for the scientific community outside the ARM Science Team—of submitting proposals for conducting field campaigns, or IOPs. Implemented via a website, the new system describes the ACRF and allows for online submissions. ACRF management also improved the IOP proposal, planning, tracking, and documentation processes. In addition to speeding up reviews and response time to the submitting principal investigator, these improvements ensure that IOP data are available to the scientific community in a reasonable timeframe upon completion of the campaign.

Featured Field Campaigns

ACRF users—whether sponsored by ARM or other scientific organizations—regularly conduct field campaigns to augment routine data acquisitions and to test and validate new instruments. A field campaign that is proposed, planned, and implemented at one or more research sites is also referred to as an intensive operational period (IOP), as during this time, increased activities to support additional data acquisition occur. These concentrated efforts direct focused resources on a specific research area, resulting in valuable data to further scientific understanding of cloud and radiative processes.

AIRS Water Vapor Experiment-Ground

In October-November 2003, the SGP site hosted a large field campaign, sponsored by NASA, to study water vapor in the upper troposphere. The goal of this campaign, the AIRS Water Vapor Experiment-Ground (AWEX-G), was to evaluate the accuracy of the observations from a wide variety of water vapor sensors to provide a well-characterized water vapor profile to the Atmospheric Infrared Sounder (AIRS) science team. The AIRS instrument is a high-spectral-resolution infrared instrument borne by the NASA Aqua satellite; it was launched in May 2002. Accurate water vapor profiles are critical in the validation of a variety of products being produced by the AIRS science team.

AWEX-G was modeled after the very successful ARM-FIRE Water Vapor Experiment (AFWEX, Ferrare et al., 2004, *J. Atmos. Oceanic Technol.*) in November-December 2000, before AIRS was launched. Like AFWEX, AWEX-G focused on nighttime radiosonde, Raman lidar, global positioning system, and microwave radiometer (MWR) measurements of water vapor for comparison. Instruments were operated during a three-week period of time to characterize the measurement differences of the water vapor technologies and to better understand the existing differences in the AIRS validation measurements. Radiosonde technologies evaluated included:

- Vaisala - RS80-H, RS90, and RS92
- University of Colorado - Cryogenic Frost Point Hygrometer
- Meteolabor - “Snow White” Chilled-Mirror Hygrometer
- Intermet
- Sippican

AWEX-G took place in the fall, when cloud-free conditions at the SGP are most likely to occur.

During the experiment, 56 balloons carrying 112 radiosonde packages were launched; typically, multiple packages were launched on the same balloon for comparison purposes.

In coordination with the radiosonde launches, more than 40 hours of scanning Raman lidar measurements of water vapor were acquired. The ARM Raman lidar, MWR, and a SuomiNet Global Positioning System (deployed along with the scanning Raman lidar) also ran continuously through the experiment.

Results: Analysis of the AWEX-G data set allowed the researchers to assess the accuracy of the subject radiosondes and their suitability for AIRS validation, including Vaisala RS80-H (used by the National Weather Service (NWS)), Vaisala RS90 and RS92 (used by ARM), Intermet and Sippican (used or scheduled for use by NWS), and the Meteolabor "Snow White" chilled-mirror hygrometer. From the AWEX-G data set, researchers were also able to derive and validate a calibration correction for the Vaisala radiosondes. This produced corrected data within the 10% absolute accuracy goals of the AIRS validation effort, even in the challenging measurement environment of the upper troposphere and lower stratosphere. These new correction schemes are being used in the effort to provide the best possible data for AIRS water vapor validation.

Arctic Winter Water Vapor IOP

The Arctic Winter Water Vapor IOP, a collaborative effort with the National Oceanic and Atmospheric Administration (NOAA) Environmental Technology Laboratory (ETL), took place between March and April 2004 in Barrow, at the NSA locale. The major goal of the Arctic Winter Water Vapor IOP was to demonstrate that millimeter wavelength radiometers can substantially improve water vapor and cloud liquid path observations during the Arctic winter, when conventional microwave radiometers lack the sensitivity required to accurately detect low water vapor and cloud amounts. Supplemental goals included evaluating and improving forward radiative transfer models over a broad frequency range, demonstration of recently developed calibration techniques, and application of infrared cloud imaging techniques. In addition, because the surface conditions at NSA in March are similar to those that are found at high altitudes at lower latitudes, the effort was particularly useful for studying parts of the thermal infrared spectrum that are normally opaque at the other ACRF sites.

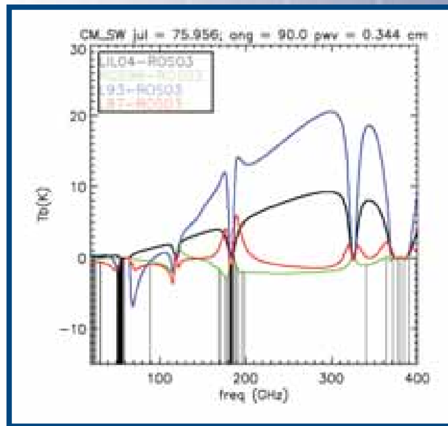
Some of the instruments collecting data during the Arctic Winter Water Vapor IOP included ARM's microwave radiometer profiler (left) and microwave radiometer (right), and NOAA's ground-based scanning radiometer (middle).

In support of the IOP, the microwave radiometer profiler (MWRP) was deployed permanently at the NSA site in Barrow. The MWRP collects continuous, real-time vertical profiles of atmospheric temperature, water vapor, and cloud liquid water from the earth's surface up to 6.2 miles into the atmosphere in nearly all weather conditions. This instrument joined a suite of other ARM and NOAA instruments contributing to the IOP, which also included daily radiosonde and in situ observations. A scanning, multi-frequency millimeter wave radiometer from ETL and an infrared sky imager from Montana State University were also deployed at the NSA site for the IOP.

During the 4 weeks of data acquisition, Vaisala RS90 radiosondes were launched four times a day from a mezzanine adjacent to the ARM duplex in Barrow, and once daily from ARM's nearby instrumentation site. In addition, 10 dual radiosonde launches (RS90 plus chilled mirror) were sent up from the mezzanine. Afternoon and early morning launches were timed to be simultaneous with NWS launches about 8 km away. In all, more than 120 radiosondes were launched in connection with this IOP.

Results: During the IOP, both the ARM MWR and MWRP, as well as ETL's Ground-Based Scanning Radiometer, yielded excellent data over a range of conditions. Angular scanned and calibrated radiometer data ranging from 22 to 380 GHz were taken. Precipitable water vapor varied more than an order of magnitude from 1 to 10 mm, and surface temperatures varied from -10 to -40 C. Data plots from the cloud radar and the depolarization micropulse lidar indicated that clearly identifiable conditions of clear, liquid, mid-level ice, and mixed-phase clouds were present during the IOP. High quality thermal images of the atmosphere were also taken throughout the IOP.

Because moisture and clouds in dry polar regions play key roles in climate feedback, development of accurate radiative transfer models requires accurate measurement of water vapor. This IOP provided a critical data set that will help improve the radiative transfer models in this spectral regime, and thus improve our abilities to retrieve geophysical quantities from these data in the future.



A comparison of various models shows large differences in water vapor measurements at various millimeter and microwave sensing frequencies.

Second Diffuse Irradiance IOP

As part of an ongoing effort to develop a working standard for shortwave diffuse horizontal irradiance, the second Diffuse Irradiance IOP (DIOP2) took place at the SGP site in October 2003. The goal of DIOP2 was to compare measurements obtained from a variety of shaded pyranometers to assess their agreement.

The diffuse irradiance measurement is the largest source of uncertainty in the total horizontal irradiance (sum of direct beam and diffuse) measurement, despite the fact that it contributes only about 10% of the total irradiance at solar noon on a clear day. Because of the lack of an absolute reference for this measurement, researchers use an assortment of the "best available" commercial and prototype pyranometers—calibrated using a reference cavity radiometer—to derive a "working" reference for this measurement. With no efforts foreseen for developing an absolute standard for diffuse measurements, the DIOP2 was conducted with the goal of developing an ARM working standard with the lowest possible uncertainty.

Pyranometers mounted on an automatic solar tracker, equipped with a shade mechanism to block the direct solar rays, provide measurements of diffuse irradiance.

The first DIOP took place at SGP in the fall of 2001. This effort revealed a consistency near the 2 W/m^2 level among more than half of the pyranometers involved. For the FY 2004 campaign, the most consistent of the first DIOP pyranometers, plus prototypes with demonstrated marked improvement, were included. During one of the clearest solar noon periods of DIOP2, all participating pyranometers were calibrated using the preferred shade/unshade technique, and were corrected for zero irradiance offsets. Fortunately, very clear and totally overcast conditions during DIOP2 allowed comparisons under these extreme sky conditions.

Results: Due to unstable and noisy signals or poor offset corrections, four of the 15 pyranometers were eliminated from the analysis. Measurements from the remaining 11 pyranometers agreed to within 2% of their mean value for a large range in irradiance levels in overcast conditions. For clear conditions, measurements from three of the remaining 11 pyranometers were 3-5% higher than the majority. Attempts to explain the differences using geometry, spectral, and angular response arguments narrowed the gap, but did not explain most of the discrepancy. Currently, the uncertainty in diffuse measurement is around 4% for all sky conditions. Additional work is needed to better characterize the candidate standards in the laboratory before another outdoor comparison is conducted.

Infrastructure Achievements

Infrastructure activities include management of site operations at the research facilities, instrumentation and engineering support, data quality and storage, and communication and education/outreach. All of these areas are key components of enabling ARM science and promoting the capabilities of the ACRF for new users.

Site Operations

Disaster Plan Deflects Problems During Downpour

A late-winter storm in the Midwest could have wreaked havoc at the SGP site in northern Oklahoma, but thanks to quick actions by site personnel, disaster was averted. SGP's 160-acre Central Facility, the heart of the site, is heavily instrumented to collect and monitor atmospheric data collected from in situ and remote-sensing instrument clusters arrayed throughout the 55,000 square mile site. Although the Central Facility is on the highest point of land in the county, extreme rainfall (6 inches in 24 hours) and flooding on March 4, 2004, rendered access roads from the East impassable to vehicular traffic, and the West access road through Lamont was submerged in several locations. Putting the site's Disaster Plan into effect, all operations personnel were safely evacuated from the site that afternoon, except for one emergency contact person to cover site security and act as liaison.

The site's Disaster Plan provides, among other things, a checklist of activities that need to be completed in an evacuation of the site. The plan not only allows for the safe evacuation of personnel, but also outlines precautionary actions for minimizing impacts to instruments, data systems, and structures. Such planning also minimizes (to the extent possible) unplanned data loss. Quick actions by site personnel ensured the safety of workers while also securing the sensitive instrumentation critical to ARM's mission of collecting long-term data for climate research. No power or data interruptions were experienced and, other than heavy precipitation on upward looking sensors, no instruments were damaged from the storm.

Military Facilities, Restricted Airspace Okayed to Support Arctic Cloud Experiment

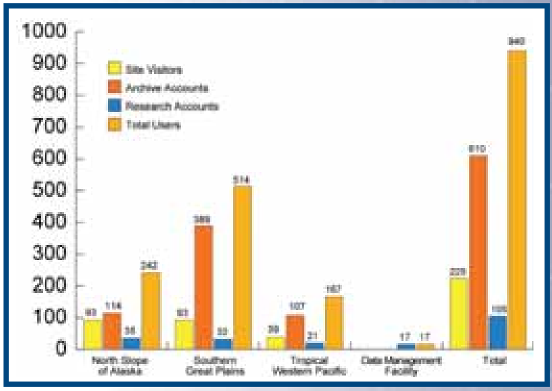
ACRF instrumentation for the experiment will be located just south of Dew Line Station, near the aircraft hangar. (Photo courtesy of Aeromap U.S.)

After more than a year and a half of planning, proposals, and paperwork, management staff at the NSA locale received permission from the U.S. Air Force (USAF) to use their facilities at Oliktok Point, Alaska, for the upcoming Mixed-Phase Arctic Cloud Experiment. In addition, the Federal Aviation Administration (FAA) granted approval for the use of restricted airspace (albeit at night) in Oliktok during the experiment. In April 2003, the first briefing to USAF officials at Elmendorf Air Force Base in Anchorage, Alaska, took place. Thus began a year of subsequent administrative actions, with approvals spanning from Anchorage to Hawaii and points in between, and concluding with a final USAF permit signed by the DOE. Gaining the necessary approvals reflected a strong commitment to cooperation between the various agencies, and represented a big step forward in preparing for the experiment.

An important part of the experimental plan included flying an instrumented, tethered balloon to make in situ measurements in the clouds while observing the same clouds from instrumentation on the ground. Oliktok Point was identified as the only place on the NSA that the FAA would agree to for flying tethered balloons in clouds. This led to the hunt for an accompanying ground-based instrument location. A commercial location was considered and rejected, leaving the USAF Oliktok Point Long Range Radar Station (also known as Dew Line Station, as shown in photo) the only option.

ACRF Achieves User Milestone Three Months Ahead of Schedule

Far exceeding the established milestone of 800 users in FY 2004, at the end of June the ACRF reported a cumulative total of 940 users for the year so far. The DOE requires its national user facilities to report facility use by total visitor days—broken down by institution type, gender, race, citizenship, visitor role, visit purpose, and facility—for actual visitors and for active user research computer accounts. For research computer accounts (or "virtual visitors"), an individual is counted only once per account, even though they may open and close an account several times to obtain data from one or more sites. However, users are counted each time they physically visit a site, because many visitors participate in multiple, unrelated experiments or events.



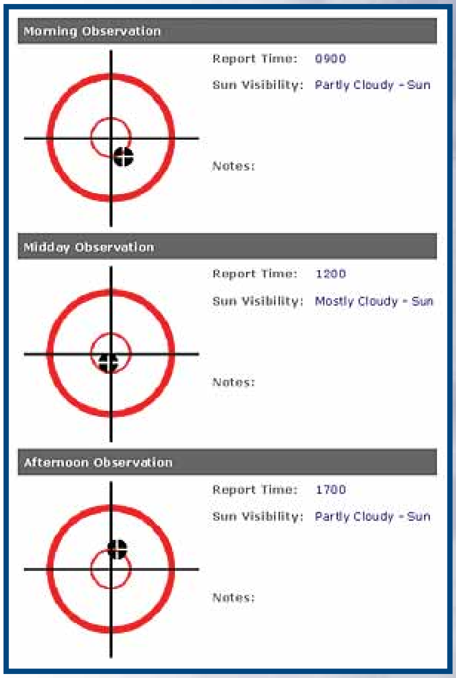
This summary of user statistics for the period of October 1, 2003-June 30, 2004 clearly shows ACRF usage far above the goal of 800 users for the year.

While the third quarter typically generates higher user activity due to actions resulting from the annual ARM Science Team Meeting each spring and the start of graduate student research projects, general user activity steadily increased throughout the year. Similarly, the volume of data storage and distribution continued to climb each month.

Instrument Enhancements

New Web Interface for Solar Tracking is Right on Target

At the TWP sites, radiometer sensors mounted on solar trackers provide critical radiation balance measurements. If a tracker is off even a small amount, the data from the diffuse radiometers and the normal incidence pyrheliometer (NIP) are worthless, and therefore the overall combined data coming from the site's other instruments is less valuable. As part of an investigation into performance problems with the trackers, local observers were asked to check and report on the trackers three times a day. Unfortunately, communication of the trackers' ability to follow the sun was somewhat subjective due to the reporting method of faxing penciled-in diagrams.



The TWP's online solar tracking feature allows the Daily Operations Coordinator to make a quick, objective assessment of tracker performance each day.

To eliminate any judgment questions inherent in reading the diagrams, ACRF software engineering developed a reporting tool that enabled the observers to enter tracker shading information directly into TWP's routine "daily rounds" report. Recently, the capability to view the tracker reports on the web (i.e., decode the shading report data and generate the corresponding web graphic) was added. This enhancement allows operators to easily note where the sunspot shadow outline from the rim of the NIP falls on the small target "bull's eye" on the tracker body, and provides a good single point measure of the overall solar tracking accuracy.

The new ECOR systems use proven technology selected on the basis of successful deployments of similar systems at SGP by other organizations.

Eddy Correlation Deployments Completed

In mid-March, the last of a series of new eddy covariance or "eddy correlation" (ECOR) systems was installed at the SGP extended facility at Cyril, Oklahoma. This completed the replacement of the original ECOR systems initiated in 2002. The new ECOR systems provide measurements of the fluxes of heat (sensible and latent), moisture, momentum, and carbon dioxide (CO_2) from adjacent crop fields or forest canopy. These measurements complement the heat and moisture flux measurements from the Energy Balance Bowen Ratio systems located at 14 SGP pasture sites, thereby filling a critical gap in the measurements of the surface energy balance over the SGP domain.

Since the first of these new ECOR systems became operational in September 2003, they have proven both reliable and accurate. In all, nine new ECOR systems were deployed, including one on the 18-meter tower at the SGP's unique forest station at Okmulgee, Oklahoma.

Inside the instrument shelter, the MMCR data system collects radar spectral data and processes these into reflectivity, vertical velocities, and spectral width.

Upgrade to Millimeter Wave Cloud Radar Increases Volume of Data Collection

In mid-April, hardware and software upgrades to the NSA millimeter wave cloud radar (MMCR) were completed. The MMCR probes the extent and composition of clouds at millimeter wavelengths. The main purpose of this radar is to determine cloud boundaries (e.g., cloud bottoms and tops). It also reports radar reflectivity of the atmosphere up to 20 km, and possesses a doppler capability that allows the measurement of cloud constituent vertical velocities. As a result of the upgrades, NSA operations staff are collecting MMCR data up to 5 times faster than the old system, as well as collecting continuous spectral data.

Hardware upgrades included replacing the OS/2 and Solaris computers with two Windows 2000 computers. One of these computers is for the MMCR radar. It now has a new digital signal processing board that allows much more efficient processing of the radar return signals, resulting in higher temporal resolution. The receiver was also upgraded from a 12 bit to 14 bit analog-to-digital converter. Software on the MMCR radar computer was upgraded to run a modified version of Vaisala's LAP-XM software for controlling and acquiring the radar data. The other computer—for managing the MMCR data—monitors the system, controls calibration, and makes the processed radar moments data available to the site data system.

The sun photometer installed at ACRF's Darwin site is similar to this one located in Tinga Tingana, Australia, as part of the AERONET. (Photo courtesy of NASA Goddard Space Flight Center)

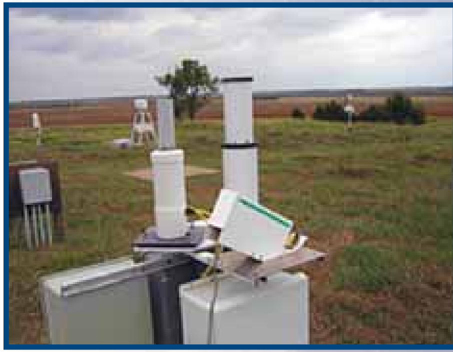
CIMEL Sunphotometer Helps Researchers See the Light in Australia

Science collaborators at the Australian Bureau of Meteorology and the Australian Commonwealth Scientific and Industry Research Organization (CSIRO) are using the ACRF Darwin site in Australia to evaluate aerosol optical properties during the tropical dry season. As part of the Darwin Aerosol IOP, a CIMEL sunphotometer was installed by CSIRO staff in mid-April at Darwin. The CIMEL sunphotometer is a sun-and-sky scanning radiometer that measures direct solar irradiance and sky radiance at the earth's surface. During the IOP, the CIMEL will allow intercomparison and validation of aerosol optical depths obtained from the multifilter rotating shadowband radiometer in routine operation at the Darwin site. In addition, sky radiance retrievals will be used to infer microphysical aerosol properties needed to evaluate aerosol radiative forcing.

In addition to the Darwin site, the ACRF TWP locale includes sites at Nauru and Manus Islands. A CIMEL has been operating at the Nauru site since May 1999 as a part of NASA's Aerosol Robotic Network (AERONET), but the ARM Program could not secure another CIMEL through AERONET for the Darwin site. The new CIMEL at Darwin is identical to the CIMEL at Nauru, but is owned by the CSIRO. Data derived from the CIMEL at Darwin is available on the AERONET at http://www.aeronet.gsfc.nasa.gov. It is expected that the CIMEL will be extracted from Darwin at the end of the southern hemisphere wet season (December) and may be redeployed as part of the Tropical Warm Pool-International Cloud Experiment in 2006.

New Narrow Field of View Radiometer Widens Range of Radiance Data

In September 2004, ACRF operations staff installed a new 2-channel narrow field of view (NFOV) radiometer at the SGP site. They also installed a repaired 1-channel NFOV radiometer that had been damaged by lightning in June 2002. Instrument output consists of a time series of 1-second observations of zenith spectral radiance. These radiance data can be used to characterize the optical properties of clouds. The 2-channel NFOV adds a 673 nm (red) measurement to the measurement at 870 nm (near infrared). The additional 673 nm radiance measurement is an important element in developing cloud optical depth algorithms and retrieval methods, particularly for broken cloud fields.



The cylindrical 1-channel (left) and 2-channel (right) NFOV radiometers are collocated with the infrared thermometer (front) at the SGP site.

Repairs to the original NFOV were completed and calibrated first, so that it could be used to check the calibration of the 2-channel version. This comparison proved to be a very valuable step, as it revealed a subtle electronics problem in the new version that caused a drift in the readings. With the problem solved, both NFOV radiometers are now collocated at the SGP site with the infrared thermometer that measures brightness temperatures at 10 μm. They are also in proximity to the microwave radiometer, which measures water vapor and liquid water. Because their fields of view overlap, the various instruments are able to obtain cloud property measurements from the same area in an atmospheric column.

Data Delivery

High-Speed Internet Service Established at Oliktok, Alaska

Thanks to a collaboration with Barrow Arctic Science Consortium (BASC), Starband satellite internet service to Oliktok Point—located on the eastern side of the NSA locale—was established to support the upcoming Mixed-Phase Arctic Cloud Experiment (M-PACE). With various modes of 50kb up/500kb down data transfer available, this new internet service—already in place at the Toolik Field Station, another locale where M-PACE research was conducted—will substantially enhance data transfer rates during the experiment. BASC provided the hardware for the link, and the service rates are inexpensive. M-PACE, scheduled to occur in early FY 2005, will provide critical measurements to aid in understanding mixed-phase (ice and water) clouds wherever they occur, leading to improvements in cloud models used in simulating global climate.

Preparations for M-PACE included establishing high-speed internet service at the surface measurements sites to enable rapid and reliable data transfer and communication.

A not-for-profit organization based in Barrow, Alaska, BASC is dedicated to the encouragement of research and educational activities pertaining to Alaska's North Slope and the adjacent portions of the Arctic Ocean. The ACRF NSA Site Manager was elected chair of the BASC Scientific Management Advisory Committee, which provides advice to the BASC Board of Directors regarding research projects, educational outreach, and management of the Barrow Environmental Observatory.

Instrument States Database Up and Running

At the three ACRF locales, more than 260 instruments and 1,500 individual sensors operate continuously to provide uninterrupted streams of data to the ARM research community. Existing principle metrics provide information on what data is or is not available, but do not explain the reason for any missing data. In early April, a new web-based information tool was implemented, greatly improving operations performance by providing the answer to "why" certain data is not available. The Instrument States Database gathers quantitative instrument information to help identify issues, set priorities, and guide decisions objectively.

The Instruments States Database gathers information from maintenance reports, shipping and receiving reports, calibration reports, and problem reports to track the operational states of instrument systems, computer systems, and facilities along with their components. Combining the diagnostic metrics gathered from the Instruments States Database with the principle metrics derived from data files delivered to the Data Archive enables users to assess what data are available and when. Because the metrics are easily accessible and clearly presented via a website, any negative trends can be quickly identified and actions taken to correct the situation in a timely manner.

Data Archive Hits Record High

April was a record month for the ACRF Data Archive, with 1.2 terabytes (or 1.2 trillion bytes) of data delivered to customers, and about 1 terabyte of data delivered and stored in the Archive. This impressive statistic represents 450,000 files retrieved—roughly double the largest previous month of data distribution! This upward trend continued throughout the year, with the average number of files delivered more than doubling last year's March-October average. At years' end, the Archive recorded an average of 239,000 files delivered each month, with a high of 1.55 terabytes of data delivered to customers in August.

The Archive supports the scientific research and field campaigns of ARM researchers and collaborators by storing and distributing large quantities of measurement data and related information collected from instruments in the field. These data are used by researchers to investigate atmospheric radiation balance and cloud feedback processes. Recent data storage increases are due to enhanced instrument systems, collection and networking systems, and data processing capacity improvements. The rise in data distribution appears to be widely spread over the available data streams.

SuomiNet-Type Instruments Tested and Ready for Tropics

ARM Program scientists are concentrating on developing techniques for obtaining the best possible water vapor measurements under a wide range of conditions (clear/cloudy, day/night, etc.). In 2001, 15 SuomiNet systems were installed at selected facilities at the SGP site to obtain these measurements (see photo). SuomiNet is an international network of global positioning system (GPS) receivers and meteorological instrument packages, configured and managed to generate near real-time estimates of precipitable water vapor in the atmosphere, total electron content in the ionosphere, and other meteorological and geodetic information. To acquire total column water vapor measurements at its TWP sites, the ACRF is deploying a similar system developed by COSMIC, including GPS and meteorological packages (from Paroscientific).

To ensure compatibility with the existing SuomiNet data processing systems, ACRF operations staff began working with COSMIC representatives in July to configure and test the systems at SGP prior to deployment to the tropics. Siting requirements, such as a clear view of the sky down to an elevation angle of 5 degrees, the need to be away from metal structures, etc., were considered in the testing. Testing was successfully completed, and installation at TWP will occur once the final setup designs and necessary operations and maintenance documents are delivered to site operations staff. Approximately one megabyte of data for each SuomiNet site will be delivered with the new system each day. These additional data will help ARM researchers quantify improvements to clear-sky radiative transfer, which are currently limited by the uncertainty in atmospheric water vapor distribution profiles.

The SuomiNet software integrates a network of global positioning systems to distribute spatially and temporally dense atmospheric data in real time from broad and diverse regions.

The COSMIC system, based on the Trimble netRS receiver, connects directly to a network, eliminating the need for a separate dedicated computer for communication and data transfer.

Communication, Education and Outreach

Kiosk Dedicated at North Slope of Alaska

In October 2003, DOE unveiled to the Barrow, Alaska community a new touch-screen kiosk that provides an interactive forum for weather enthusiasts of all ages to learn about clouds, solar energy, and climate from a cultural perspective. In partnership with the Iñupiat Heritage Center in Barrow and many community members, ACRF Education and Outreach staff developed the kiosk, entitled “Climate Change: Science and Traditional Knowledge.”

The ACRF is involved in K-12 education and public outreach activities in the communities that host the program’s data-gathering field sites. The integration of traditional Iñupiat knowledge into classroom science brings a more balanced approach to the learning environment, as students use cultural values to enhance their comprehension of science subjects.

Located in the Iñupiat Heritage Center museum, the kiosk presents general information on climate change for the casual museum visitor, as well as more in-depth interactive modules for K-12 students.

WeatherFest Draws Public Interest; Display Informs Scientific Community

Involvement at the 84th Annual American Meteorological Society Conference kicked off with participation in WeatherFest on Sunday, January 11. Geared toward the general public, this free, four-hour science and weather day featured hands on demonstrations, videos, and experiments. Education and Outreach staff

Kids and adults who attended WeatherFest were invited to participate in a demonstration showing the concept of air pressure.

On May 12, 2004, www.arm.gov received this new look. From planning to implementation, rolling out the new website across 3 servers and 7 databases took the help of an estimated 22 people, including 12 developers and server administrators from coast to coast.

spent the day answering questions, discussing lesson plans, and inviting visitors to take part in a hands-on experiment.

For the remaining four days of the conference, held in Seattle, Washington, Communications team members hosted a display booth in the event's exhibit hall. Information available at the booth included printed materials, CDs, and interactive kiosks. When not in session, ARM researchers rotated in and out of the booth throughout the conference to address questions from science collaborators and other interested visitors.

Website Redesign Rolled Out

In early FY 2004, the ARM Communications team began working hard to restructure the existing website to meet ARM, ACRF, and general audience needs. Since the website was originally developed almost 10 years ago, information about the Program had become more complex. Also, the content was out of date given the decision to designate ARM infrastructure a national user facility. In May, the new look was rolled out. Through the redesign, the site was restructured to represent both ARM Science and ACRF infrastructure activities. In addition, it provided an opportunity to reduce redundancy, apply consistency, and improve overall site content.

Following the initial rollout, another key area of the website was subsequently revamped and went online in August. The new Education webpages include updated content and a fresh look to complement the Program website redesign effort. Specifically, this area of the website was divided into three specialized and easy-to-navigate sections: Homeroom, featuring information about ACRF education and outreach efforts; Study Hall, a resource for students; and Teachers Lounge, containing sample lesson plans, activity ideas, and valuable background information for educators.

EarthStorm Lands Near SGP Site

In July, the SGP Educational Outreach Program hosted an EarthStorm Weather Institute for Teachers at the University of Oklahoma's Sarkeys Energy Center in Norman. In the EarthStorm Weather Institute, meteorologists from the Norman area and educators from neighboring states shared ideas and resources for teaching meteorological concepts, establishing long-term associations supporting science education. The free 4-day workshop gives K-12 teachers an opportunity to investigate weather and improve their skills in preparing students to design and implement science fair projects. The SGP Educational Outreach Program is administered by and in partnership with the Oklahoma Climate Survey, the University of Oklahoma (with funding from ARM), and the Oklahoma Mesonet.

FY 2004 Field Campaigns

Dates	Name	Status	Description
North Slope of Alaska			
March 2001 - April 2004	Russian Ice Station Comparison	Completed; awaiting data	An intercomparison was conducted between the Russian radiometer suite (similar to the suite used at the Russian ice stations between the early 1950s until the early 1990s), and the current ARM (and NOAA/CMDL) radiometric instruments. The resulting data set from this intercomparison will enable ARM to gather climatologies for the Arctic basin back to 1950, which will be extremely valuable for assessing performance of global climate models in the Arctic.
January - August 2004	Extended Range Atmospheric Emitted Radiance Interferometer (AERI-ER) Intercomparison IOP	Completed	This intercomparison was conducted to verify the reproducibility of calibration on the Atmospheric Emitted Radiance Interferometer-Extended Range (AERI-ER) and to identify the source of a small (~1 mW / (m2 ster cm-1)) bias identified in AERI-ER data in clear-sky, low precipitable water vapor situations. To meet these objectives, two AERI-ER systems (one provided by the University of Wisconsin) were operated side-by-side at the NSA site in Barrow for a 6-week period during the cold, dry season. Preliminary results indicate the AERI-ER calibration can be reproduced using an out of band correction procedure, however the bias in clear, dry conditions remains unresolved.
March - April 2004	Arctic Winter Water Vapor IOP	Completed; awaiting data	During this IOP, well-calibrated radiometers were deployed over a broad frequency range (18 to 380 GHz), including several channels near the strong water vapor absorption line to demonstrate that millimeter wavelength radiometers can substantially improve water vapor observations during the Arctic winter. The radiometers were supplemented by 4-times-daily radiosonde observations and other in situ observations. Secondary goals of this campaign include forward model studies over a broad frequency range, demonstration of recently developed calibration techniques, the comparison of several types of in situ water vapor sensors, and the application of infrared imaging techniques.
April - September 2004	AIRS Validation Soundings Phase III (Also conducted at SGP and TWP)	Completed; awaiting data	Because the global distribution of water vapor is important for climate simulations, the objective of this field campaign is to demonstrate and quantify the accuracy of the water vapor retrieval algorithms of the Atmospheric Infrared Sounder (AIRS) instrument. Additional radiosonde launches from TWP are being timed to coincide with overpasses of NASA's Aqua satellite carrying the AIRS sensor for the purpose of providing in situ validation data for development and testing of AIRS water vapor retrievals. This is a user support activity with funding provided by the user.
November 2003 - February 2004	AIRS Validation Sonde Support (Also conducted at SGP and TWP)	Completed	In support of validation studies for the AIRS instrument aboard NASA's Aqua satellite, a special series of radiosonde launches were completed. The AIRS instrument is intended to make highly accurate measurements of air temperature, humidity, clouds, and surface temperature. The data collected by AIRS will be used by scientists around the world to better understand weather and climate.
Southern Great Plains			
May-August 2003, April-August 2004	Mesoscale Convective System	Completed; awaiting data	This experiment seeks to use profiler data from SGP's Central Facility to document the vertical wind and buoyancy field, as well as the microphysical characteristics of precipitation within convective systems, and to compare characteristics with similar analyses performed in tropical convection. These data also provide profiles of the mass flux and microphysical characteristics of the precipitation within the convection. These fields represent major issues for cumulus parameterizations and explicit microphysical schemes used in the present generation of atmospheric models.
October 2003	Second Diffuse Irradiance IOP	Completed; awaiting data	The goal of this effort was to develop a consensus reference standard for shortwave diffuse horizontal irradiance, because no absolute reference currently exists. The first diffuse horizontal irradiance comparison (in fall 2001) revealed a consistency near the 2 W/m2 level among more than half of the pyranometers used. This second comparison used the most consistent of the first-round comparison pyranometers, plus some prototypes that have demonstrated marked improvement. Emphasis was placed on the calibration of pyranometers with a clear tie to the World Radiometric Reference.
October 2003	Spectral Liquid and Ice Comparison	Completed; awaiting data	Near-infrared spectral measurements of scattered sunlight will be used to retrieve path-integrated liquid and ice water paths from clouds at the SGP site. These retrieved values will be compared to similar quantities retrieved from the AERI instruments (for optically thinner clouds) and the microwave radiometer (for optically thicker clouds) to validate a new technique. This technique uses the spectral signatures of liquid and ice absorption in the near-infrared to measure the path-integrated liquid water path and ice water path.

June-October 2004	WSI Stereoscopic Experiment	In Progress	Shallow convection and periods with contrails are not well-sampled by ARM vertically pointing sensors. Within the European Commission project CLOUDMAP2, the Institute of Geodesy and Photogrammetry, ETH Zurich, developed new methods for retrieving cloud-base height from at least two sets of ground-based imager observations. To test the applicability of this approach with Whole Sky Imager (WSI) instruments, a second WSI was deployed at the SGP site with a horizontal distance of about 500 m from the operational WSI. In collaboration with ARM, ETH will analyze selected WSI stereo cases, especially broken-cloud conditions such as shallow convection and periods with contrails.
February 2004	Surface Albedo IOP	Completed; awaiting data	The purpose of this field campaign was to (a) collect surface albedo spectra for representative surface types in the SGP locale, (b) gather information useful for conducting surface type classification from aerial/satellite remote sensing data, and (c) develop the detailed spectral model of surface reflectance over the SGP site for winter conditions. This information is required as boundary conditions for radiative transfer modeling, cloud and atmospheric dynamics modeling, carbon and hydrological studies, and remote sensing studies.
April-May 2004	WB57 Midlatitude Cirrus Cloud Experiment	Completed; awaiting data	To address specific issues related to the basic properties of mid-latitude cirrus clouds, NASA's WB57F research aircraft—instrumented with a new suite of cloud property probes—conducted several flights over the SGP Central Facility to gather data above ARM remote sensors. These data will allow for validation and improvement of existing and emerging cloud property retrieval algorithms.
April-August 2004	2004 Precision Gas Sampling (PGS) Validation	Completed; awaiting data	Ecosystem-atmosphere exchange of carbon, water, and energy varies with climate, soil, and land management, in ways that (a) influence the carbon dioxide (CO_2) flux and planetary boundary layer CO_2 concentration and (b) can be modeled and predicted. To test model predictions, measurements of these properties are necessary. The original PGS validation activity in 2001 obtained measurements of carbon, water, and energy fluxes in fields surrounding the SGP Central Facility. The 2004 effort continues those measurements, and extends the spatial campaign to a site northwest of the SGP that receives roughly 50% less precipitation than the Central Facility.
October-November 2003	AIRS Water Vapor Experiment – Ground (AWEX-G)	Completed	Uncertainties associated with the calibration of water vapor instrumentation used in the Aqua validation effort limits the usefulness of these validation data, especially for AIRS radiance validation and, to a lesser degree, for Aqua retrieval validation. To address these instrument calibration issues and acquire a high-quality ground-based set of measurements for radiance validation, the AWEX-G field campaign was conducted to coincide with the radiosonde launches occurring for AIRS validation at the SGP site. Additional radiosondes were launched during daytime and night-time overpasses of the Aqua satellite for comparison with AIRS radiances. Scanning Raman lidar measurements of water vapor were performed during the nighttime overpasses.
Tropical Western Pacific			
September 2003- November 2004	Darwin Aerosol IOP	In Progress	A CIMEL sun/sky radiometer was deployed at Darwin for the 2004 dry season. This deployment allows for intercomparison and validation of aerosol optical depths previously obtained from the multifilter rotating shadowband radiometer operated at Darwin. In addition, sky radiance retrievals will be used to infer microphysical aerosol properties needed to evaluate aerosol radiative forcing.
Off Site Campaigns			
July-August 2004	Pennsylvania Aerosol Campaign	Completed; awaiting data	A multi-program aerosol and air quality study was conducted this summer that ranged from the Ohio Valley area to the Atlantic. As part of an aerosol properties characterization study on the upwind edge of this domain, a ground station was installed about 60-100 km northeast of Pittsburgh. Meteorological sounding instruments, such as a radar wind profiler and radiosonde station, were deployed, as well as instruments to measure light scattering and absorption and elemental and organic carbon. A Gulfstream G-1 aircraft also made soundings over the surface site for comparisons of in situ and remote sensing data. ACRF instrumentation deployed in support of this campaign included a scanning micropulse lidar (to profile backscatter and extinction) and multifilter rotating shadowband radiometer (to determine aerosol optical depth).

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For more information, contact:

Wanda R. Ferrell, Ph.D.
ARM Program Manager
301.903.0043
wanda.ferrell@science.doe.gov

www.arm.gov

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