Site Science for ARM Mobile Facility #1 (AMF#1)

This report documents progress on DOE Grant# DE-FG02-08ER64531 funded by the Department of Energy's Atmospheric Systems Research (ASR) program covering the period between its inception in 2008 and its conclusion in 2014. The Atmospheric Radiation Measurement (ARM) Program's Mobile Facility #1 (AMF#1) is a collection of state-of-the art atmospheric sensing systems including remote and *in situ* instrumentation designed to characterize the atmospheric column above and in the immediate vicinity of the deployment location. The grant discussed in this report funded the activities of the AMF#1 Site Scientist Team. Broad responsibilities of this team included examining new deployment sites and recommending instrument deployment configurations; data quality control during the early stages of deployments and for certain instruments through the course of the deployment; scientific outreach in the host country or location (particularly international deployments); scientific research oriented toward basic questions about cloud physics and radiation transfer in the deployment region; and training of Ph.D. students to conduct future research relevant to the Atmospheric Systems Research (ASR) program.

The final two years of the grant also included the responsibility of stewarding activities related to the spin-up of the Eastern North Atlantic (ENA) fixed site, which followed the AMF#1 deployment on Graciosa Island during CAP-MBL (described in a later section).

Below is a list of "scientific highlights" and publications generated as a direct consequence of DOE Grant# DE-FG02-08ER64531. Three additional publications in 2016-2017 are expected and are listed beneath those already published or in-press. Following this list is a description of the deployments that occurred during the course of the grant, a list of specific outreach efforts conducted during the course of two deployments, and a partial list of presentations.

Scientific Firsts

- Direct measurement of the cross-atmosphere radiative flux divergence on a scale compatible with cloud development (15 minutes)
- Comparison of Cloud Radiative Effects (CRE) observed over the West African Sahel with CRE produced by two IPCC AR4 Global Climate Models
- Characterization of the Diurnal Cycle of CRE in the West African Sahel and Amazon Rainforests
- Statistical surveys of Eastern North Atlantic shallow cumulus vertical velocity, radar reflectivity and mass flux characteristics

- Statistical comparisons of shallow cumulus vertical velocity, radar reflectivity and mass flux characteristics from the Eastern North Atlantic, Southern Great Plains, and Tropical Western Pacific
- Comparisons of cloud structural elements, thermodynamics, and radiation characteristics from multiple stratocumulus regimes
- Study showing the importance of mixing (adiabaticity) in the implementation of the aerosol first indirect effect.

Publications

The PI's name is highlighted in black and author names annotated in red indicate funded Ph.D. students and Research Associates.

[24] Collow, A.M. and **M.A. Miller**, 2016: The seasonal cycle of the radiation budget and cloud radiative effect in the Amazon rainforest, *J. Climate* (accepted)

[23] Collow, A.M., **M.A. Miller**, and L. Trabachino, 2016: Cloudiness over the Amazon rainforest: meteorology and thermodynamics, *J. Geophys. Res.* (accepted)

[22] Martin, S., P.Artaxo, L.Machado, A. Manzi, R. Souza, C. Schumacher, J. Wang, J. Brito, J. Brito, K. Jardine, A. Medeiros, de Sa, S., Biscaro, T., Calheiros, A., Portela, B., **M.A. Miller**, and co-authors, 2016: The Green Ocean Amazon Experiment (GoAmazon2014/15) observes pollution affecting gases, aerosols, clouds, and rainfall over the rainforest, *Bull. Amer. Met. Soc.* (accepted)

[21] Ghate, V.P., **M.A. Miller**, and B.A. Albrecht, 2015: Similarities and Differences between Cumulus Topped Marine Boundary Layers, *Monthly Weather Review* (accepted).

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Additional Manuscripts to be submitted in 2016 that resulted from work completed during the course of the grant

[3] Trabachino, L.C., M.A. Miller, M.P. Jensen, and T.Toto, 2016: High-resolution thermodynamic profiles for atmospheric model evaluation, *J. Clim and Appl. Met*., (submission September 2016)

[2] Trabachino, L.C. and M.A. Miller, 2016: The significance of convective cloud microphysics for climate model simulations of rainfall in the West African Sahel at seasonal time scales, *J. Clim.*, (submission October 2016)

[3] Kafka, J., M.A. Miller, V.P. Ghate, and K. Lamer: Thermal structure in the clear convective continental boundary layer (title subject to change-December 2016)

Description of AMF#1 Deployments

The initial deployment of the AMF1 took place at Point Reyes, CA between March and September 2005 in support of the Marine Stratus, Radiation, and Drizzle (MASRAD) experiment proposed by the PI while in residence at the Brookhaven National Laboratory, which was designed to sample coastal marine stratocumulus clouds and serve as a burn-in for the new system. Pt. Reyes National Seashore was chosen as the initial deployment location because it was a long, linear coastline nearly orthogonal to the mean northwesterly wind direction that carried marine stratocumulus inland. The National Park Service had helped identify potential deployment locations for the new AMF1 that met the noise restrictions and visual standards for a National Park. A standard suite of ARM instruments were deployed along with a 95 GHz cloud radar borrowed from the University of Miami.

Figure 1. The AMF1 in its initial deployment at Pt. Reyes, California in 2005. It was housed in four shipping containers and included 30 instruments.

RADAGAST

The initial winning AMF1 proposal was submitted by Anthony Slingo who proposed an experiment using the AMF1 to be conducted in West Africa as part of a larger, multi-year experiment known as the African Monsoon Multidisciplinary Analysis (AMMA). The RAdiative Divergence using AMF1, GERB and AMMA STations (RADAGAST) served as an embedded component of AMMA. West Africa was the second deployment location for the AMF1 and was the first real test of the concept.[1]

Just as MASRAD was beginning in Pt. Reyes, California, an AMF#1 advance team including the PI traveled to Niamey, Niger, Africa to find a location where the AMF1 could be deployed in support of RADAGAST. Niger exposed many of the challenges that would be faced when deploying in underdeveloped regions. The PI visited the US Embassy and three different governing agencies during its initial trip to Niger and struggled to understand which of these

[1] Miller and Slingo, 2007; contains an image of the deployment

agencies controlled the airport where it seemed obvious that the AMF1 had to be deployed. The airport had generator power and security and its landscape was similar to the surrounding Sahelian landscape except for its single runway. Eventually, the airport was made available for the deployment and the AMF1 arrived via a Boeing 747 cargo jet. Some months after the advance team's trip to Niamey and the AMF1 deployment planning was in full swing, the PI attended a planning meeting for AMMA in Dakar, Senegal.

It had been suggested by the PI during the initial site survey that an ancillary site that collected basic radiation and surface meteorological measurements be established away from the airport to help assess the regional representativeness of the AMF1 deployment location. As a result, a small, solar powered site was established near Banizoumbou, Niger in a radiatively natural environment.

The RADAGAST deployment was extremely successful and there is no question that this deployment is one of the most significant achievements of the ARM and AMF1 program[2]. The only setback in the deployment was that the AMF1 cloud radar was still under construction during the first three months, but this period was during the dry season when clouds were less prevalent over the Sahel. The RADAGAST deployment produced the first cross-atmosphere radiation budget on a time scale compatible with cloud development (15 minutes) and the first comparison of this budget with simulations from GCMs.[3]

The Convective Orographic Precipitation (COPS) Experiment

Germany has experienced has a serious problem with flash flooding in the Black Forest region. Models had failed to forecast major flash flooding events that had resulted in significant losses of life and property and there was a basic lack of understanding of the organizing principals of the convection that was responsible. A proposal submitted by Volker Wulfmeyer to simultaneously collect data from aircraft and the AMF1 in the Black Forest region during the formative stages of convection was selected by the ARM Science Board.

The AMF1 was again embedded in a large international experiment and its mission was to address the nature and structure of orographic flows and the microphysical morphology of associated convection. The plan included contributions from scientific groups in Germany who deployed instrumentation such as a scanning Doppler lidar and several specialized microwave radiometers alongside the AMF1. The expanded capabilities that were provided by these guest instruments served as a blueprint for the development of AMF1 over the next few years. It was operated in the Black Forest for one year in concert with an array of sensors within a dense COPS network. The data collected captured the position and characteristics of convergence zones and other convective initiation processes and how they related to the resulting convection.[4] It was found that flows

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[2] Slingo et al., 2006, Miller and Slingo, 2007; See JGR Special Issue: First Results from the RADAGAST Experiment

[3] Miller et al., 2012

[4] Wulfmeyer et al. 2008 (contains image of deployment)

induced by orographic forcing and channeling were the principal mechanisms that initiated convection. It was also discovered that these flows strongly modulated the precipitation distributions within and downstream of the COPS domain. Observations also showed that the latent and sensible heat fluxes in the COPS domain were primarily driven by vegetation rather than by soil moisture, which was erroneously serving as the dominant driver of these fluxes in mesoscale models.

The Study of Aerosol Indirect Effects in China

The scientific rationale for the AMF1 deployment in China evolved from curious satellite observations. Evidently, liquid clouds in southeastern China contained much more liquid water than liquid clouds with the same thickness in other parts of the world. Zhanqing Li and Graham Stevens hypothesized that these clouds were potentially subject to the second aerosol indirect effect[5]. This effect was based upon a hypothesis suggesting that clouds formed in polluted regions produced precipitation less efficiently than in pristine regions. This encumbrance was thought to have increased cloud liquid water over southeastern China. But validation of these satellite observations was required to confirm that the second aerosol indirect effect was the culprit. Such a validation required a state-of-the-art remote sensing system, so Zhanqing Li submitted a successful proposal to deploy the AMF1 in the vicinity of Lake Taihu, which is a large lake in southern China. Proximity to this lake was important because it could be used to assist in the interpretation of accompanying satellite measurements.

While modern China was beginning to embrace western science, it was unclear if the geopolitical boundaries were relaxed enough to allow for scientific measurements of this type sponsored by the US DOE. Furthermore, the experiment plan was complicated and called for three measurement sites: the AMF1 itself, an ancillary facility borrowed from NASA that was deployed at the edge of the Taklimakan Desert in northwest China, and a small collection of instruments situated near Beijing, which hosted the Olympic Games during the same year as the AMF1 deployment.

A key issue at Taihu was the ability to launch radiosondes in proximity to a Chinese Military base, which was nearby. Upon return to the US, the advance team learned a few weeks later that the request to launch radiosondes at Taihu had been declined. This event required switching to a contingency plan, but this setback was one of many. A few nearby locations were suggested by the Chinese government, but none were optimal for an AMF1 deployment. Finally, a site near Shouxian, which is 500 km west of Shanghai was chosen. It was small and the AMF1 had to be deployed in a compressed configuration. An ancillary site at Taihu that consisted of a microwave radiometer, surface radiometers, and surface meteorology was established, since the radiometer was a passive sensor and provided some limited information about the atmospheric column.

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[5] Albrecht, 1989

Before the AMF1 instrumentation was to be deployed, a data transmission and sharing agreement was with the Chinese Government. Normally, AMF1 data were transmitted daily to a Data Management Facility (DMF) in the US and, shortly thereafter, to the ARM Archive. This was not consistent with Chinese data sharing policy, so concessions were necessary. It was mutually agreed that data would be supplied directly to the Chinese government who would inspect it and, ultimately, release it to the DMF. Unfortunately, this agreement led to a sequestration of AMF1 data in China for nearly the entire deployment, but a more restrictive limitation was the prohibition of any internet connectivity to the AMF1 instrumentation. This precluded the usual ARM quality assurance process. Shortly after the AMF1 began operating in China, its cloud radar failed and was shipped back to the US for repair. As a result, only two months of cloud radar data were collected during the autumn of 2008. Sadly, observations of the low stratus liquid clouds, which were desired to satisfy the scientific objectives of the deployment, were virtually absent from the cloud radar data, though an analysis of these data in conjunction with radiosonde data was used to produce a cloud climatology.[6] The wealth of general and specialized measurements that were collected using AMF1 in China in combination data collected by coincident programs has led to successful investigations of the optical, physical, chemical, and cloud nucleating properties[7] of anthropogenic, natural, and mixed aerosols and interactions with the East Asian monsoon system.[8]

Inasmuch as the deployment in Africa was a crowning achievement of the AMF1 program, the AMF1 deployment in China was limited by geopolitical and logistical considerations. On the bright side, the development of new scientific partnerships may have opened the door for additional scientific collaborations with China.

Clouds, Aerosol and Precipitation in the Marine Boundary Layer (CAP-MBL)

There was a general consensus that varying depictions of the cloud feedbacks associated with boundary layer stratocumulus clouds in Global Climate Models (GCMs) were partly responsible for the spread in predictions of global warming. As a consequence of their large areal coverage on the Earth's surface, their radiative feedbacks must be accurately portrayed in GCMs, and the original plan for ARM fixed sites had included a marine boundary layer site in the Azores.

Recognizing the need for long term and comprehensive measurements of marine stratocumulus clouds, Robert Wood had proposed the CAP-MBL experiment and his proposal had been approved. Earlier surface-based remote sensor measurements collected during ASTEX from the islands of Santa Maria and Terceira laid the groundwork for the CAP-MBL experiment and the ARM program in general. Island effects had been documented during ASTEX[9] and had been linked to the significant terrain on the island of Santa Maria, which implied that Graciosa Island

[6] Zhang et al., 2010
[7] Liu et al., 2011
[8] Li et al., 2011
[9] Miller and Albrecht, 1995

in the Azores was a preferable location for an AMF1 deployment. It was smaller in size, had lower terrain, was slightly farther north than the islands used during ASTEX, and it had a small airport.

Data collection began on Graciosa in May 2009. A few months after AMF1 data collection began at Gracisa, it became clear that marine stratocumulus clouds were being observed in a new light. The AMF1 provided a new level of detail about the diversity of marine clouds over the north central Atlantic Ocean. So encouraging were these initial data that Robert Wood submitted a second proposal to the ARM Science Board to extend the deployment for an additional year. Perhaps having sensed the pent up demand for these data, ARM accepted Dr. Wood's follow-up proposal and the CAP-MBL deployment was extended for an unprecedented second year[10]. During this extended deployment period, the ARM program tested a new scanning cloud radar at Graciosa.

Many years prior to the AMF1 deployment an International Chemical Observatory (ICO) station had been established at 2225 m above sea level on the summit caldera of Pico Mountain. The ICO had collected trace gas and related data during the summer for many years and the PI submitted a proposal to ARM to deploy radiometers in coincidence with the ICO site. The scientific objective of this deployment was to measure the radiative fluxes and aerosol optical thickness above marine boundary layer clouds and thereby provide a constraint to be used in conjunction with surface radiation measurements from the AMF1 at Graciosa to directly measure the cloud optical thickness in broken cloud fields. There was no road to the top of Pico, only a narrow, steep trail. So the AMF1 technician, Carlos Sousa, carried a small radiation platform on his back to the peak and installed it during the summer of 2010. This system provided extremely unique data and had demonstrated the cleanliness of the air mass above Pico, which rivaled the low aerosol loads observed at Mauna Loa.

As always, there were a few problems. The most significant was the loss of the Atmospheric Emitted Radiance Interferometer (AERI) for most of the CAP-MBL deployment. The AERI provided invaluable, nearly continuous information about the details of infrared emissions and the thermodynamic profile. This information was a crucial supplement to radiosonde data and was used to measure the liquid water content of extremely thin clouds. Another problem discovered after the deployment ended was that the rainfall measurements at Graciosa were biased. This bias was due to improper mounting of the optical rain gauge and the present weather detector. An investigation by Mark Miller's research team revealed that the instrument mounting was altered to accommodate the deployment in Shouxian, China. When the system was shipped to Graciosa, an operations team comprised of some new members reconstructed the configuration that they had disassembled in China rather than reverting to the original, correct configuration. The lesson learned in light of the rain gauge mounting issue was configuration control: when changes were

[10] Wood et al. 2014 (contains image of the site)

made to the deployment configuration to accommodate a peculiarity they had to be carefully recorded and reversed during the following deployment.

Results from CAP-MBL altered some traditional views of stratocumulus clouds and of the marine boundary layer clouds over the Eastern North Atlantic (ENA) in general. The first long-term study of the climatology of cloud structure and its links to drizzle demonstrated that stratocumulus clouds with a depth exceeding 250 m and a liquid water path exceeding 60 gm^{-2} produced drizzle over the ENA.[11] Known mesoscale circulations in marine stratocumulus, termed mesoscale cellular convection, were implicated as being partly related to air mass type. Cold air outbreaks over the ENA were linked to high concentrations of a certain type of mesoscale cellular convection (open cell), which is, in turn, was shown to be associated with reduced pollutant loads. Comparisons of the morphology of marine stratocumulus observed at ENA with those observed over other parts of the world had exposed differences in the thermodynamic environments in which they formed.[12] And the first measurements of the updraft mass flux in a large population of small marine cumulus clouds provided new information about cumulus dynamics.[13]

The Ganges Valley Aerosol Experiment (GVAX)

The Indian Monsoon was the lifeblood of India because it supplied rain for agriculture and snowfall to the Himalayas that eventually melted into freshwater that supplied many of India's rivers. There were known and hypothesized links between the Indian Monsoon and other important atmospheric circulations. And economic growth in India produced a juxtaposition of this monsoon circulation and the byproducts of manufacturing in northern India, which included large quantities of highly absorbing black carbon aerosols. In addition to the obvious health issues caused by this black carbon, it had been thought to deposit on snow surfaces in the Himalayas thereby reducing the snow's albedo and potentially altering the dynamics of the Indian Monsoon. Measurements were needed to evaluate the impacts of black carbon in the region.

Rao Kotamarthi submitted a successful proposal to the ARM Science Board that outlined a plan to obtain measurements of clouds, precipitation, and complex aerosols and study their impact on cloud formation and monsoon activity in the vicinity of the Ganges Valley. The experiment plan combined aircraft measurements collected over the valley itself with AMF1 measurements from the nearby foothills of the Himalayas. The Aries Astronomical Observatory located high on a mountain near the mountain resort city of Nainital, India was selected as the AMF1 deployment site for GVAX. The AMF1 was positioned at a location and height enabled measurements of aerosols spilling through the foothills into the snow-covered peaks of the Himalayas.

The GVAX experiment began in June 2011. Its scientific objective was to measure clouds, precipitation, and complex aerosols to study the relationship between the aerosols, cloud

[11] Rémillard et al., 2012
[12] Ghate et al., 2014
[13] Ghate et al., 2011

formation, and monsoon activity in the region. Siting and logistical difficulties prevented the vertically pointing cloud radar and a new dual-wavelength scanning cloud radar from being deployed, but two important new instruments were added: a scanning Doppler Lidar and a solar spectrometer. The AMF1 was deployed in support of a planned aircraft campaign in the Ganges Valley with AAF[14] aircraft to have served a pivotal role in the experiment, but ARM was denied flight clearance US research aircraft. Indian research aircraft surveyed pollution in the Ganges Valley, but lack of AAF support was a serious detriment to GVAX. As in the deployment in China, data were sequestered by the Indian scientific agencies. This caused a significant delay in data access, but all data collected were released at the conclusion of the experiment.

The Two-Column Aerosol Project (TCAP)

The principal theme of the TCAP campaign proposed by Carl Berkowitz and Larry Berg was to quantify the impacts of aerosol mixing state and optical properties upon aerosol radiative effects. To meet these scientific objectives, AMF1 and the Mobile Aerosol Observing System were deployed on Cape Cod, Massachusetts for one-year beginning in the summer of 2012. These observations were supplemented by two aircraft intensive observation periods (IOPS), one during the summer of 2012 and a second in the winter. Each IOP required two aircraft.

The AMF1 was deployed at a site along the Cape Cod National Seashore along the bluffs near North Truro, Massachusetts and data collection began on July 22, 2012. The experiment, while still in the analysis phase, was extremely successful, and initial results suggested that the experiment objectives were met.[15] In addition, the TCAP deployment marked another critical turning point in the history of the AMF program because several new cutting-edge instruments purchased through the American Recovery and Reinvestment Act (ARRA) were deployed. Prominent among these instruments was a scanning microwave radiometer and a scanning Ka-W band dual wavelength cloud radar that complemented the existing vertically-pointing W-Band cloud radar. The addition of these scanning systems marked a quantum leap in the observation footprint of AMF1 from its original soda-straw-like column view.

GOAmazon2014-15

The Green Ocean Amazon 2014-2015 experiment was proposed by Scot Martin and the AMF1 is currently deployed in a pasture surrounded by Amazonian jungle near the river village of Manicapuru, Brazil (Figure 2). The experiment is designed to study how aerosol and cloud life cycles are influenced by pollutant outflow from a tropical megacity. A main objective of the experiment was to examine the interplay between biogenic and anthopogenic aerosols.

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[14] See Schmid

[15] Titos et al, 2014, Kassianov et al., 2013

Figure 2. The deployment of AMF1 near Manicapuru, Brazil in 2014 in support of GOAmazon2014-15 (includes the Mobile Aerosol Observing Site, which is currently deployed alongside AMF1).

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Description of Outreach Efforts

Extensive scientific outreach activities were conducted in association with the deployments in the Sahel region of West Africa (during RADAGAST), the Azores (CAP-MBL), and GOAmazon2014/15. The initial two activities involved seminar talks given by the PI to an audience of stakeholders, and the latter involved a student workshop and site tour involving US and Brazilian Graduate Students.

Selected Presentations

2014 -The Climate of the West African Sahel: A Perspective from Observations, Global Climate Models, and the Drinking Water Adviser (**invited**, NASA Goddard Institute for Space Studies, May 30, Manhattan, NY)

2013 - St/Sc/Cu Cloud Processes Breakout Session, Charter and Overview of Low Cloud Science, ASR Science Team Meeting, Potomac, Maryland, March 21
- Clouds and Climate: New Strategies to Address Old Questions (**keynote speaker**, 50th Anniversary Meeting of the Korean Meteorological Society, April 18, Seoul, Korea)

2012 - Unraveling the Life Cycle of Low Clouds (**invited**, ASR Working Group Meeting, November 1, Rockville, MD (V. Ghate presented)
- Cloud and Radiative Effects over West Africa using a Top-Down, Bottom-Up Approach (**invited**, Brookhaven National Laboratory, June 5, Upton, NY)

2011 - On the Real and Simulated Life of Photons over the West African Sahel-Rutgers University, November 18
- Morphology and Dynamics of Non-precipitating Marine Fair Weather Cumulus Clouds, V.P. Ghate and M.A. Miller (**invited**, ASR STM, Miller presented)

2010 -Integrity of Global Climate Model Simulations of the West African Climate
- -Lamont-Doherty Observatory of Columbia University (**invited**)
- -University of Illinois (**invited**)
- -Purdue University (**invited**)

2009 - On the performance of the IPCC and NCAR climate models in West Africa (**invited**), Atmospheric Systems Research (ASR), Cloud Modeling Working Group Meeting, September 29, Boulder, CO.
-To See or Not to See: Adventures in Visibility (**invited**), Federal Aviation FAA Team Aviation Safety Seminar, May 19, Middletown HS South.
- Miller, M.A. Controls on the Atmospheric Radiative Divergence Budget in West Africa, 3rd International African Monsoon Multidisciplinary Analysis Conference, July 20-24, Ouagadougou, Burkina Faso, Africa (presentation by P. Lamb)

-RADAGAST Reprise: new results from West Africa, (**invited**), ARM Science Team Meeting, Louisville, KY, April 2.
-AMF MBL-CAP Site Selection: Clouds, Aerosol, Precipitation in the Marine Boundary Layer (CAP-MBL) Breakout Session, ARM Science Team Meeting, Louisville, KY, (April 2).
-An AMF Ancillary Site on Pico Island, Azores:MBL-CAP Breakout Session, ARM Science Team Meeting, Louisville, KY (April 2)
-Cloud Properties Working Group Meeting: shallow convection as a CPWG initiative, ARM Science Team Meeting, Louisville, KY (April 1)
-ARM Science and Infrastructure Steering Committee Meeting, ARM Science Team Meeting, Louisville, KY (April 3)

2008

-DOE ARM Cloud Properties Working Group, Landsdowne, VA (November 12-13): A case for shallow convection as an ARM science question; final plenary (November 13).
-American Geophysical Union Spring Meeting, Ft. Lauderdale, FL (May 27-30): The Cloud and Land Surface Interaction Campaign: CLASIC (**May 29, Session H43D, invited**)
-US Consulate, Lisbon Portugal: The US Department of Energy's ARM Mobile Facility: Monitoring Marine Stratocumulus at Graciosa, Azores; US Consulate Staff, (August 5)
-Monmouth Flying Club: "To See or Not to See: Adventures in Visibility"; **(April 19, invited).**
-ARM Heating Rate Profile Workshop (January 8)-University of Niamey, Niger, Africa: Subject: An ARM Mobile Facility Primer (January 16-17: rescheduled due to travel restriction)
-Cloud and Land-Surface Interaction Campaign (CLASIC) Planning Meeting, Dallas, TX; Overview of CLASIC (February 1)
-NASA Goddard Institute for Space Studies: Subject: Regimes within the First Aerosol Indirect Effect **(February 9, invited)**
-ARM Science Team Meeting: Cloud Droplet Nucleation and Aerosol Indirect Effects (March 26)
-ARM Science Team Meeting: The Cloud and Land-Surface Interaction Campaign (CLASIC) (March 28)
- The ARM Mobile Facility: Cloud and Aerosol Interaction Science Institute of Atmospheric Science, Chinese Academy of Science, Beijing, China **(April 18, invited)**
-Nanjing Institute of Geography and Limnology, Chinese Academy of Science, Nanjing, China: The ARM Mobile Facility: Cloud and Aerosol Interaction Science **(April 20, invited)**
-Lanzhou University, Lanzhou, China: The ARM Mobile Facility: Cloud and Aerosol Interaction Science **(April 23, invited)**
- The Cloud and Land Surface Interaction Campaign (CLASIC): (invited) American Geophysical Union Spring Meeting (May 22-25)
- The Cloud and Land Surface Interaction Campaign (CLASIC), Division Seminar, Brookhaven National Laboratory (early July)

- Greenland as a potential new ARM Site, DOE ARM Futures Meeting, Reston, VA (October 31-November 1)
-Early Results from the Cloud and Land Surface Interaction Campaign (CLASIC), DOE ARM Science Team Executive Committee Meeting, December 17