The Atmospheric Radiation Measurement (ARM) Climate Research Facility

Dave Turner
University of Wisconsin - Madison

2010 ASR Science Team Meeting, Bethesda, MD
The goal of ASR, in partnership with the enhanced ARM Facility, is to quantify the interactions among aerosols, clouds, precipitation, radiation, dynamics, and thermodynamics to improve fundamental process-level understanding, with the ultimate goal to reduce the uncertainty in global and regional climate simulations and projections.
The goal of ASR, in partnership with the enhanced ARM Facility, is to quantify the interactions among aerosols, clouds, precipitation, radiation, dynamics, and thermodynamics to improve fundamental process-level understanding, with the ultimate goal to reduce the uncertainty in global and regional climate simulations and projections.
Programmatic Mission

The goal of ASR, in partnership with the enhanced ARM Facility, is to quantify the interactions among aerosols, clouds, precipitation, radiation, dynamics, and thermodynamics to improve fundamental process-level understanding, with the ultimate goal to reduce the uncertainty in global and regional climate simulations and projections.
ASR / ARM Objectives

- 4 objectives listed in ASR Science Plan
- First two are really ARM Facility objectives:
  - Maintain and augment the collection of comprehensive and continuous long-term data sets that provide measurements of CARDTP at several fixed and mobile sites
  - Supplement long-term data with lab studies and field campaigns to target specific atmospheric processes in a wide variety of conditions
- Other two objectives are ASR focused
Coupling between ASR & ARM

- Section 3 of the science plan outlines the observational and modeling approach

- To paraphrase:
  
  The observations informs the modeling
  
  and
  
  The modeling informs the observations
ARM Facility Resources

- Fixed ground-based sites
  - Southern Great Plains (CF at Lamont, BFs, and EFs)
  - Tropical Western Pacific (Manus, Darwin, Nauru)
  - North Slope of Alaska

- Two mobile facilities
  - California, Niger, Germany, China, Azores, Colorado

- Airborne facility
  - Many missions

- Data processing system and archive
Airborne Facility
AAF Supports...

- Intensive observation periods
  - Short-term campaigns
  - Non-hardened instruments

- Routine observations
  - Long-term campaigns
  - Hardened instruments (hands-off)

- Instrument development
  - Moving proven instruments closer to ‘hands-off’ ops
AAF Routine Flights

- Regularly scheduled flights with instruments that are largely automated
- Objective: generate better statistics by flying in a wide range of conditions
  - Less reliance on “golden days”
- Four examples to date:
  - In-situ aerosol profiling (IAP): 2000-2007
  - Warm, thin liquid water clouds (RACORO): 2009
  - Small ice crystals in cirrus (SPartICus): 2010
  - Airborne carbon measurements (ACME): 2008-2011
Mobile Facilities

- Mobile facilities have the same core instrumentation as fixed facilities
- Deployed for 6 months to 2 years
- Can be requested by ASR investigators or scientific community
- Two AMFs
  - AMF-1: est 2005; currently on its 5th deployment
  - AMF-2: starting its first deployment in Colorado
- Mobile ground-base aerosol facility
Mobile Facility Deployments

- 2006 Niger
- 2007 Germany
- 2008 China
- 2009-2010 Azores
Fixed Sites

- Different climatic regimes
- Long-term data sets (decades)
- Wide range of instrumentation
  - Ground-based in-situ (e.g., basic met, flux stations)
  - Airborne in-situ (e.g., radiosondes)
  - Active remote sensors (e.g., radars, lidars)
  - Passive remote sensors (e.g., radiometers, spectrometers)
Pushing the Obs Envelope

- Pioneered the use of autonomous active and passive remote sensing observations of the atmospheric column
  - Millimeter-wave cloud radar (MMCR)
  - Raman lidar
  - Atmospheric Emitted Radiance Interferometer (AERI)
- Developed instruments to sample aerosol particle size, composition, absorption, etc.
  - Photo-thermal interferometer
  - Single particle laser ablation time-of-flight (SPLAT)
Recovery Act of 2009

- Provided an opportunity to dramatically expand observational capabilities of facility
  - $60M in capital investments
- Instrumentation drawn from working group recommendations, DOE workshops, etc.
- Improve data system and infrastructure
- Provide 3-d measurements of cloud scale dynamics, microphysics, and precipitation
- Enhanced measurements of aerosol composition and chemistry
Facility Instrumentation

- Millimeter-wave cloud radar (MMCR)
- SGP, NSA, TWP, AMF
- Radar reflectivity, Doppler velocity, cloud boundaries, cloud liquid and ice water content profiles, cloud particle motion
Facility Instrumentation

- Scanning dual frequency cloud radar
- SGP, NSA, TWP, AMF
- Elevation and azimuth scans of: radar reflectivity and Doppler velocity at 2 wavelengths, cloud boundaries, cloud liquid and ice water content profiles, cloud particle motion
Facility Instrumentation

- Scanning precipitation radar
- SGP, NSA, TWP, AMF
- Azimuth and elevation scans of radar reflectivity and Doppler velocity at longer wavelengths, rain rate, cloud motion
Facility Instrumentation

- Radiosonde
- SGP, NSA, TWP, AMF
- Profiles of pressure, temperature, humidity, wind speed, wind direction
- Autosonde launcher for NSA
Facility Instrumentation

- Raman lidar
- SGP, TWP
- Water vapor mixing ratio profiles, aerosol and cloud backscattering and extinction profiles, depolarization profiles, cloud boundaries, cloud and aerosol optical depth, cloud phase
Facility Instrumentation

- Scanning Doppler wind lidar
- SGP, TWP, AMF
- Radar reflectivity, Doppler velocity, cloud boundaries, cloud liquid and ice water content profiles, cloud particle motion
Facility Instrumentation

- High spectral resolution lidar (HSRL)
- NSA, AMF
- Profiles of aerosol and cloud backscatter and extinction, depolarization ratio, cloud boundaries, cloud optical depth, cloud phase
Facility Instrumentation

- Microwave radiometer (MWR)
- SGP, NSA, TWP, AMF
- Downwelling emission at 23.8, 31.4, and 90 GHz, precipitable water vapor, liquid water path
- Upgraded by ARRA
Facility Instrumentation

- Atmospheric emitted radiance interferometer (AERI)
- SGP, NSA, TWP, AMF
- Downwelling infrared radiance spectrum, temperature and humidity profiles, cloud optical depth and effective radius, cloud phase
- Upgraded by ARRA
Facility Instrumentation

- Solar spectrometer
- SGP, AMF
- Solar spectral radiance and irradiance, aerosol and cloud optical depth, Angstrom exponent, cloud particle effective radius
- Upgraded by ARRA
Facility Instrumentation

- Multi-filter rotating shadowband radiometer (MFRSR)
- SGP, NSA, TWP, AMF
- Direct and diffuse solar irradiance in 6 narrow spectral bands, aerosol optical depth, Angstrom exponent, aerosol single scatter albedo, precipitable water vapor
Facility Instrumentation

- Cimel sunphotometer
- SGP, NSA, TWP, AMF
- Solar irradiance and radiance in 6 spectral channels, aerosol optical depth, Angstrom exponent, aerosol size distribution, aerosol single scatter albedo
Facility Instrumentation

- Aerosol observing system (AOS)
- SGP, NSA, TWP, AMF, MAOS, AAF
- In-situ aerosol scattering and backscattering, absorption, number concentration, size distribution, cloud condensation nuclei counter, single scatter albedo, asymmetry parameter, hygroscopic growth
- Upgraded by ARRA
Facility Instrumentation

- Aerosol chemical speciation monitor
- SGP, TWP, MAOS
- Particulate composition for ammonium, nitrate, sulfate, chloride, and organic species

- Photon transfer mass spectrometer
- MAOS
- Gaseous organic compounds
Facility Instrumentation

- Particle into liquid sampler (PILS)
- MAOS, AAF
- Aerosol chemical composition, water soluble organic carbon

- Scanning mobility particle sizer
- MAOS, AAF
- Aerosol size distribution from 15 nm - 450 nm
Facility Instrumentation

- Cloud in-situ probes
- AAF
- Cloud droplet size distribution, cloud particle images, cloud water content, cloud particle phase

2D Stereo Probe

Cloud Imaging Probe

High Volume Precipitation Spectrometer
Facility Instrumentation

- 2-dimensional video disdrometer
- TWP, AMF, MAOS
- Droplet size distributions, precipitation rate, liquid water content

- Disdrometer
- SGP, TWP
- Droplet size distributions, precipitation rate
- Upgraded by ARRA
Facility Instrumentation

- Eddy correlation flux measurement systems
- SGP, TWP, NSA, AMF
- Latent and sensible heat flux, turbulence, carbon dioxide flux
- Upgraded by ARRA
Facility: More than Instruments

- Site infrastructure
  - Data management facility
  - Archive
- Data processing system
  - External data center
  - Metadata databases
- People
  - Program office
  - Site operations
  - Instrument mentors
  - SW Developers
  - Contracts / Financial
  - Outreach
  - Communications
Data Archive

- All ARM data stored
  - Raw data, and higher data levels
- Simple web interface
- Improving data ordering and visualization
- Expanding rapidly to handle the explosive growth in data volume
  - E.g., radar spectra
Which SGP ARM data streams are the most requested from the Archive?
Which SGP ARM data streams are the most requested from the Archive?
Which SGP ARM data streams are the most requested from the Archive?

Radiosonde

Microwave Radiometer

3

4

5
Which SGP ARM data streams are the most requested from the Archive?

- Radiosonde
- Microwave Radiometer
- ARSCL (MMCR)

3. Radiosonde
4. Microwave Radiometer
5. ARSCL (MMCR)
Which SGP ARM data streams are the most requested from the Archive?

- Radiosonde
- Microwave Radiometer
- ARSCL (MMCR)
- Raman lidar

5
Which SGP ARM data streams are the most requested from the Archive?

- Radiosonde
- Microwave Radiometer
- ARSCL (MMCR)
- Raman lidar
- W-band cloud radar (WACR)
Value Added Products

- Create new data streams by from others
- Different levels of VAPs:
  - Convert raw instrument data into geophysical data
    - Liquid water path and precipitable water vapor retrieved from microwave radiometer
    - Water vapor mixing ratio data from Raman lidar
  - Optimally combine data from different sources to provide a best estimate or higher order dataset
    - Active remote sensing of cloud locations (ARSCL)
    - Objective analysis data product for modelers
Value Added Products

- VAPs greatly enhance the scientific utility of the facility
  - Make the data more useable to the community
- New suite of instruments will require VAP development to:
  - Derive basic geophysical variables from the new obs
  - Combine data from existing and new instruments into unique and powerful new data sets
- VAP process is being scrutinized to improve the efficiency of the development process
Value Added Products

- Only works if the scientists are engaged!
- Need PIs to:
  - Develop prototype algorithms and datasets
  - And archive the PI-generated data in the archive!
  - Prioritize the implementation by the infrastructure
  - Use the data and provide feedback
- Need to start using the ARRA instrumentation immediately, which means we need VAPs
- We need your expertise, creativity, and time!

ARM
CLIMATE RESEARCH FACILITY

U.S. DEPARTMENT OF ENERGY
Office of Science
The ARM Climate Research Facility is a U.S. Department of Energy scientific user facility for the study of global climate change by the national and international research community.

FEATURE 01.06.2010
Cirrus Clouds Hold Clues to Climate

On January 4, scientists sponsored by ARM began a five-month aircraft campaign to gather data from cirrus clouds in the skies above Oklahoma. Using an instrumented Learjet 25 research aircraft, their goal is to obtain a new and comprehensive set of in-cloud, or “in situ,” measurements about the size and number of ice crystals that make up cirrus clouds. 

USING OUR FACILITIES
Preproposals for FY2012 for ARM and AAFC deployments due February 16. Successful candidates will be eligible for up to $180K per year for three years of research funding from Atmospheric System Research. To learn more, see announcements.

FIELD CAMPAIGNS
CARES
Carbonaceous Aerosol and Radiative Effects Study

SPARTICUS
Small Particles in Cirrus

RHUBC-II
Chile: Radiative Heating in Undersampled Basins Campaign 2

USER HIGHLIGHTS
02.26.2010
Analyzing Tropical Mesoscale Convective Systems in Monsoon Region

02.16.2010
Investigating Water Vapor Variability by Ground-Based Microwave Radiometry

01.25.2010
Detangling Convective Oscillations at ARM Tropical Western Pacific Site: Menus
The ARM facility has pioneered the use of advanced observational tools in a routine manner to collect a unique and powerful dataset.

These data have greatly advanced the science over the last 20 years.

The ARRA enhanced facility will provide new ways to view our atmosphere and the processes at work within it.

Teamwork: infrastructure + science team.
The Atmospheric System Research (ASR) science and program plan is now available.

Welcome

The first Science Team Meeting of the Atmospheric System Research (ASR) program will be held March 15-19, 2010, at the Marriott Bethesda North Hotel & Conference Center in Bethesda, Maryland. ASR is a new U.S. Department of Energy climate research program formed from the merger of the Atmospheric Radiation Measurement (ARM) Program and the Atmospheric Science Program (ASP).

The ASR Science Team Meeting officially begins on Tuesday, March 16, with a plenary session, followed by a full schedule of formal presentations by invited speakers and breakout sessions through Thursday. Orientation for new Principal Investigators and special focus meetings will be held on Monday, March 15. Poster session receptions will be held on Tuesday and Wednesday to review research results. Working group meetings will be held on Thursday.

Meeting Info
See the meeting agenda. Be sure to catch the new PI orientation on Monday and working group meetings on Thursday. See the hotel floor plan.

Registration
Registration is now closed. On-site registration will begin Monday, March 15, 2010, at 7 a.m.

Poster Abstracts
Poster abstracts are no longer being accepted. Please contact Dana Duggan with any questions or for assistance.

Travel Information
The DCA, IAD, and BWI airports serve the Bethesda area. The hotel website offers driving directions and more information on transportation, including public transportation options.