ARM

CLIMATE RESEARCH FACILITY

The Atmospheric Radiation Measurement (ARM) Climate Research Facility

James Mather
ARM Technical Director
June 28, 2013

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Outline

- Motivation
- Overview of the ARM Climate Research Facility
- Facility applications and science highlights
- Facility Expansion
- Upcoming Activities

DOE Climate Change Research

BER Climate and Environmental Science Division (CESD) Mission Statement:

To advance a robust predictive understanding of Earth's climate and environmental systems and to inform the development of sustainable solutions to the Nation's energy and environmental challenges.*

* From the 2012 BER CESD Strategic Plan

CESD Goals

- **Goal 1:** Synthesize new process knowledge and innovative computational methods advancing next-generation, integrated models of the human-earth system.
- **Goal 2:** Develop, test, and simulate process-level understanding of atmospheric systems and terrestrial ecosystems, extending from bedrock to the top of the vegetative canopy.
- **Goal 3:** Advance fundamental understanding of coupled biogeochemical processes in complex subsurface environments to enable systems-level environmental prediction and decision support.
- **Goal 4:** Enhance the unique capabilities and impacts of the ARM and EMSL scientific user facilities and other BER community resources to advance the frontiers of climate and environmental science.
- **Goal 5:** Identify and address science gaps that limit translation of CESD fundamental science into solutions for DOE's most pressing energy and environmental challenges.

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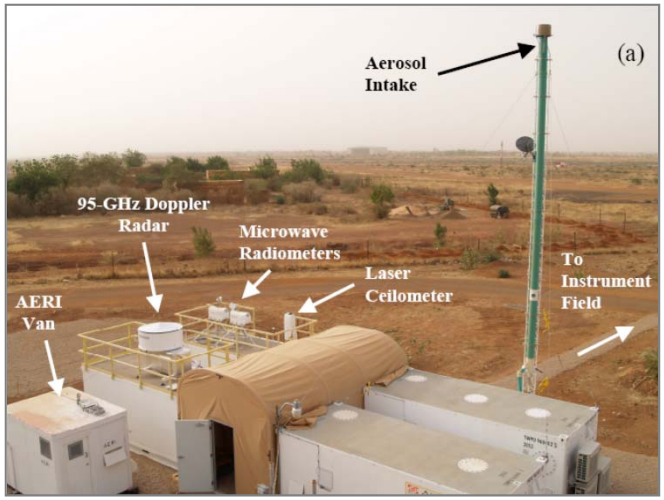
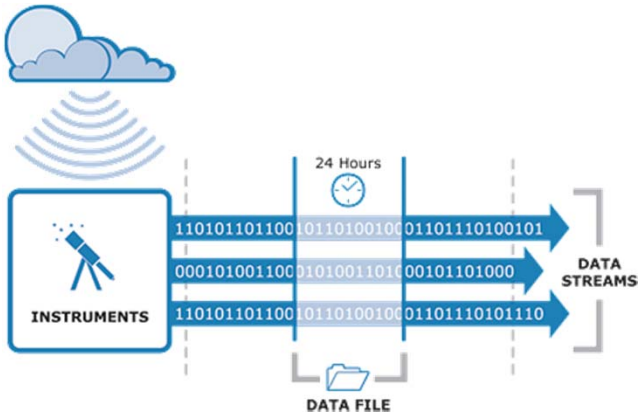
Climate Science Issues

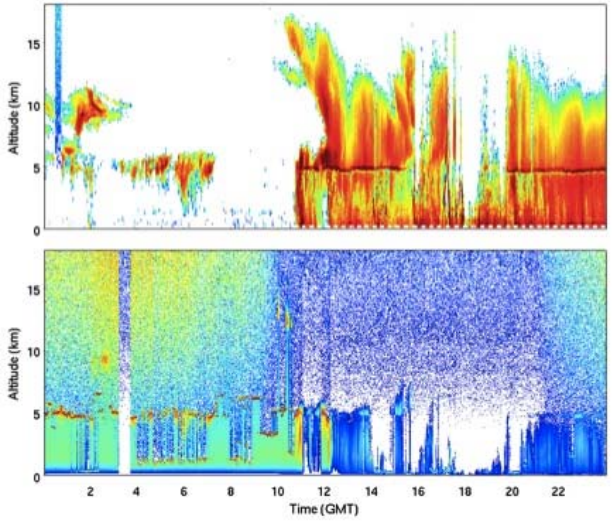
- Source and cycling of greenhouse gases
- Source and cycling of aerosols and their radiative and microphysical properties – including biogenic and anthropogenic sources
- Characterization of current cloud properties and radiative feedback due to changes in cloud populations
  - Marine stratus along western continental boundaries
  - Tropical convection systems – e.g. El Nino/La Nina; Madden Julian Oscillation
  - Mixed-phase arctic clouds
  - Southern Ocean storm track systems
- Interactions of clouds and aerosols with the earth surface

The ARM Climate Research Facility

- Research sites – permanent, mobile, and aerial
- Instruments and measurements
- Field campaigns – ground-based, ship-based, airborne
- Data processing, data quality, Data Archive







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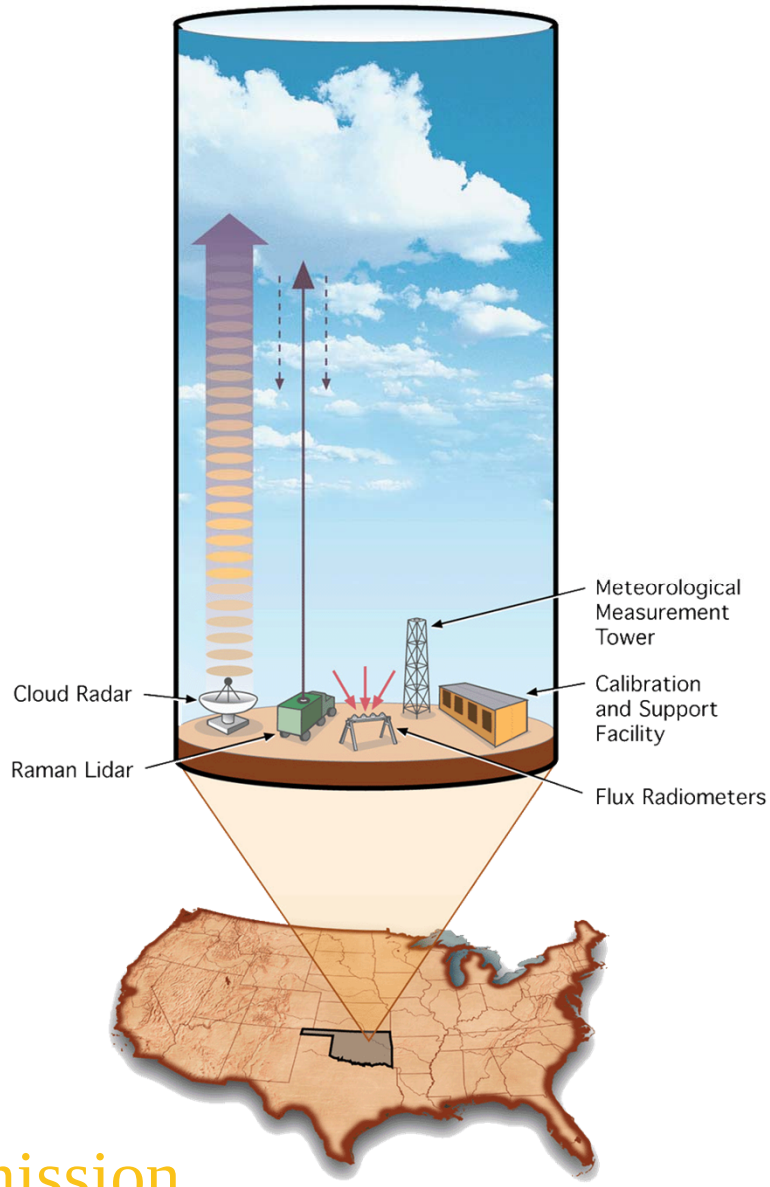
ARM Mission and Vision Statements

Mission

The ARM Climate Research Facility, a DOE scientific user facility, provides the climate research community with strategically located in situ and remote sensing observatories designed to improve the understanding and representation, in climate and earth system models, of clouds and aerosols as well as their interactions and coupling with the Earth's surface.

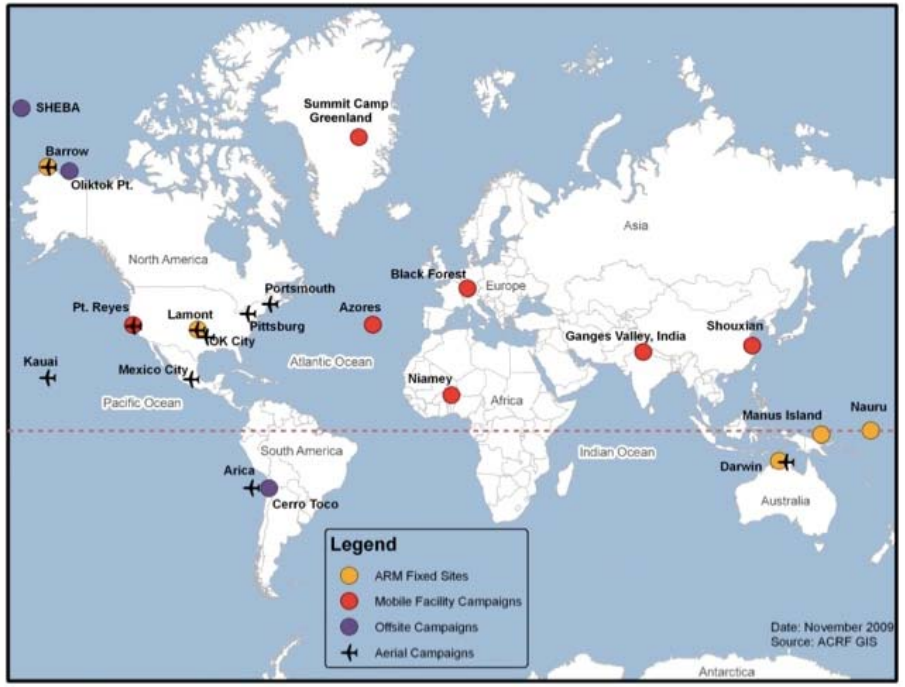
Vision

To provide a detailed and accurate description of the earth atmosphere in diverse climate regimes to resolve the uncertainties in climate and earth system models toward the development of sustainable solutions for the Nation's energy and environmental challenges.



http://www.arm.gov/about/mission

Research Sites



- Southern Great Plains (1993)
- North Slope of Alaska: Barrow (1998) and Atqasuk (1999)
- Tropical Western Pacific: Manus (1996), Nauru (1998), and Darwin (2002)
- First ARM Mobile Facility (2005); Second ARM Mobile Facility (2010)
- ARM Aerial Facility (2007)
- Eastern North Atlantic and Third ARM Mobile Facility (2013)

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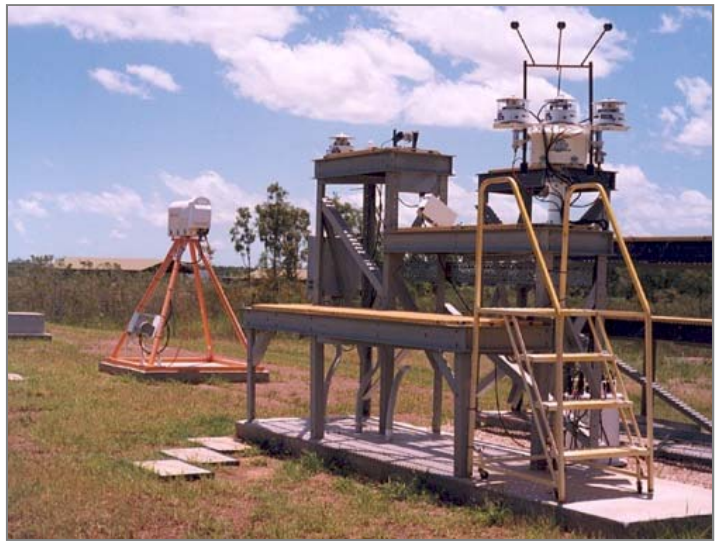
Overview: Measurements and Instruments

- Cloud profiles: millimeter radar and lidar
- Temperature/relative humidity/wind profiles: radiosondes
- Column water: microwave radiometer
- Column aerosol: solar spectral radiometer
- In situ aerosol optical and cloud nucleation properties
- Surface radiation budget: solar and terrestrial IR radiometers
- Surface meteorology: T/RH/wind



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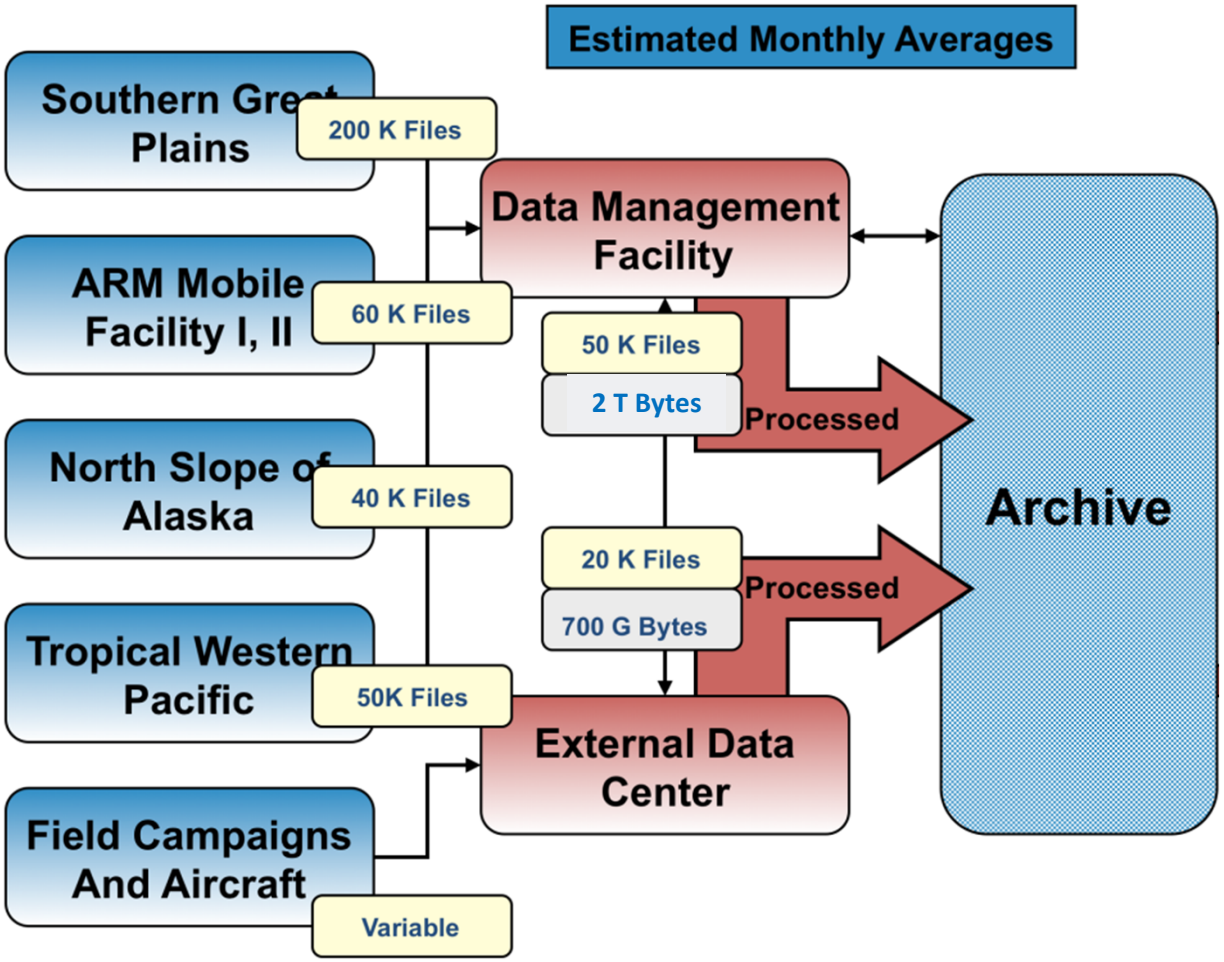
Overview: Data Products



Most instrument data are processed to a standard NetCDF format before being delivered to the Archive.

When necessary, higher-order Value-Added Products (VAPs) are developed.

Science User Interactions

Individuals become ARM science users through several processes including successful field campaign proposals, successful proposals to use ARM computing facilities, or through peer-reviewed science proposals requiring access to archived ARM data.

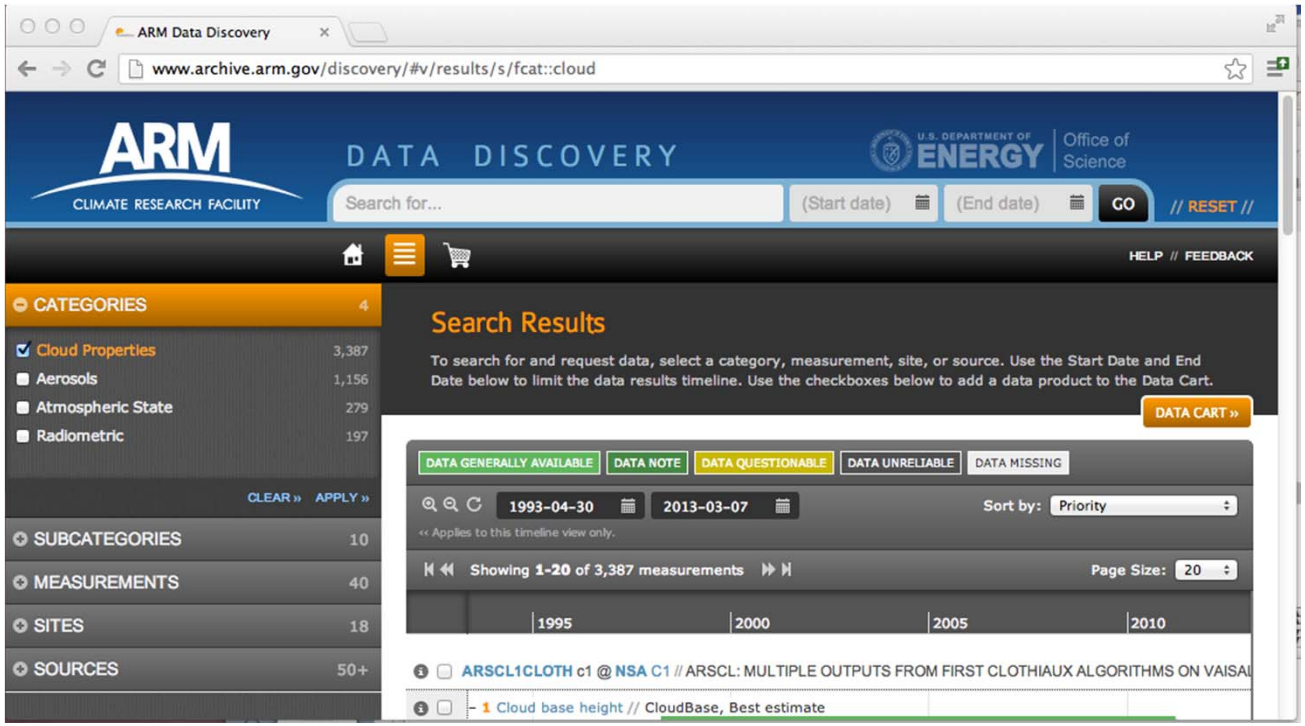
Science users interact with the ARM Facility in several ways:

- Data Access
- Field Campaigns and Facility Deployments
- Data Product requests
- Feedback for new capabilities

Tools for Data Discovery and Analysis

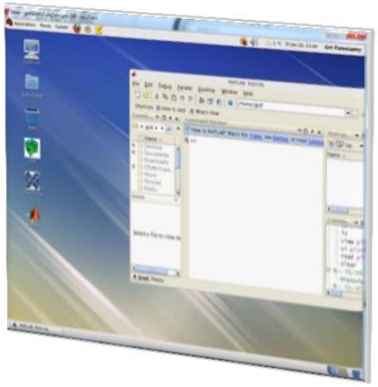
Archive Data Discovery Browser Go to www.arm.gov/data and select “Data Discovery”

- Provides faceted data search
- Auto-fill quick search
- Graphical data quality information



Other recent data advances include:

- Digital Object Identifiers
  - (http://www.arm.gov/data/docs/doi-guidance)
- A development area for large data sets
- Machine-Readable Data Quality Reports



- Designed for data analysis and visualization
- NX client for remote access to Linux desktop
- ~15 TB of online radar data (and growing)
- IDL, MATLAB, VisIt, Python/PERL modules

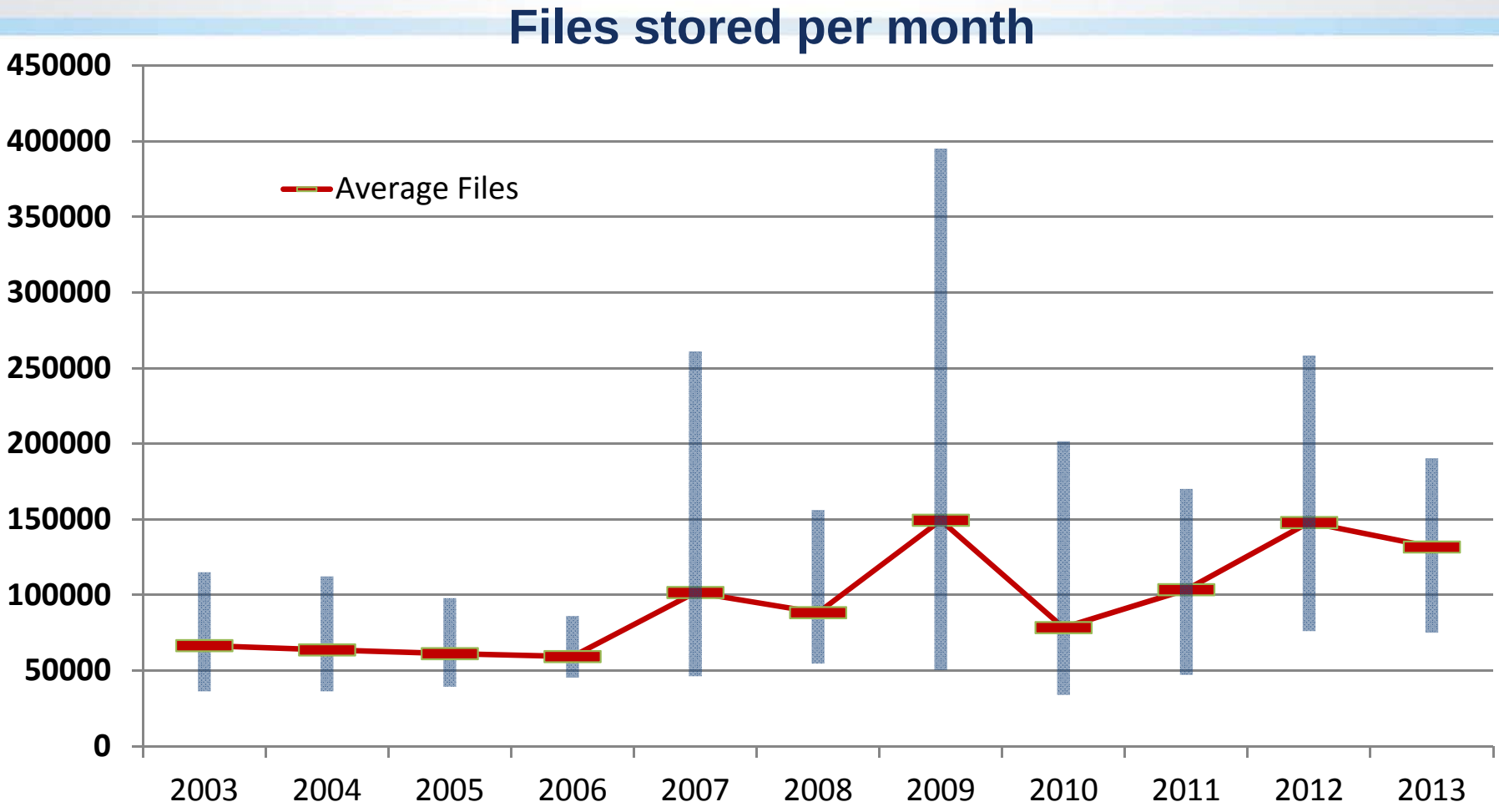
http://www.archive.arm.gov/cluster.pdf

Archive Statistics

Data flow statistics through the ARM data archive courtesy of Stephanie Shamblin:

- Number of files and volume stored
- Number of files and volume accessed

Number of Files Stored



- Relatively flat growth over past decade; 2013 average *less than* 2012.
- 2013 average monthly files stored is only 2x average in 2003.
- ~150,000 new files each month

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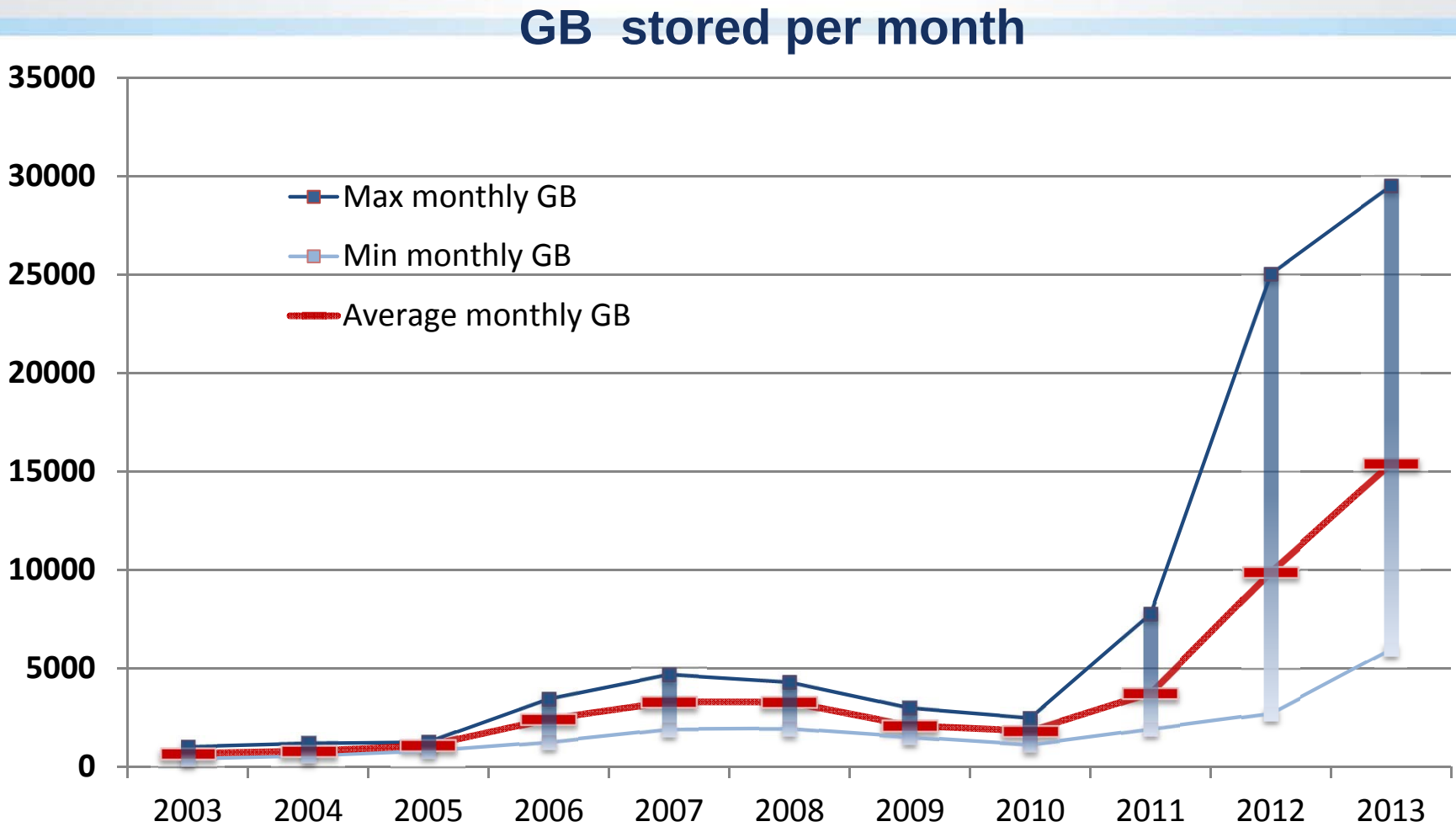
Data Volume Stored



- 2013 average monthly storage volume is more than 20x average in 2003.
- Much larger range in terms of volume: 5 TB – 30 TB per month in 2013.
- Quickly approaching rate of 1 TB per day.

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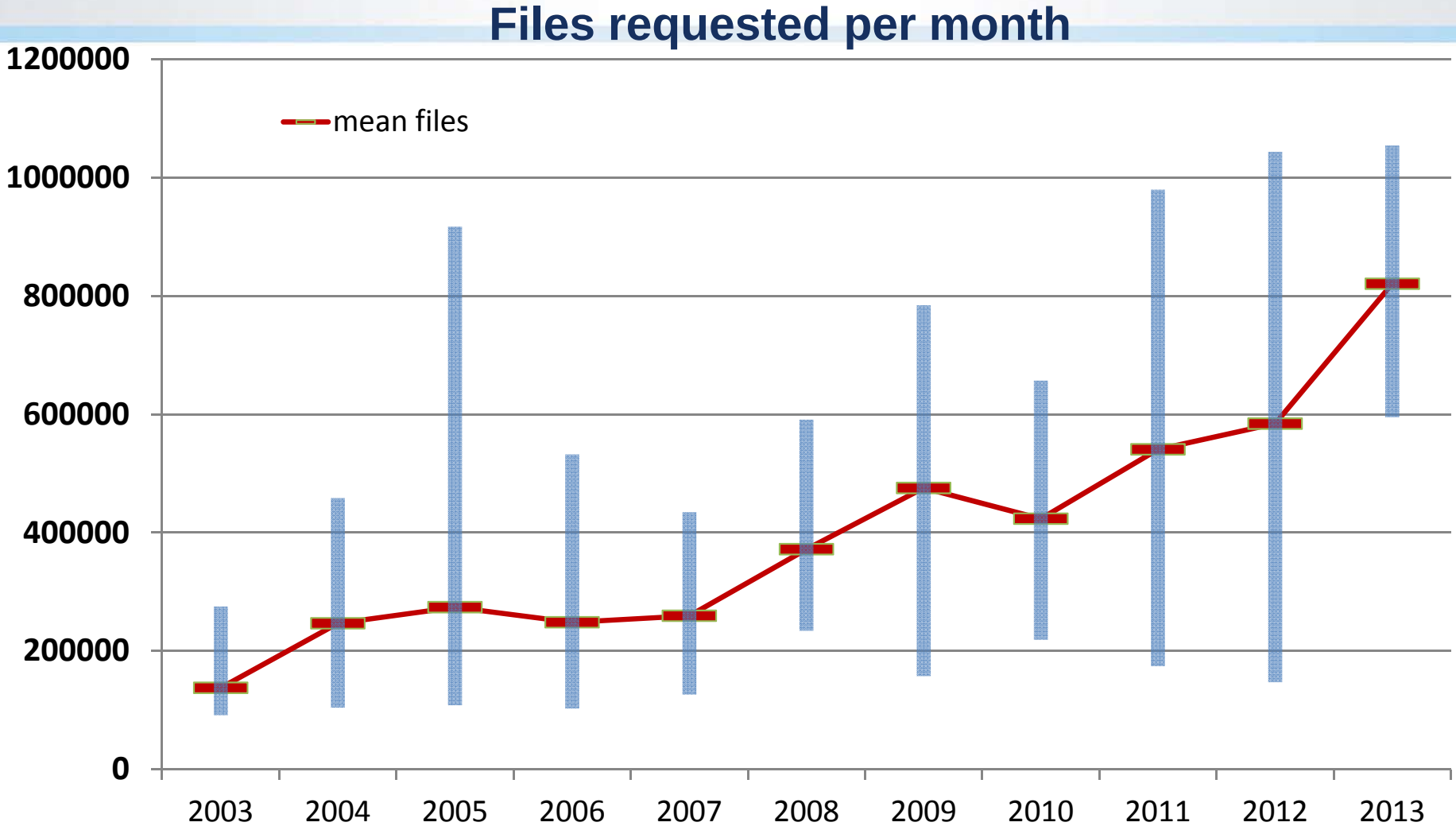
Number of Files Requested



- Average number of files requested per month in 2013 is around 6x average in 2003.
- Up 40% over 2012.

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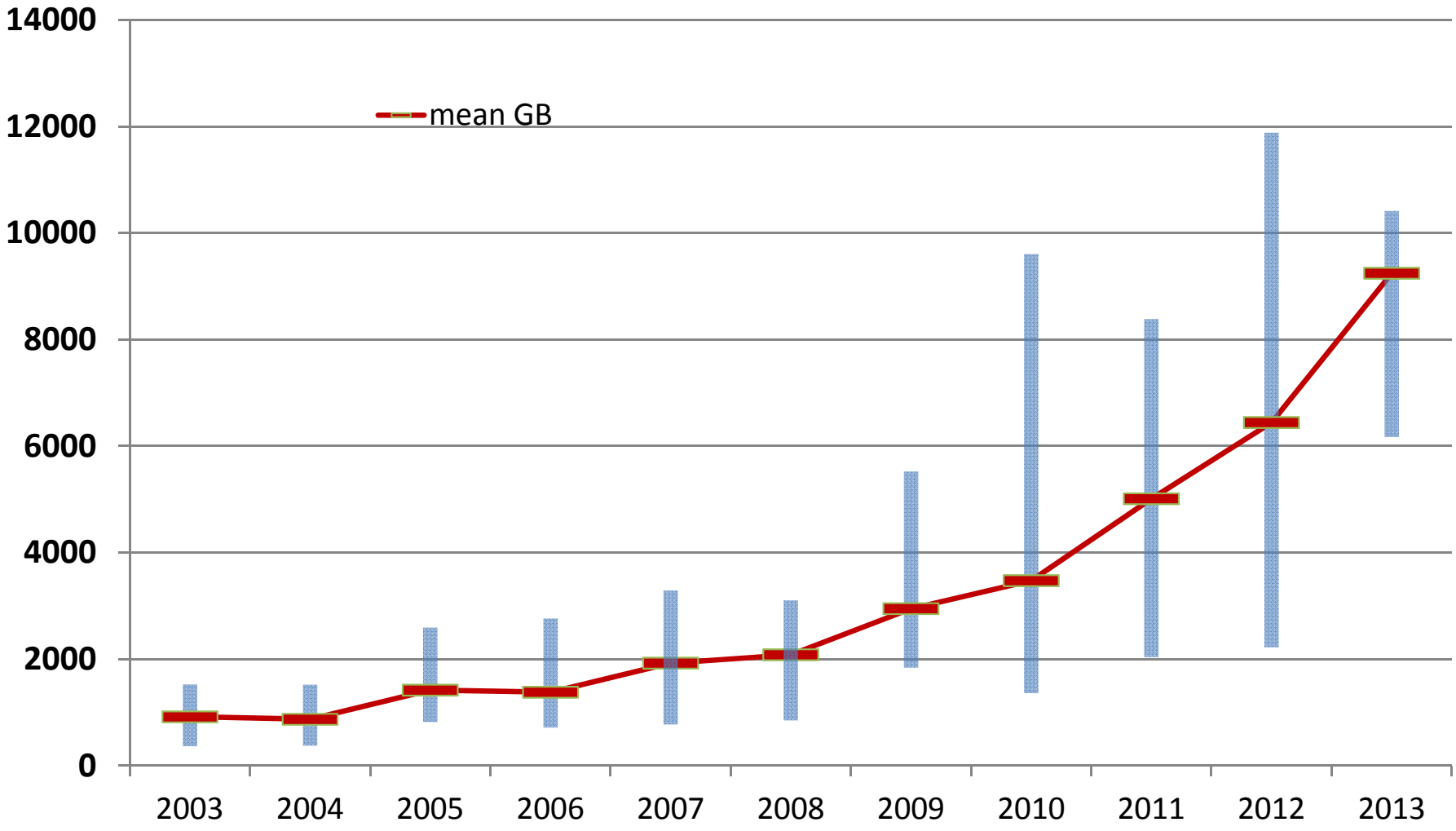
Data Volume Requested

GB requested per month



- Increasing at an increasing rate
- Average 9 TB of routine data distributed each month so far in 2013 – ~40% higher than 2012.

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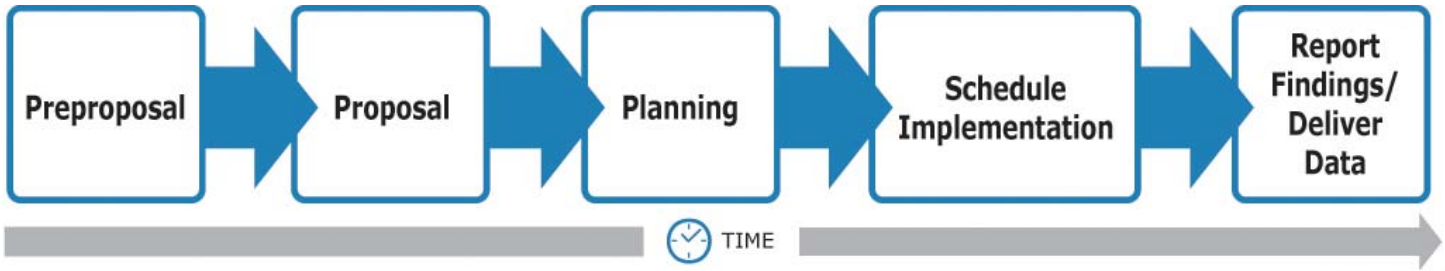
Annual Field Campaign Call (>$300K)

- ARM Facility Announcement- Call for Preproposals: January for FY(n+2)
  - ARM-all, BAMS, EOS, and ARM Website
- Preproposals Call Closed: February 1
- Notifications sent for Full Proposal: Mid-February
- Full Proposals Due: May 15
- Infrastructure Costs and Logistics Analysis: June 15
- Field Campaign Proposals + Costs to Science Board: June 15
- Reviews by Science Board due 2 weeks before Science Board meeting
- Science Board Review: Mid-August
- Award for ARM Fixed Sites, AMF, and AAF Campaigns: End-September
- Science Plan developed and Field Campaign is executed
- Experiment results and all collaborative data submitted to ARM Archive within 6 months after end of field campaign



AMF1 Transportable and Land-Based Deployments

Facility Manager: Kim Nitschke
Los Alamos National Laboratory

North America (California): 2005
Africa (Niger): 2006
Europe (Germany): 2007
Asia (China): 2008
Europe (Azores): 2009-2010
Asia (India): 2011-2012
North America (Cape Cod): 2012-2013
South America (Brazil): 2014

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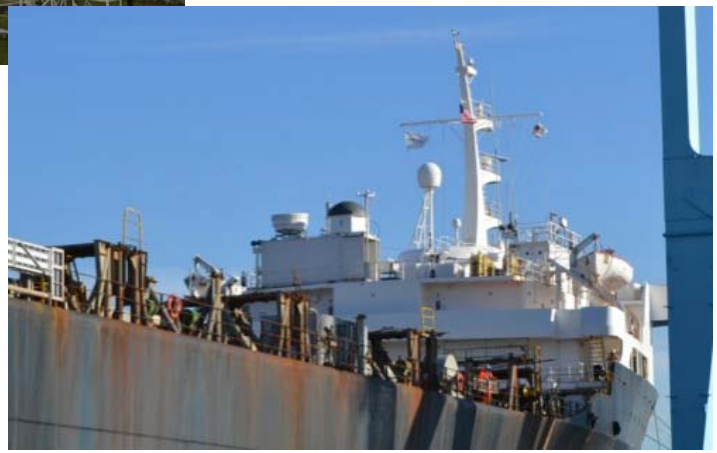
AMF2: Modular for Ship and Complex Terrain Deployments

Facility Manager: Nicki Hickmon
Argonne National Laboratory



North America (Colorado): 2011
Asia (Maldives): 2012
Eastern Pacific (Ship-based): 2012-13
Europe (Finland): 2013-14

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The ARM Aerial Facility (AAF)

Virtual Hangar

- CLASIC, Oklahoma: 6/2007
- ISDAC, Alaska: 4/2008
- RACORO, Oklahoma: 1–6/2009
- SPARTICUS, Oklahoma: 1–6/2010
- ARM Airborne Carbon Measurement Experiment, Oklahoma: 2008 – 2013 with TES since 2011
- So far worked with 13 aircraft: ER-2, Lear 25, P-3 (2), B-200, CV-580, J-31, G-1, Twin Otters (3), C206, Bell 206

+ Instrumentation

- Legacy (AVP, ASP)
- Recovery Act
- PIs
- Maturation Program

+ G-1

- PNNL since 1989
- ARM since 2010
- CARES, Sacramento: 6/2010
- CALWATER, Sacramento: 2-3/2011
- TCAP, Cape Cod: 7/2012, 2/2013
- BBOP, Washington, Tennessee

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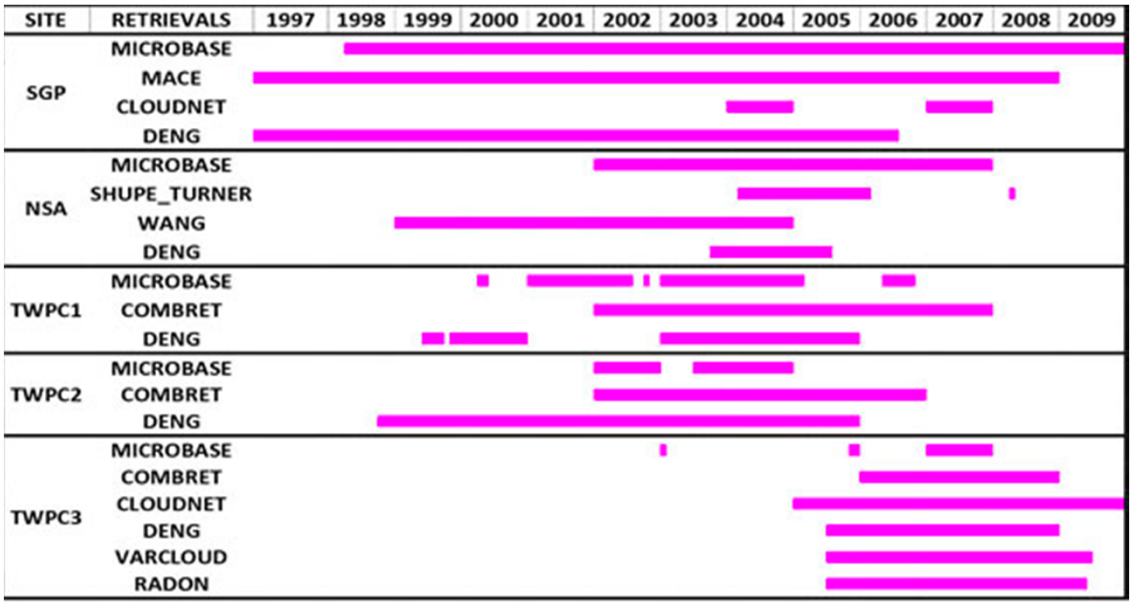
Value-Added Products (VAPs)

- VAPs are algorithms that translate measurements of geophysical parameters into data products that enable scientific analysis.
  - Merging data from multiple instruments
  - Providing derived parameters
  - Adding QC/QA information
- Production of a VAP consists of 4 stages:
  - Initiation – idea to implementation plan
  - Development – programming, review and beta testing
  - Evaluation – user testing and feedback
  - Release – quality control and documentation
- Use feedback from the ASR Science and Infrastructure Steering Committee (SISC), ASR working groups, and the wider user community to assess priorities

Synthesis Data for Model Evaluation

Model Best Estimate/Evaluation Data Sets

- ARM Best Estimate Products (formerly CMBE): Parameters on 1-hour Grid; specifically intended for model evaluation
- Variational analysis based model forcing datasets
- Radiatively Important Parameters Best Estimate: Set of inputs for a Radiative transfer model on 1-min and 30-min grid

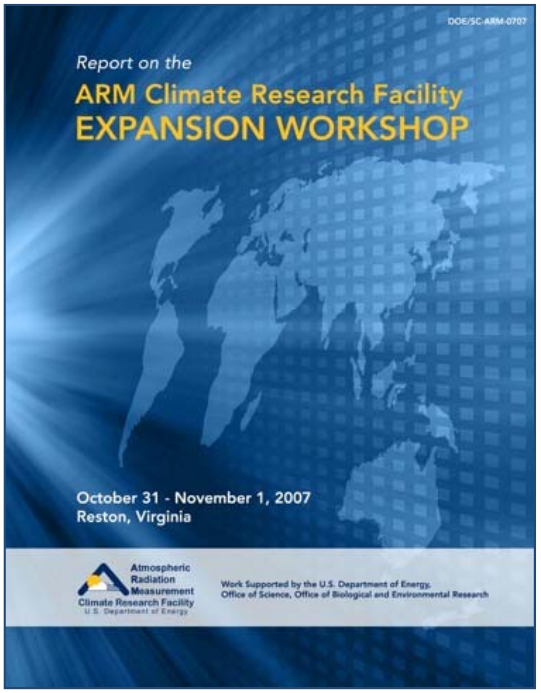


Availability of ARM Cloud Retrieval Ensemble Dataset. Courtesy: Shaocheng Xie

Information on these and other Value Added data products including vertical velocities, aerosol properties, and thermodynamic profiles is available at:
http://www.arm.gov/data/vaps/

User Feedback

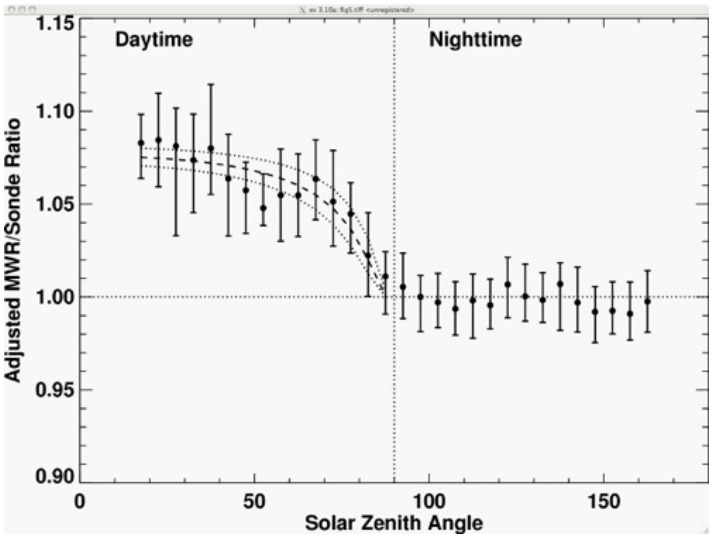
- ASR science team and working group meetings
- ASR Science and Infrastructure Steering Committee meetings and interactions
- User workshops
  - Archive User Meeting, 2007
  - ARM Climate Research Facility Expansion workshop, 2007
  - ARM Climate Research Facility workshop, 2008
  - AAF Airborne Instrumentation workshop, 2009
- User surveys, 2009, 2011
- General science meetings (e.g. AGU, AMS, EGU)



Measurement Techniques: Broadband Radiation and Water Vapor

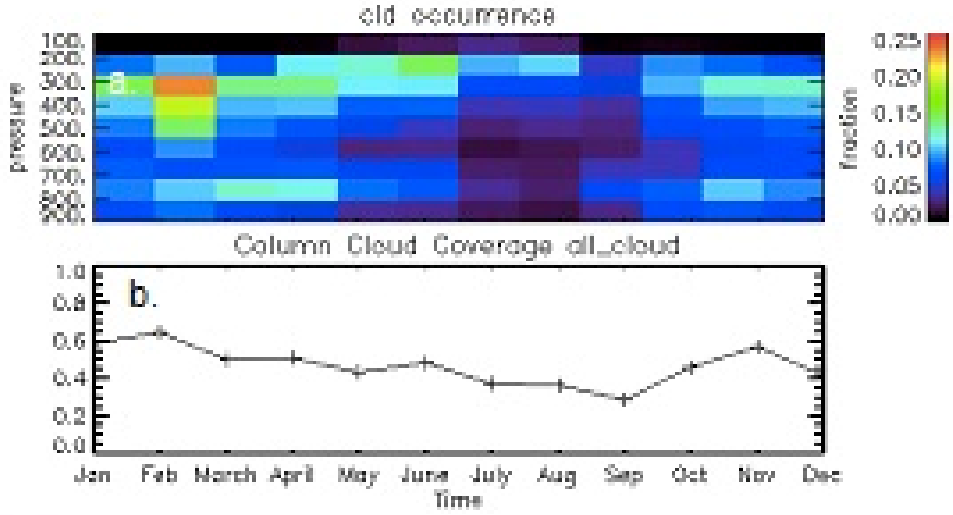
Broadband radiation measurement techniques, e.g., development of a diffuse shortwave standard: Michalsky et al., 2007, JGR.

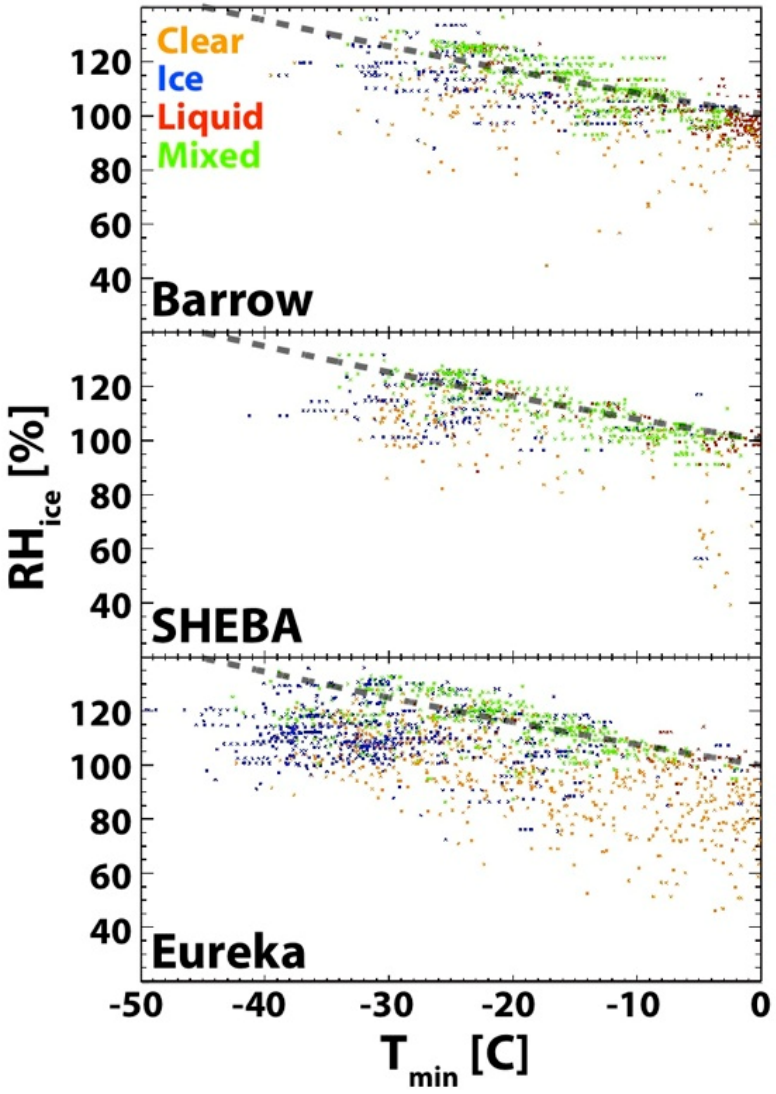
Improvements in water vapor measurements using radiosondes and microwave radiometers: e.g., Turner et al., 2003, JAOT (RS-80); Cady-Pereira et al., 2008, JAOT (RS-80/RS-90).



Measurement Techniques: Cloud Properties

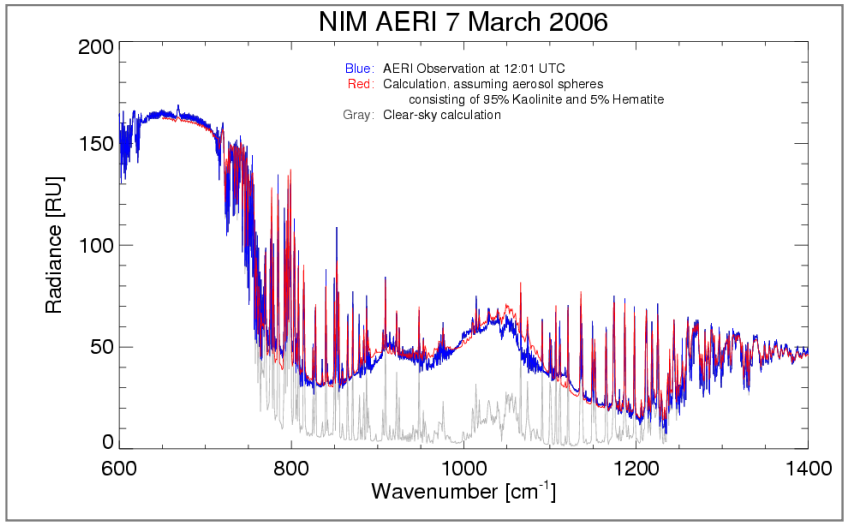
Derivation of cloud macrophysical and microphysical properties using millimeter radar and lidar, e.g., climatology of cloud properties at SGP (Mace, 2008; below) or an analysis of ice nucleation in the arctic
(de Boer et al., 2011; right).



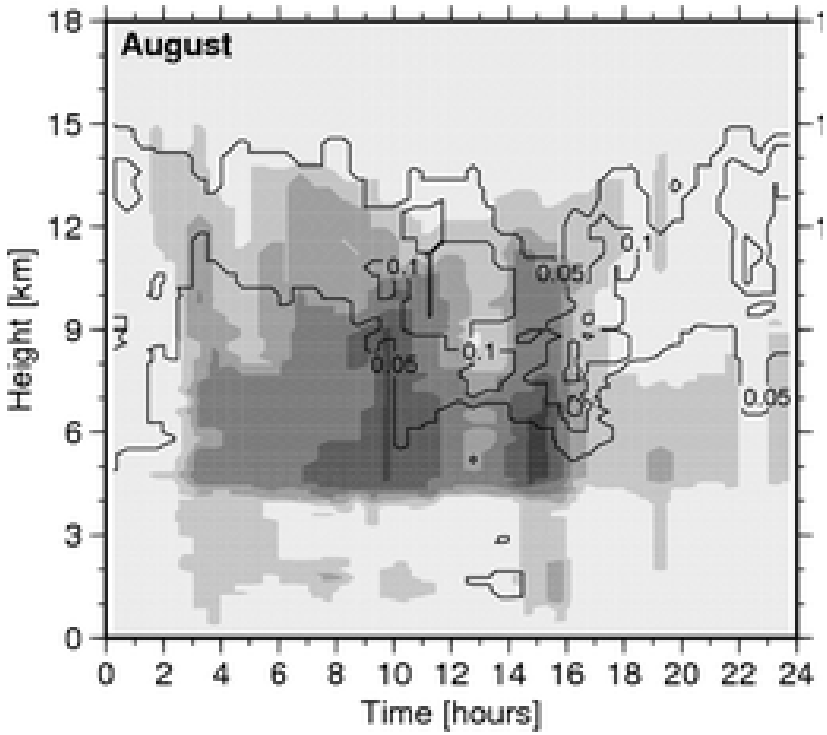


Characterization of the Sahel

- Research highlights include analyses of:
  - The column radiation budget
  - Relationships among thermodynamic and radiative parameters
  - Cloud microphysics properties
  - Aerosol properties
  - Convective anvil properties



AERI spectra used for dust property retrievals from Turner, 2008 (JGR)



Diurnal cycle of cloud occurrence (precipitating, shaded contours; non-precipitating, solid lines) from the cloud radar retrievals from Bouniol, 2012 (J. Appl. Met.)

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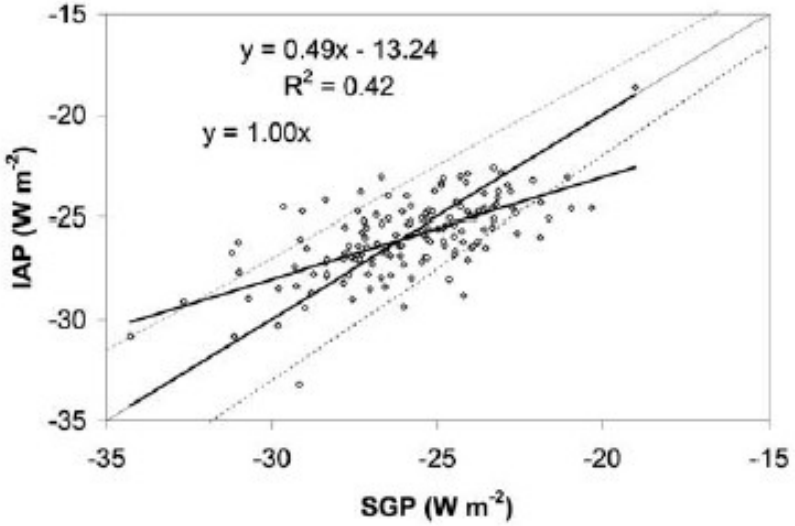
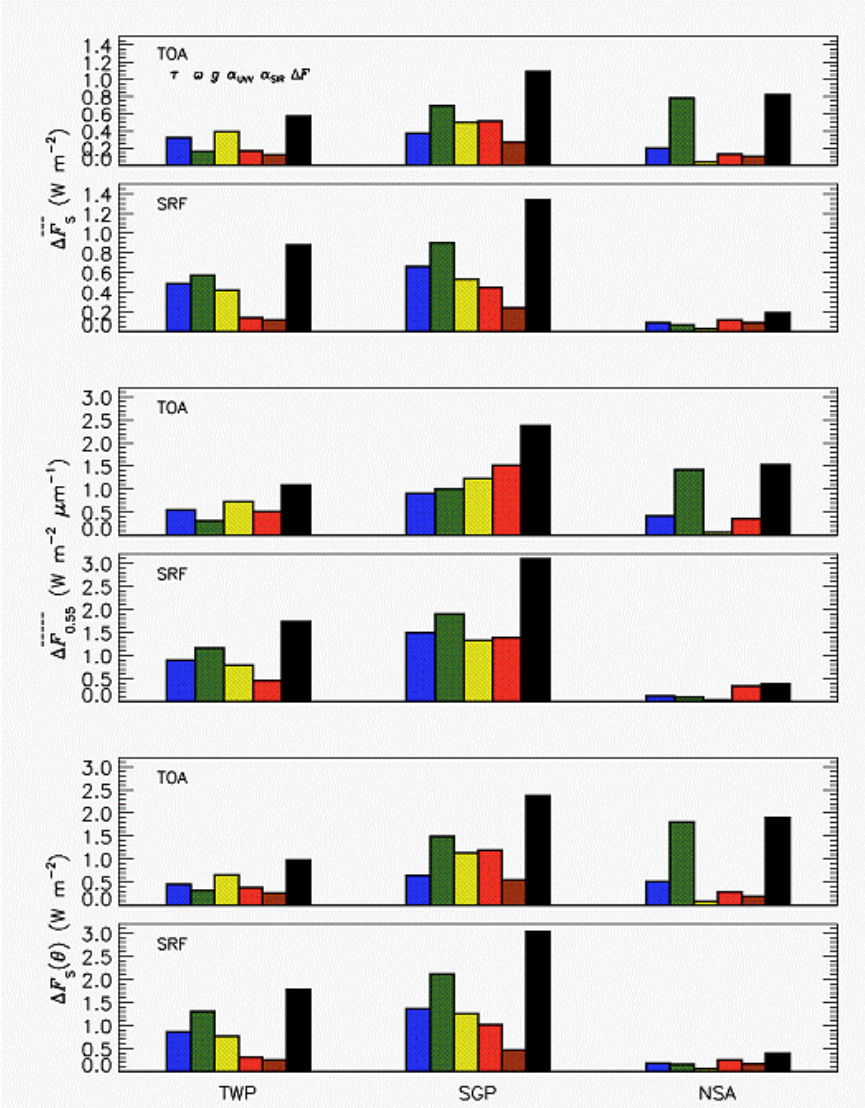
Measurement Techniques: Aerosols

There has been an emphasis on measurements of aerosol optical properties, e.g., the sensitivity of radiative forcing to aerosol optical properties (McComiskey et al., 2008; right) and the effects of scale (McComiskey and Feingold, 2012) and the representativeness of aerosol radiative forcing derived from surface measurements vs. airborne measurements (Andrews et al., 2004; below).





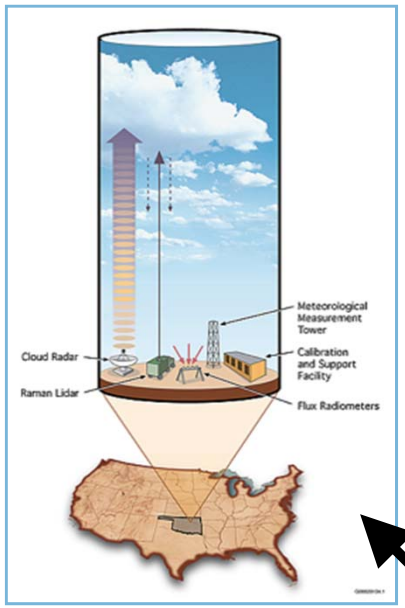
Exploring Aerosol Mixing State

The 2010 Carbonaceous Aerosols and Radiative Effects Study (CARES) included measurements of aerosol composition and structure (mixing state) from the ground and the G1 aircraft downwind of Sacramento, CA. Analysis of these data show:

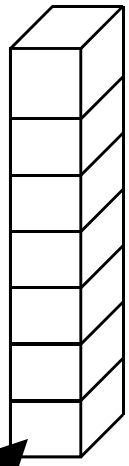
- A high fraction (88%) of particles measured contained internal mixtures of multiple chemical species with key aerosol components including soot, organic carbon, sulfate, and nitrate
- The aerosol composition varied significantly with location as well as time.

Quantifying the effect of aerosols on climate requires predicting the evolution of aerosol properties. This study describes the properties of aerosols in a region affected by pollutants and biogenic sources and emphasizes the need to carefully account for regional aerosol sources. Cahil et al., 2012 (ACP)

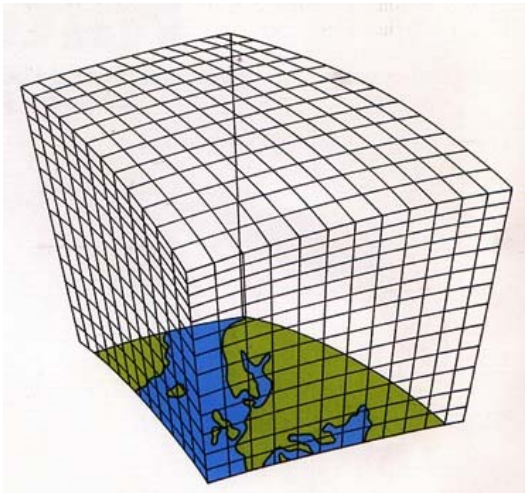
ARM Observations for Model Evaluation and Improvement



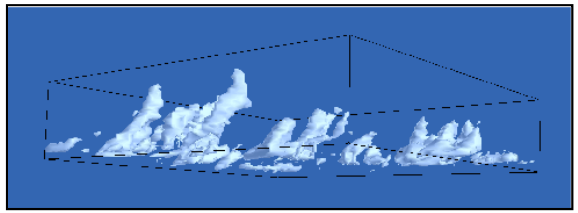
ARM Data



SCM



GCM



CRM/LES

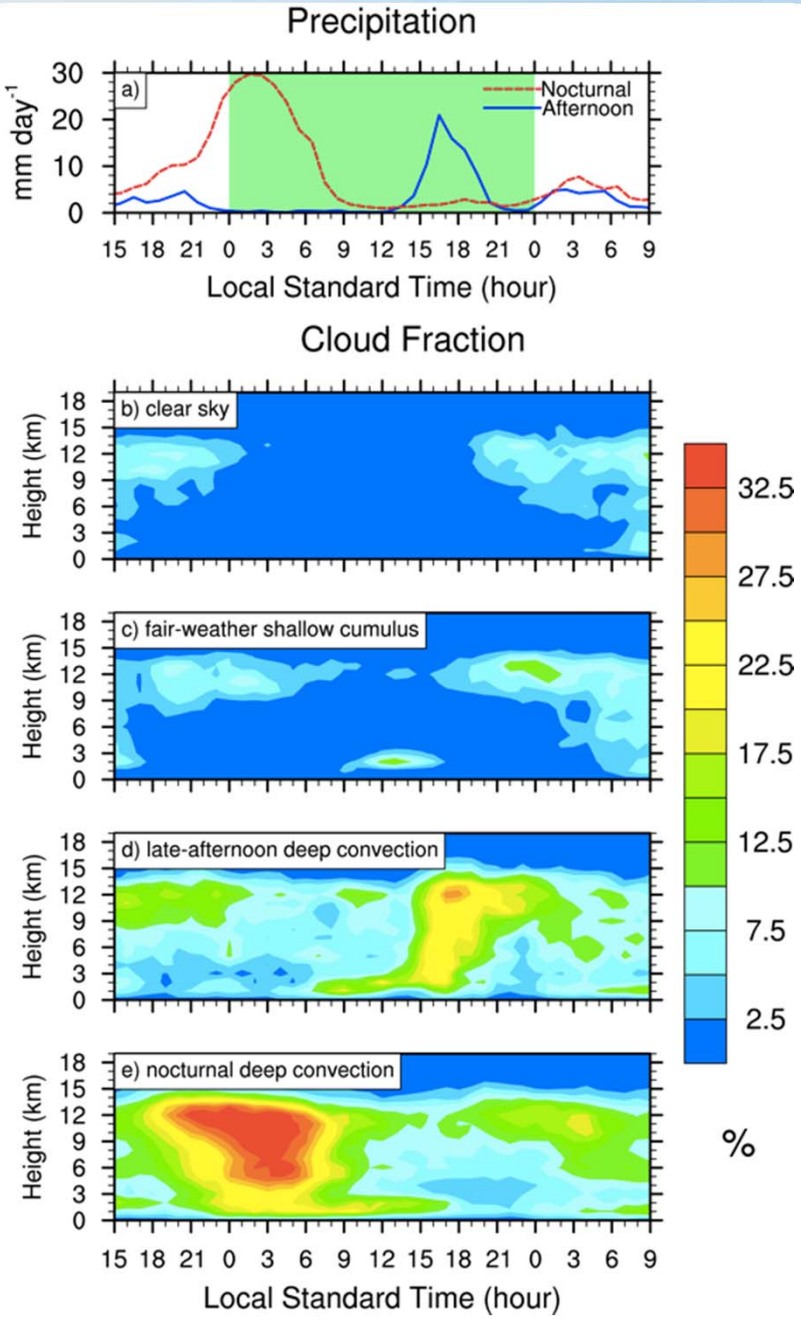
Observational data provides a grounding for physical understanding that leads to improvement of GCM processes

Diagram source: Pier Siebesma

Cloud Processes

Merged data products such as the Climate Modeling Best Estimate (CMBE) facilitate complex analyses involving multiple parameters or both observations and model data.

Zhang and Klein (2010; JAS) used CMBE and other data sets to explore the factors associated with the transition from shallow to deep convection over the SGP.



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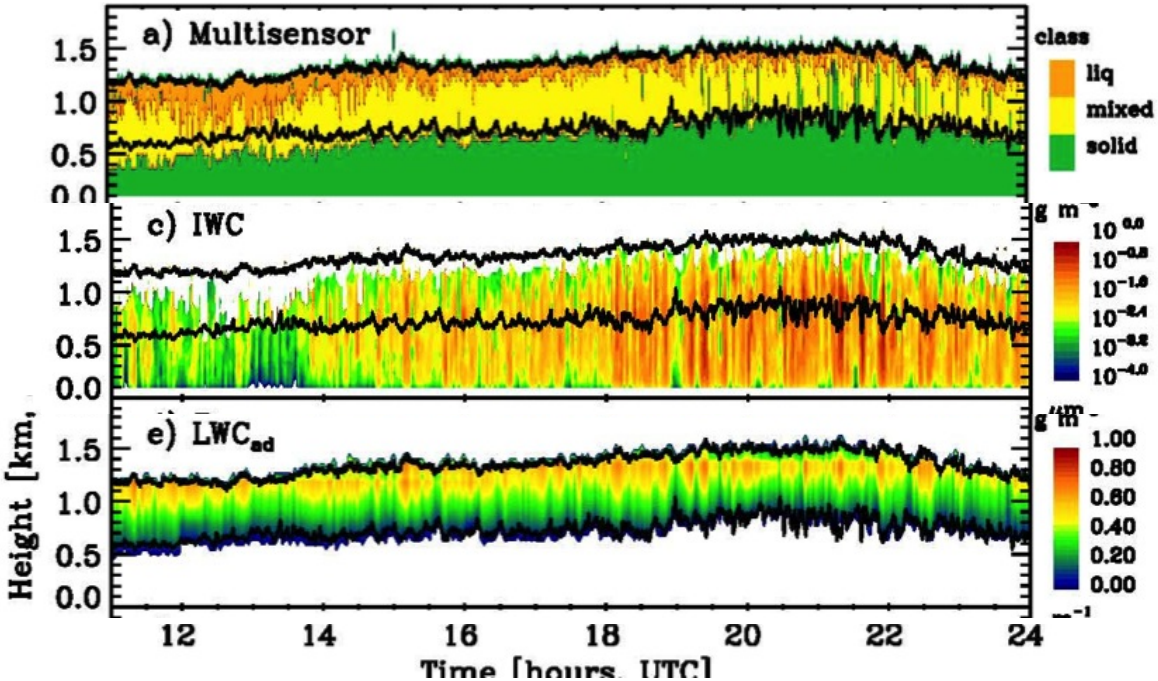
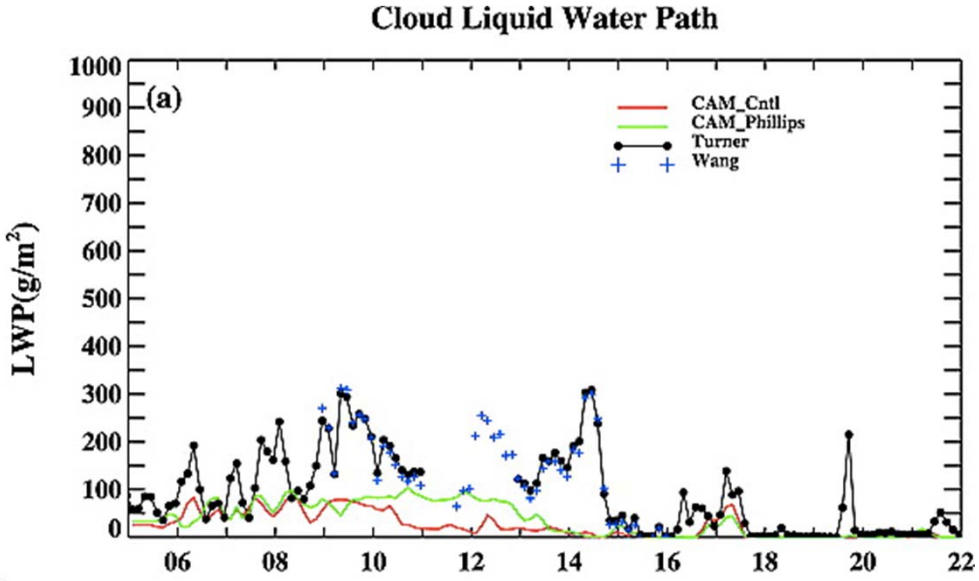
Arctic Mixed-Phase Clouds

Significant advances in ability to measure mixed-phase cloud properties using airborne measurements from two campaigns and combinations of ground-based sensors (Shupe et al., 2008 (BAMS; right); de Boer, 2011 (GRL)



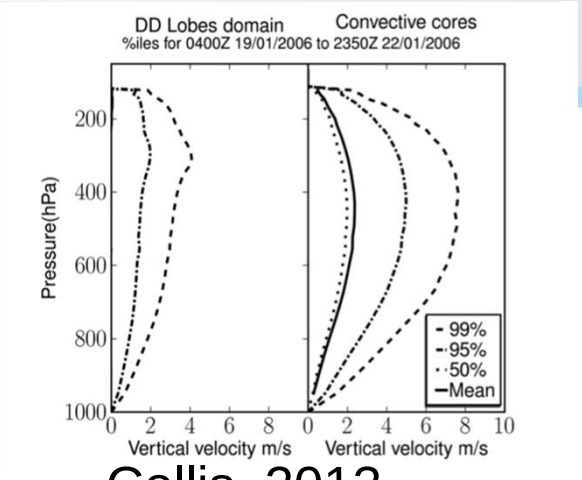


Modeling studies have advanced understanding of mixed clouds (e.g. Morrison et al 2009) and have improved their representation in GCMs (Liu et al 2009; left)

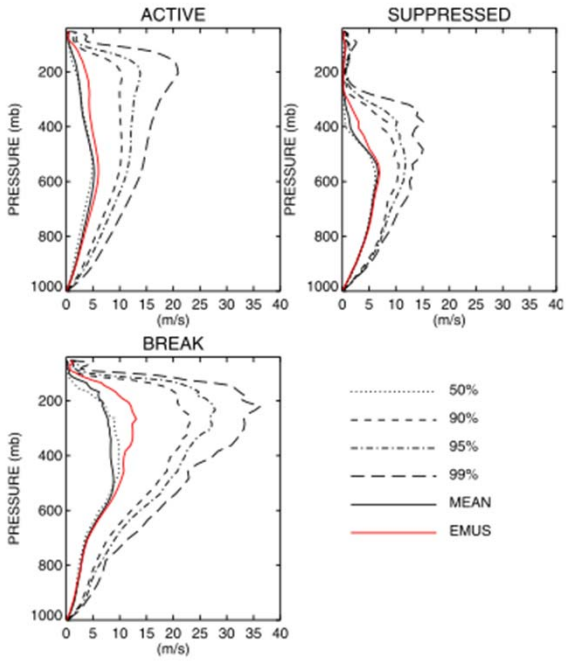
Tropical Convection

The 2006 Tropical Warm Pool International Cloud Experiment has led to over 50 publications ranging from analyses of cloud observations to model studies. Key studies to date include:

- Ice cloud properties from ground-based remote sensors and aircraft
- Vertical structure of heating in deep convection
- Sensitivity of convection in GCMs to mid-troposphere humidity
- Sensitivity of convection in GCMs to model resolution
- Observations of vertical motion in convective cores



Collis, 2013



Wu, 2009

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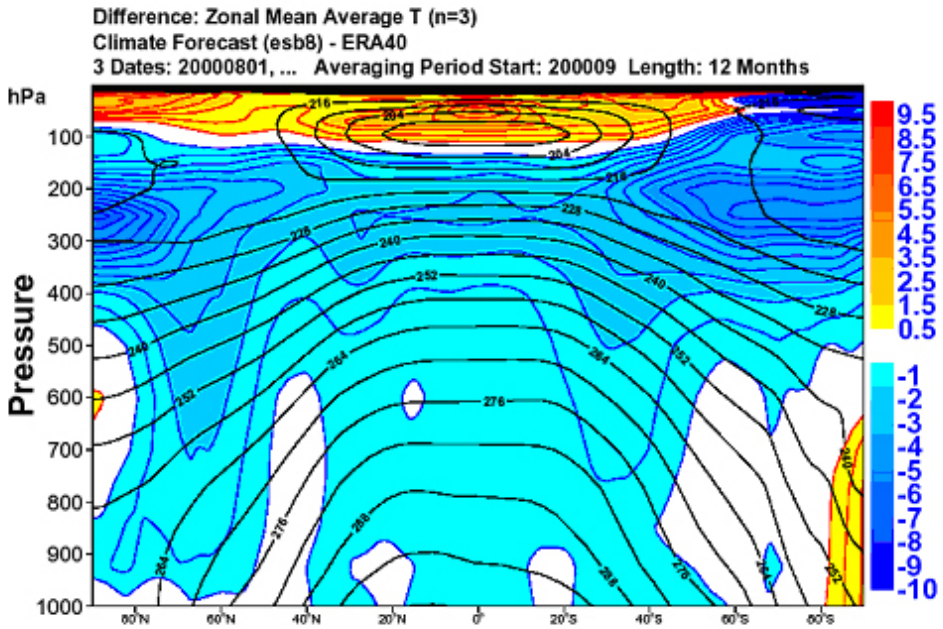
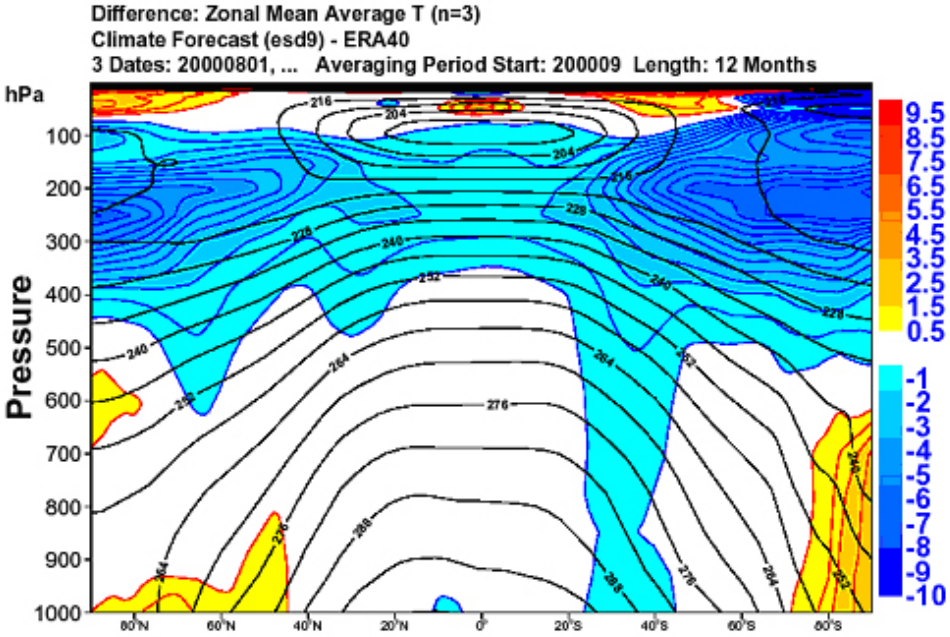
Cloud/Radiation Interactions in Global Models

Use of the RRTMG radiation code plus the Monte Carlo Independent Column Approximation (MCICA) scheme for radiation/cloud interaction in the ECMWF model led to improvements relative to the ERA40 reanalysis (Morcrette et al. and Barker et al. 2008)





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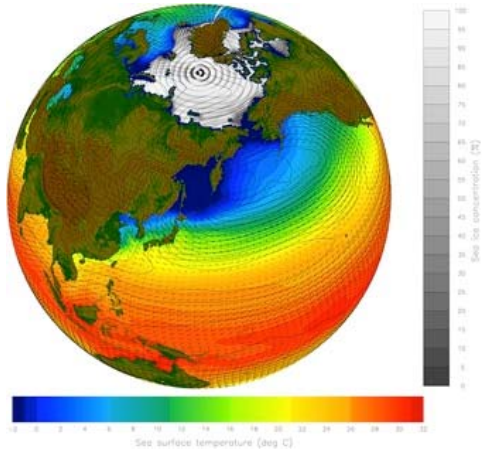
Contributions to the Community Atmosphere Model (CAM) Version 5

- CAM5 has been modified substantially with a range of enhancements and improvement in the representation of physical processes since version 4 (CAM4).



- DOE/ARM contributions to the model include:
  - Rapid Radiative Transfer Method for GCMs (RRTMG)
  - Three-mode modal aerosol scheme
  - Two-mode cloud microphysics scheme
  - Planetary Boundary Layer/Shallow convection scheme
- The ARMBE data product also serves as part of the suite of standard CAM validation data products

User Feedback: 2007/2008 Workshops

- 2007: Provided feedback regarding siting priorities, data infrastructure needs, aircraft measurement needs, and design priorities for a second mobile facility.
  - The 2007 workshop led to design requirements for the second mobile facility and provided important insights into data infrastructure needs.
- 2008: Provided feedback regarding instrument/measurement needs. Needs identified included improved remote sensing to better retrieve cloud properties, scanning capability, improved boundary layer fluxes, and improved aerosol measurements.
  - The 2008 workshop recommendations were the primary source of input for the Recovery Act instrument plan.

Recovery Act

In 2009, ARM received $60M from the DOE Office of Science for investments in instrumentation and research infrastructure to support the instrumentation and the associated increase in data volume and complexity.

http://www.arm.gov/about/recovery-act

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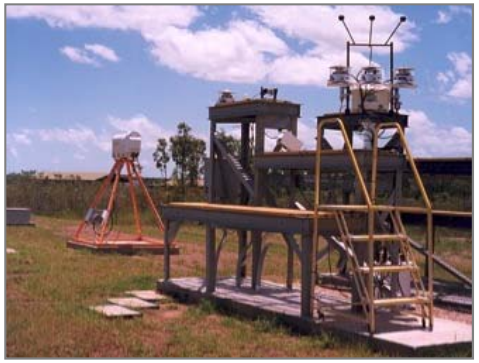
Measurements and Instruments

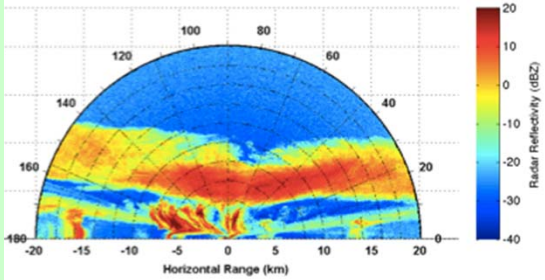
Baseline Capabilities

- Cloud profiles: millimeter radar and lidar
- T/RH/Wind profiles: radiosondes
- Column water: microwave radiometer
- Column aerosol: solar spectral radiometer
- In situ aerosol optical and cloud nucleation properties
- Surface radiation budget
- Surface meteorology



New Measurements as of 2011

- 3-dimensional measurements of cloud properties
- Enhanced measurements atmospheric aerosol absorption, scattering, composition and chemistry
- Improved measurements of humidity and vertical motion
- Expanded capabilities for airborne measurements



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Aerosol Measurements

Aerosol Observing System: Provides measurements of optical properties (scattering and absorption) and CCN concentration: Southern Great Plains, Barrow (with NOAA), **Darwin**, AMF1, **AMF2**

Mobile Aerosol Observing System: Provides measurements particle size distributions and composition.
Instruments include:

- Single Particle Soot Photometer (SP2)
- Photon Transfer Reaction Mass Spectrometer (PTRMS)
- Particle-into-Liquid Sampler (PILS)
- Aerosol Chemistry Speciation Monitor (ACSM)
- Ultra-High Sensitivity Aerosol Spectrometer (UHSAS)

Initial deployment at Brookhaven National National Laboratory – summer, 2011

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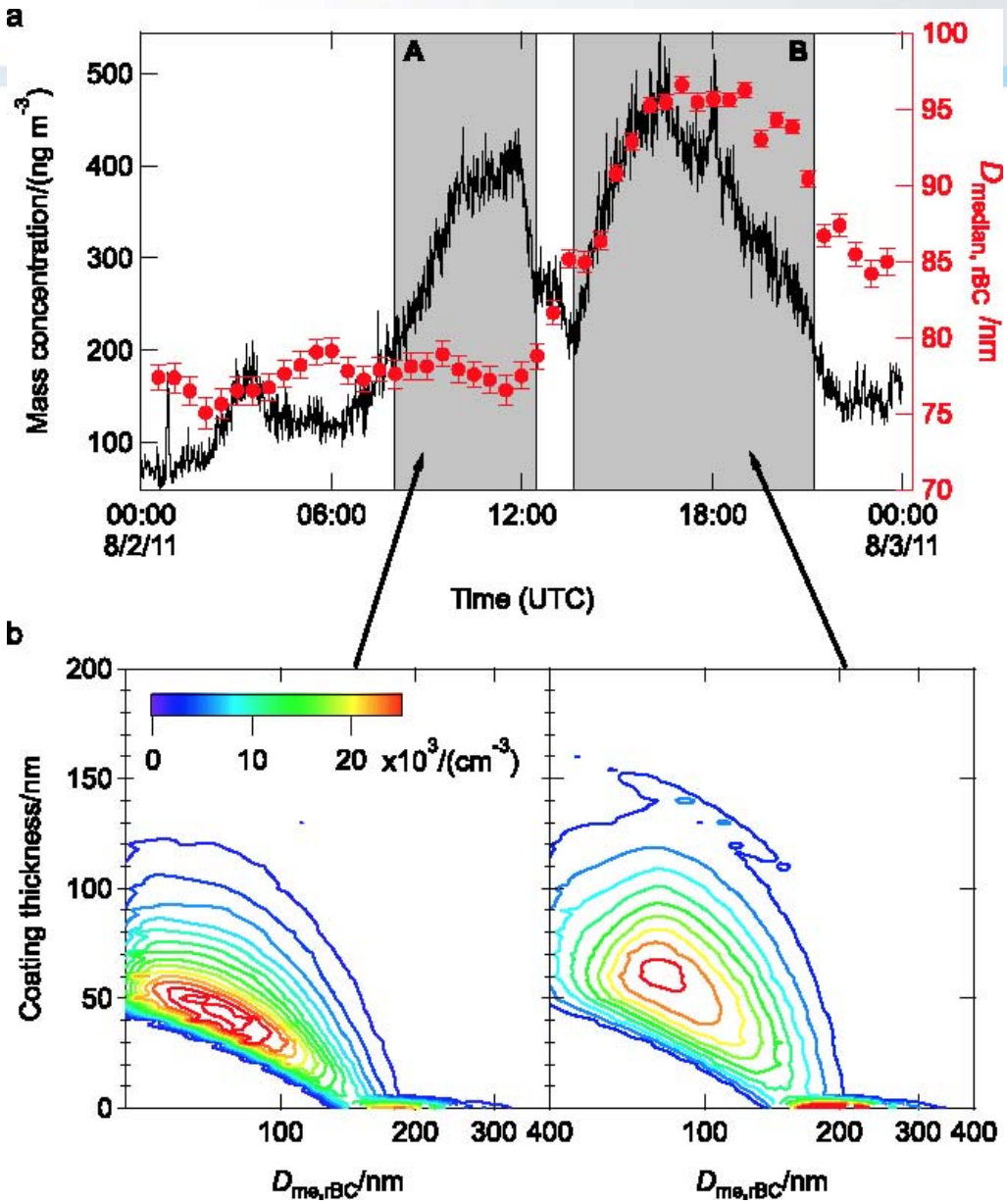
Mobile **Aerosol Observing System (MAOS)**

MAOS provides a suite of instruments to address science questions posed by aerosol and aerosol-cloud interaction field campaigns

- Carbonaceous aerosols and secondary organic aerosol formation
- Optical properties – absorption and scattering
- Size distribution from 10 to 3000 nm
- Relationships between trace gases and aerosols
- Cloud condensation nuclei



Carbonaceous aerosol observations from the Single Particle Soot Photometer (SP2); Sedlacek et al., 2012

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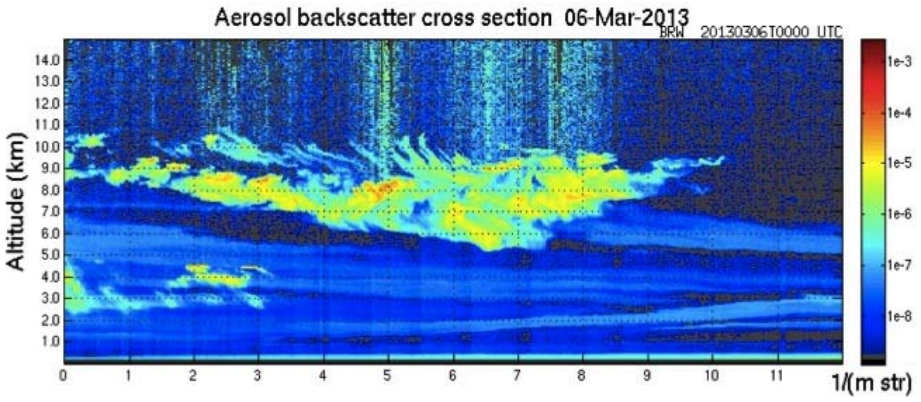
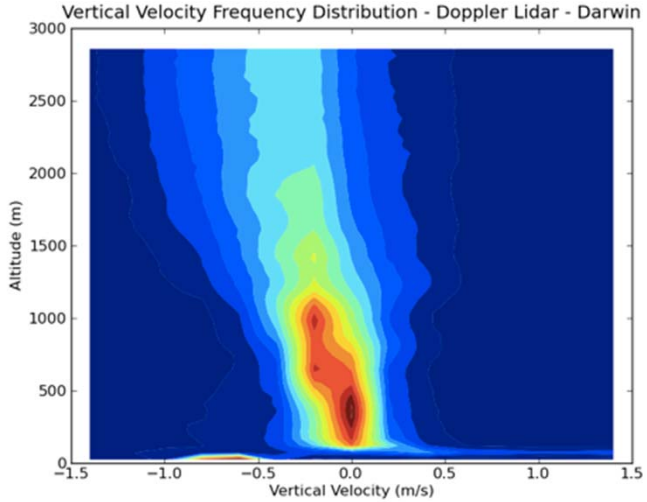
HSRL, Raman, and Doppler Lidars



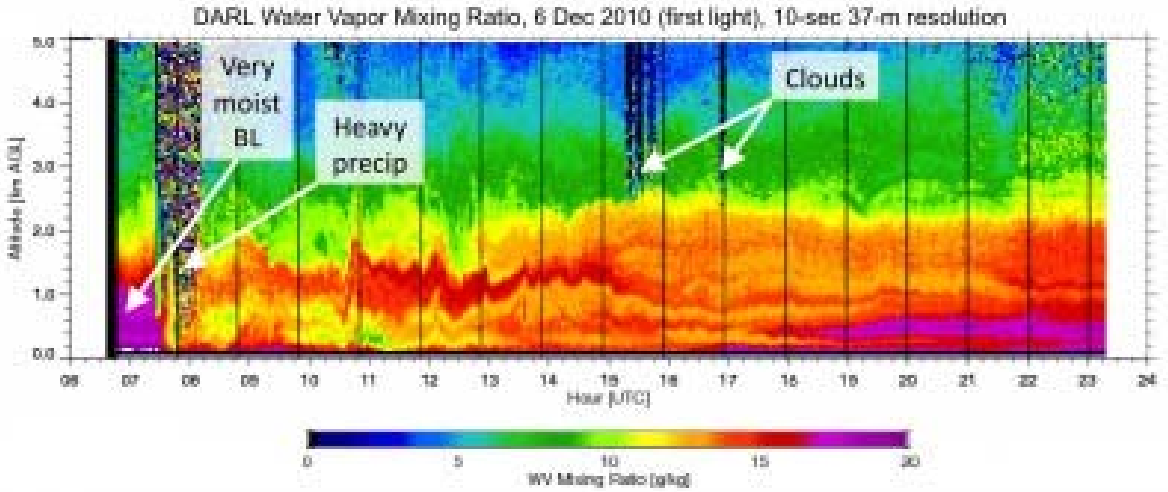
Aerosol backscatter from Barrow, AK, March 2013

- HSRL located at Barrow and 2nd mobile facility
- HSRL provides aerosol extinction and liquid/ice discrimination in thin clouds



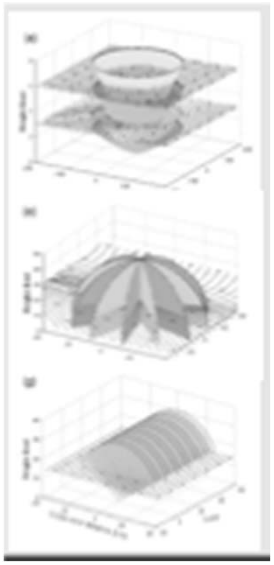
PDF of vertical velocities from the Darwin Doppler Lidar from Feb 2011.

- Doppler/Raman at Darwin and SGP
- Provides means to study details of convection, water vapor profiles and fluxes
- Raman also provides improved sensitivity (over MPL) to optically thin tropical cirrus



Water vapor mixing ratio from Darwin ARM site from Dec. 2010 (Plot courtesy Dave Turner).

mm/cm-Wavelength Radars



Cloud-Detecting mm-wavelength radars include:

- Zenith-pointing Ka (35 GHz) and W (94 GHz)
- Scanning Ka/W or Ka/X (10 GHz)

Scan geometries sample cloud properties and 3-D structures with modes including:

- Zenith-pointing
- PPI (conical scan)
- Horizon to horizon scans
- Volume sector scans

cm-wavelength radars focused on precipitation and storm dynamics are deployed at Oklahoma (X and C-band) Barrow (X-band), and Manus (C-band).

The combination of radars at multiple wavelengths with lidars gives profiles of particles from aersosols to clouds to precipitaiton.

Radar Science and Operations Group

Operations Team

Manages day-to-day operations, technical advances, procurements

- Engineering/lead radar points of contact
- Site operations
- Data Quality Office
- Product development

Ensure dialog between operations and science through:

- Clear structure/roles
- Monthly meetings/reports
- Annual workshop
- Clear goals/expectations

Science Team

Liaison to science community, provides recommendations for science needs/priorities, assists with quality assessment

- Steering committee
- Product liaisons/"translators"

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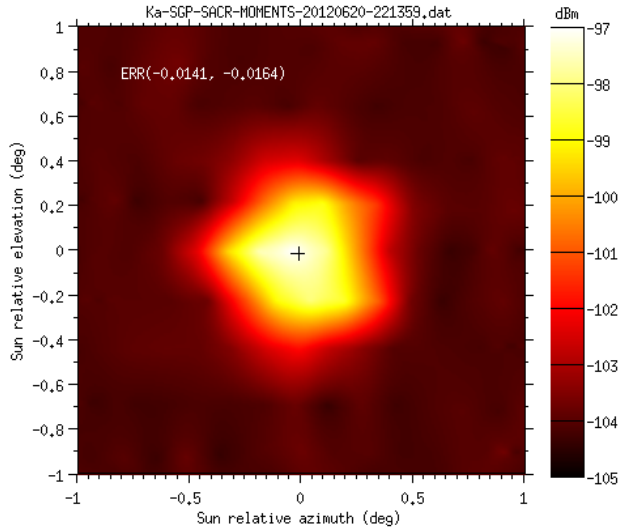
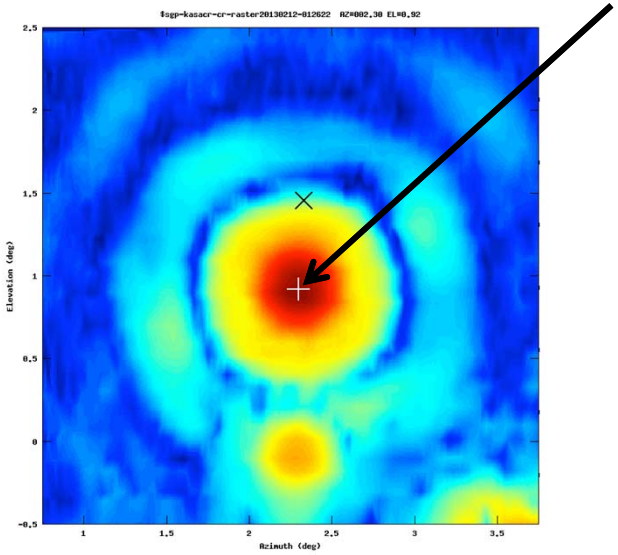
Radar Calibration

- The Sun can be used to calibrate the absolute position of the pedestal
- The location of the sun is well know for a given geo-location
- The Sun is also a noise source which can be observed with the radar



Observation of sun for maintaining pointing accuracy. The observation is with Ka-SACR.

Corner reflector with good Signal to Clutter Ratio (SCR)



- A corner reflector mounted on a tower is used to calibrate scanning radars
- Raster scans also provide detailed information about the antenna pattern
- Operation of a scanning radar next to a zenith-pointing instrument provides a transfer standard

Source: Nitin Bharadwaj.

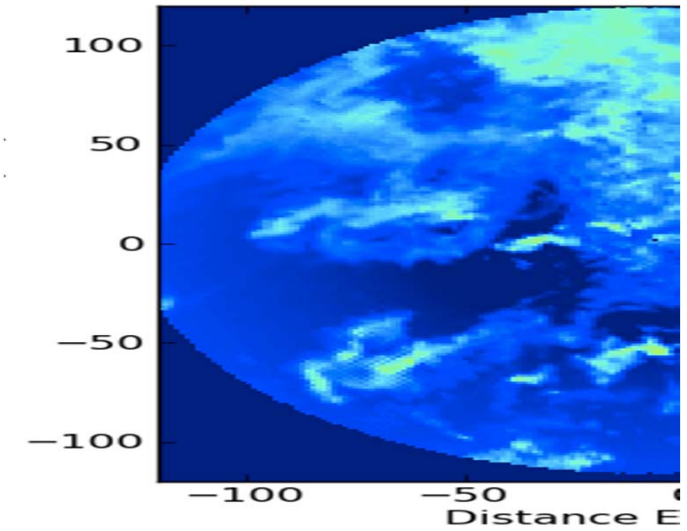
Upcoming Activities

- Maturation of applications for new instruments
- Focus groups
  - Vertical Velocities
  - Quantification of Uncertainties In Cloud Retrievals
- Upcoming AMF Deployments
- Collaborative activities with the European Union
- New Sites

Radar Data Products/Development

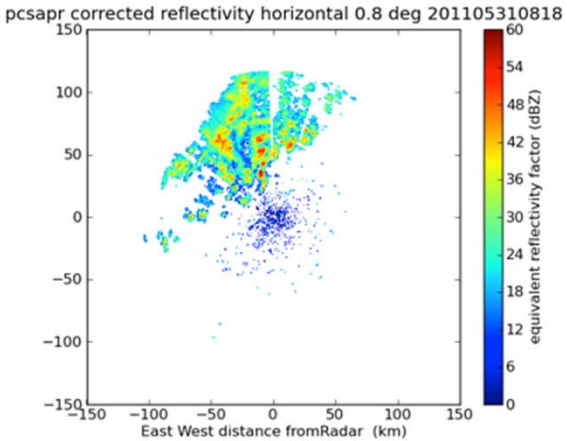
Cloud (mm-wavelength) Radars

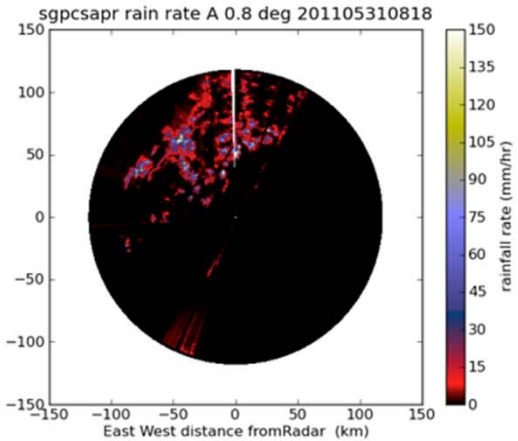
- Cloud mask for upgraded zenith-view cloud radar
- 3-D cloud mask for scanning cloud radars
- Corrections for attenuation and velocity folding
- Optimization of radar scanning modes



Precipitation (cm-wavelength) radars

- Gridded precipitation from X and C-band radars
- Multi-Doppler storm dynamics





Corrected Moments in Antenna Coordinates (CMAC)

- Correct for velocity aliasing
- Correct polarimetric parameters
- Correct for liquid path attenuation
- estimate rainfall rates using the specific attenuation.

(Scott Collis)

Vertical Velocity

Vertical motion is central to many atmospheric science issues and particularly the cloud life cycle. New measurement capabilities puts in reach the ability to characterize vertical motion like never before:

- Radars scanning broad range of frequency make it possible to study precipitating and non-precipitating clouds
- Doppler lidars probe clear air below cloud base
- Array of data products coming on-line to capitalize on these measurements
- Special session at this year's AGU will explore measurement techniques and applications of these measurements.

Addressing Uncertainties in Cloud Retrievals and Other Parameters

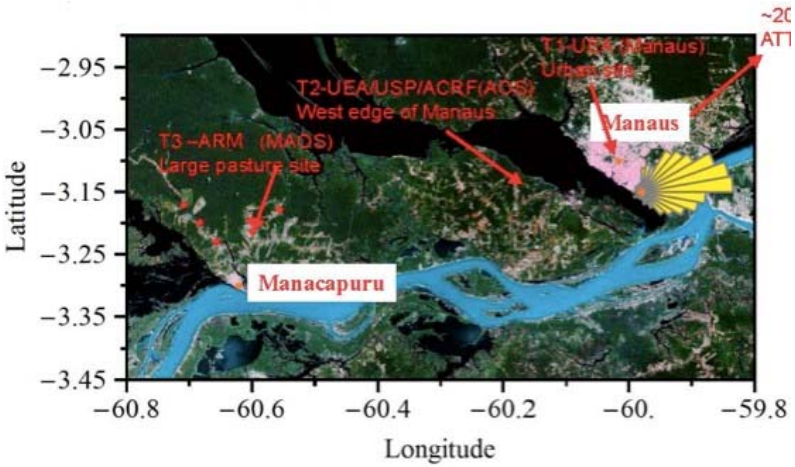
We are working to better document and communicate measurement uncertainties. Recent activities include:

- Collection of instrument level uncertainties from all instrument mentors. Documentation of this process is on-going.
- Applications of machine-readable Data Quality Reports (DQRs) and associated web services.
- Joint ARM/ASR focus group for the Quantification of Uncertainties in Cloud Retrievals (QUICR).

GOAmazon – Collaborative Research in a Tropical Rainforest

The Next deployment of the first AMF will be to Manaus, Brazil in the heart of the Amazon to study anthropogenic and biogenic aerosols and their effect on tropical convection. GOAmazon begins in January 2014 and will run for two years. Both GOAmazon and TCAP include the following observation systems:

- AMF1
- AAF G1 Aircraft
- Mobile Aerosol Observing System



Additional partnerships with CESD modeling and Terrestrial Ecosystems, EMSL, partners in Brazil, as well as other agencies and nationalities

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Second ARM Mobile Facility: Biogenic Aerosols

The next AMF2 campaign will be to study Biogenic Aerosols – effects on clouds and climate at the Hyytiala field station north of Helsinki.

Hyytiala has a long history as a terrestrial ecosystem research facility. Recent study (Nature Geo., 2013) suggests negative climate feedbacks from biological processes. ARM data will help to test this.

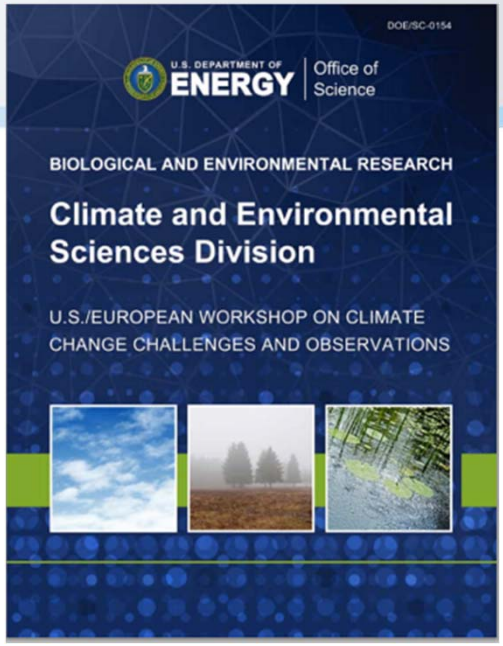
The site is also part of Pan-Eurasia Experiment (PEEX), an iLEAPS coordinating regional climate research.

Picture: Nicki Hickmon

http://www.atm.helsinki.fi/peex/

2012 DOE/European Workshop

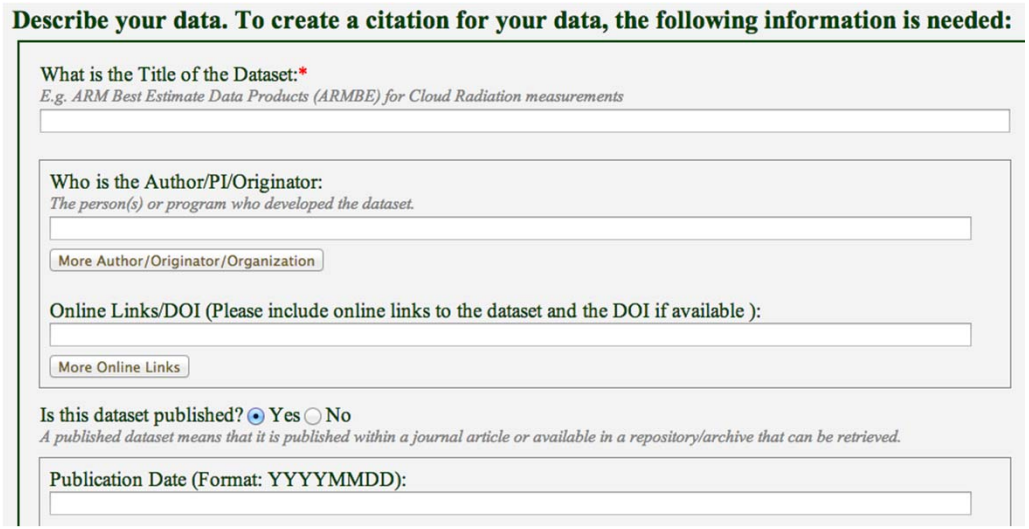
In November 2012 the US Department of Energy hosted a workshop with colleagues from the European Union. The purpose of the workshop was to identify strategies for advancing the application of ground-based remote sensing measurements to key atmospheric science research problems.



Key outcomes from the meeting included plans for joint efforts related to:

- Cloud retrievals
- Radar calibrations
- Microwave radiometry
- Model forcing data sets
- A common data portal
- LES model simulations
- Field campaigns

http://science.energy.gov/~/media/ber/pdf/CESD_F workshop_report.pdf


Describe your data. To create a citation for your data, the following information is needed:

What is the Title of the Dataset:*
E.g. ARM Best Estimate Data Products (ARMBE) for Cloud Radiation measurements

Who is the Author/PI/Originator:
The person(s) or program who developed the dataset.

More Author/Originator/Organization

Online Links/DOI (Please include online links to the dataset and the DOI if available):

More Online Links

Is this dataset published? Yes No
A published dataset means that it is published within a journal article or available in a repository/archive that can be retrieved.

Publication Date (Format: YYYYMMDD):

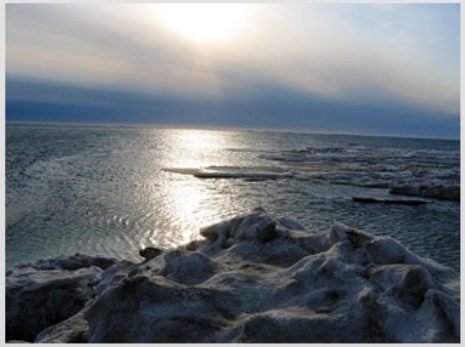
On-line Meta-data Editor (OME)

Two New ARM Sites in 2013

Azores

The ***Azores*** are an island group in the **Eastern North Atlantic (ENA)** ocean in a region characterized by marine stratocumulus. Marine stratocumulus have a strong influence on climate yet are poorly represented in global climate models.

Led by Kim Nitschke at Los Alamos National Laboratory



Oliktok Point

The ***Oliktok Point*** site is located approximately 300 km Southeast of the existing ARM site in Barrow and provides an opportunity to link coastal conditions from the standard ARM measurement suite with near-coast conditions using an ***Unmanned Aerial System*** (UAS).

Led by Mark Ivey at Sandia National Laboratory

- Sites scheduled to come on line by September 2013
- The facility at Oliktok Point is a mobile facility deployed for an extended term
- Instruments at these sites match those found at other sites including many of the enhancements added through the Recovery Act and plans to add Unmanned Aerial component at Oliktok – workshop planned for July

For More Information on ARM

- Description of sites, instruments, data
- Upcoming campaigns
- Science highlights
- ARM News (subscribe to RSS feed); proposal and job opportunities
- Social Media: Facebook, YouTube, Flckr, Twitter
- Contacts

Visit the ARM website: http://www.arm.gov