ARM Sites Report

ARM Sites Update

ARM Facility Reconfiguration - Doug Sisterson
MAWS at all ARM Sites - Donna Holdridge
RS41-RS92 comparison at SGP – Donna Holdridge
CFH launches at SGP – Martin Stuefer
Lidar Operations at ARM Sites – Rob Newsom
ARM Climate Research Facility Update

Mission
The ARM Climate Research Facility, a US 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.
ARM Instrument Mentors

ARM contracts ~50 Instrument Mentors to oversee the operation, documentation, training of local site operations personnel, calibration, and data quality of all the ARM Facility Instruments

- more than 325 individual instruments
- representing nearly 3,000 total data streams
- representing up to ~1 TB of data per day
ARM Three Fixed Sites - ENA

Eastern North Atlantic (ENA) Locale
Azores – Graciosa Island
Established in late 2013

The Azores are a region characterized by marine stratocumulus clouds, a major source of uncertainty in global climate models.


**Atmospheric and boundary state systems:** surface meteorological instrumentation, boundary layer cloud system, total sky imager, weighing bucket rain gauge, total precipitation sensor, eddy correlation flux measurement system, and disdrometer

**Lidars:** micropulse lidar and Doppler lidar

**Radars:** zenith cloud radar, scanning cloud radar, scanning precipitation radar, and radar wind profiler

**Radiometers:** atmospheric emitted radiance interferometer, microwave radiometer, 3-channel microwave radiometer, multifilter rotating shadowband radiometer, pyranometer, pyroheliometer, pyrgeometer, and blackbody calibration system.
Instrument systems at NSA include solar and infrared broadband radiometric instruments, a Fourier transform infrared radiometer, cloud lidars and radars, a radar wind profiler, a radiosonde system, a sky imager, and a microwave radiometers. Recent additions include three new dual-frequency scanning cloud radars that provide three-dimensional information about cloud properties, an eddy correlation (ECOR) flux measurement system and complementary surface energy balance system (SEBS); high spectral resolution lidar; and a launching system for automated release of weather balloons.
ARM Three Fixed Sites – SGP

Southern Great Plains (SGP) Locale

The SGP Site is a study area that consists of ~25-30 in-situ and remote-sensing instrument clusters arrayed across approximately 143,000 square kilometers in north-central Oklahoma.
The SGP: Flagship for ARM

• SGP site: first field measurement site established by DOE's ARM Program (1992-1995)

• Largest site: *in situ* and remote-sensing instrument clusters arrayed across approximately originally 143,000 square kilometers in north-central Oklahoma and south-central Kansas

• Largest of the ARM facility fixed sites

• Heart of the SGP site: most heavily instrumented central facility, on 160 acres southeast of Lamont, Oklahoma

• Subcontracted staff of 30 technicians ensure the operation, calibration, and maintenance of instruments and collection of data from the central facility instruments and from smaller, unstaffed facilities throughout the site
SGP Site History 1992-2010

- Initial layout configured to challenge global climate model (GCM) and other climate models
- Focused on improving radiation transfer under clear skies at the global scale

1992–2010: SGP study area established; measured 325 by 275 km
SGP Site Reconfiguration 2010

From Soda Straw to 4D

Improved models were used to reconfigure SGP footprint, combine instrumentation in 3-D spatial arrays to continue to challenge GCM and climate models at finer grid scales; changes focusing on improving cloud and aerosol parameterizations at the regional scale.

2010–2013 SGP study area was reconfigured to 150 by 150 km
The SGP Central Facility

Looking Southwest from the Raman Lidar location
The SGP Central Facility

Looking WNW from the Optical Trailer

Looking E from the Aerosol Trailer

Looking N from the Eddy Correlation location.

Looking S from the Optical Trailer
The SGP Central Facility Layout

For the most current list of instruments at the SGP Central Facility, Intermediate Facilities, and Extended Facilities, please go to:

http://www.arm.gov/sites/sgp/instruments
The ARM Facility is now embarking on a reconfiguration strategy for even better observations of atmospheric processes to constrain high-resolution process models. Key elements of the new strategy include the creation of two "super sites" in the United States.

**Southern Great Plains** – measurements at the SGP Site will be augmented to include additional scanning and profiling remote sensors and more detailed measurements of the land-atmosphere interface that support high resolution climate modeling.

**North Slope of Alaska** – aerial operations will link the measurements from Barrow and Oliktok, and unmanned aerial systems will provide additional spatial information around Oliktok.
From Observations to Models

ARM Next-Generation Processing Concept

1. Measurement Strategy Evaluation and Refinement
   - ARM High-Resolution Measurement Strategy
     (5 -> 15 -> 40 -> 200 km Scales)
   - Create Measurement Representation
     in an adaptable, 4-Dimensional State
     Space with Uncertainty Quantification by an
     integrated high-res/model-ons assimilation system
     (100 m minimum resolution)

2. Acquisition and Formatting of Necessary External Data

3. Model Refinement
   - Forcing and Data Assimilation
   - Model Structure, Configuration and Physics
   - Produce Statistical Summaries of Observations and
     Uncertainties
   - System and Error Analysis (Parametric and Structural)

4. Transform Measurements and Uncertainties for Objective Analysis/Data Assimilation to
   provide Initial Conditions, Forcing, and Evaluation Data

5. Multi-Scale Modeling Infrastructure
   - Large Eddy Simulation Scale (1 to 200 m)
   - Cloud Resolving Model Scale (1 to 4 km)
   - Mesoscale Model Scale (4 to 20 km)
   - Single Column Model (100km)
   - General Circulation Model Scale (10 to 100 KM) [NCEP, ECMWF Forcing]

6. ARM High-Resolution Measurement Strategy
   (5 —> 15 —> 40 —> 200 km Scales)

7. Surface Characteristics
   Surface and Boundary Layer
   Tropospheric Thermodynamics
   Clouds/Aerosols

8. ARM High-Resolution Measurement Strategy
   (5 -> 15 -> 40 -> 200 km Scales)

   - Observation System Simulation Experiments (OSSE)
Summary

- The TWP fixed sites (Manus Island, PNG; Nauru; and Darwin, AUS) were decommissioned in 2014.
- The ENA (Azores, Graciosa Island) fixed site was implemented in 2013.
- The NSA (Barrow) is still a fixed site with the addition of the Oliktok mobile facility for long-term deployment with routine manned and unmanned aircraft flights being planned between the two sites.
- The SGP will have a dense array of significantly more instrument clusters, but the Central Site in Lamont will not be changed.
MAWS Upgrade to ARM DigiCORA Systems

Donna Holdridge, Argonne National Laboratory
Jenni Kyrouac, Argonne National Laboratory

Presented at
GRUAN-ICM7 Meeting
23-27 Feb 2015
Matera, Italy
### Surface Measurement Configuration

**ARM Southern Great Plains Site**

<table>
<thead>
<tr>
<th>Site</th>
<th>Deployed</th>
<th>T/RH</th>
<th>Pressure</th>
<th>Winds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>THWAPS</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>SGP</td>
<td>09/2005 – 09/2014</td>
<td>SURTHREF</td>
<td>Vaisala Model PTB201A Digital Barometer</td>
<td>R.M. Young Model 05103 Wind Monitor</td>
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<td></td>
<td>THWAPS SURTHREF</td>
<td>Average of 6 probes: 3 - Vaisala HMP-45D T/RH probes 3 - Rotronic MP100H T/RH probes</td>
<td></td>
<td></td>
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<tr>
<td>SGP</td>
<td>09/2014 – present</td>
<td>Vaisala Model HMP155 T/RH Probe</td>
<td>Vaisala Model PTB330 Digital Barometer</td>
<td>Vaisala Model WMT700 Ultrasonic Wind Sensor</td>
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<tr>
<td></td>
<td>MAWS301</td>
<td></td>
<td></td>
<td></td>
</tr>
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</table>
## Surface Measurement Configuration
### North Slope of Alaska Barrow Site

<table>
<thead>
<tr>
<th>Site</th>
<th>Deployed</th>
<th>T/RH</th>
<th>Pressure</th>
<th>Winds</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSA</td>
<td>03/1998 – 09/2008</td>
<td>Vaisala Model HMP45D</td>
<td>Vaisala Model PTB201A</td>
<td>Vaisala Model WAA251 Anemometer</td>
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<tr>
<td></td>
<td></td>
<td>T/RH Probe</td>
<td>Digital Barometer</td>
<td>Vaisala Model WAV151 Wind Vane</td>
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<tr>
<td></td>
<td>09/2008 - Present</td>
<td>Vaisala Model HMT337</td>
<td>Vaisala Model PTB220</td>
<td>Vaisala Model WS425 Ultrasonic</td>
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<tr>
<td></td>
<td></td>
<td>T/RH Probe</td>
<td>Digital Barometer</td>
<td>Wind Sensor</td>
</tr>
<tr>
<td>NSA Autosonde</td>
<td>06/2009 - Present</td>
<td>Vaisala Model HMP155</td>
<td>Vaisala Model PTB220</td>
<td>Vaisala Model WS425 Ultrasonic</td>
</tr>
<tr>
<td></td>
<td>MAWS</td>
<td>T/RH Probe</td>
<td>Digital Barometer</td>
<td>Wind Sensor</td>
</tr>
</tbody>
</table>
# Surface Measurement Configuration

**ARM Tropical Western Pacific Sites** (*decommissioned*)

<table>
<thead>
<tr>
<th>Site</th>
<th>Deployed</th>
<th>T/RH</th>
<th>Pressure</th>
<th>Winds</th>
</tr>
</thead>
<tbody>
<tr>
<td>TWP*</td>
<td>08/1996 – 12/2011</td>
<td>BOM AWS</td>
<td>BOM AWS</td>
<td>BOM AWS</td>
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</table>

**ARM Eastern North Atlantic Site**

<table>
<thead>
<tr>
<th>Site</th>
<th>Deployed</th>
<th>T/RH</th>
<th>Pressure</th>
<th>Winds</th>
</tr>
</thead>
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## Surface Measurement Configuration
### ARM Mobile Facility Sites

<table>
<thead>
<tr>
<th>Site</th>
<th>Deployed</th>
<th>T/RH</th>
<th>Pressure</th>
<th>Winds</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMF1</td>
<td>02/2005 - Present</td>
<td>Vaisala Model HMP45D T/RH Probe</td>
<td>Vaisala Model PTB220 Digital Barometer</td>
<td>R.M. Young Model 05106 Wind Monitor</td>
</tr>
</tbody>
</table>
Vaisala MAWS301
Automated Weather Station - Summary

- To standardize all sonde surface measurements
- To remove operator error
- Vaisala MAWS301 systems acquired for all ARM sites
- Simple interface with DigiCOR
- Automatically provides surface measurements within GUI
- WMT700, HMP155, PTB330, QML201 Datalogger
- Currently, only SGP has been upgraded
- The rest of the MAWS are planned to be installed this year and next year.
Comparison of Vaisala Radiosondes RS41 and RS92 at the Southern Great Plains Site

Michael Jensen, Brookhaven National Laboratory
Donna Holdridge, Argonne National Laboratory
Petteri Survo, Vaisala, Oyj
Raisa Lehtinen, Vaisala, Oyj

Presented at
GRUAN-ICM7 Meeting
23-27 Feb 2015
Matera, Italy
Overview of Launches

- June 3 – 7, 2014
- ARM Southern Great Plains Site  Lamont, Oklahoma
- 20 comparison launches; 14 daytime, 6 nighttime
Launch Configuration

- MW31 and MW41 systems
- Shared one antenna set-up
- 600g balloons
- Totex parachutes
- Ozone Unwinder – 30m
- Wooden Rigging
- 20 launches of RS92/RS41 pairs
Launch Configuration

Images: Petteri Survo and Michael Jensen
Preliminary Results

Plots: Raisa Lehtinen
Preliminary Results cont.

- Mean **temperature** differences were within ±0.1 °C. There were a few cases with larger differences, typically related to challenging conditions such as the radiosondes emerging from a cloud, or large gradients in the profiles.
- Mean **humidity** profiles agreed to within ±2.1% RH. The largest differences were observed at altitudes of 8 to 12 km, with RS92 measuring 1.6 – 2.1% RH lower humidity levels.
- Mean **pressure** differences were within ±0.2 hPa in altitudes above 2 km. Near-ground mean difference between RS41 and RS92 was 0.4 hPa.
- Zonal and meridional **wind** components were within ±0.05 m/s, with standard deviation of differences within 0.26 m/s.
Conclusions

- The RS41 and RS92 radiosondes showed very similar results for all measured quantities.
- The observed differences between RS41 and RS92 are within the measurement uncertainty for all variables, and similar to those reported from previous campaigns arranged by UK MET Office and Czech Hydrometeorological Institute.
- Other ARM instrumentation measurements are being used to interpret results.
- The complete technical report should be completed in the next few months.
- The ARM Program is planning to move forward with acquisition of the MW41 upgrade, but the transition plan from RS41 to RS92 sondes has not yet been developed.
CFH Launches at ARM Southern Great Planes Site at Lamont, Oklahoma

Martin Stuefer, University of Alaska Fairbanks, CFH mentor
Donna Holdridge, ARM – Argonne National Laboratory
Jenni Kyrouac, ARM - Argonne National Laboratory
Doug Sisterson, ARM - Argonne National Laboratory
Howard Diamond, NOAA
ARM CFH Mission / Facts

- Provide long-term quality and well documented CFH measurement data.
- One CFH sounding per month.
- Howard Diamond, through NOAA funds CFH launch hardware.
- ARM provides mentorship oversight and ‘manpower’ for the efforts associated with the CFH sonde preparation and launches.
- Improve and evaluate the procedures for CFH launches at the SGP facility.
- Evaluate CFH launch logistics for use at other ARM launch sites (i.e. Barrow, Alaska) in the future.
Site location and Launch history

- Lamont, OK, 36°36'18.0" N, 97°29'6.0" W, 320 m a.s.l.
- Launch procedures from GRUAN Lead Center
- Three launches so far:
  - Sept. 11, 2014
  - Nov. 24, 2014
  - Feb. 12, 2015
- CFH are checked and adjusted with CFH setup
- Launches will be performed monthly
Launch package

- Cryogenic Frostpoint Hygrometer from Droplet Measurement Technologies (DMT)
- InterMet IMet1 RSB
- Vaisala RS92 radiosonde
RS92 calibration

- Factory
- Ground check with Vaisala GC25 prior to each launch
RH Example

2014-09-11: RH CFH (blue) versus RH (RS92)
RH Example

2014-09-11: RH CFH (blue) versus RH (RS92)

2014-11-26: RH CFH (blue) versus RH (RS92)
To Do

- Refine launch procedures for ARM operators
- CFH Handbook
- Produce baseline CFH humidity measurements
- Define uncertainties
- Work towards GRUAN certification
- Data processing: ARM DMF ↔ GRUAN Lead Center
  RS launch client
Acknowledgements

- Chris Martin – ARM SGP operations
- Dave Breedlove – ARM SGP operations
- John Schatz – ARM SGP operations
- Matthew Gibson – ARM SGP operations
- James Martin – ARM SGP operations
- Nicki Hickmon - ARM SGP operations
- Mike Ritsche - ARM SGP operations
- George Sawyer - ARM SGP operations
- Jody Martin - ARM SGP operations

- Holger Vömel – NCAR
- Michael Sommer – GRUAN Lead Center
Lidar Systems at the US Department of Energy’s Atmospheric Radiation Measurement Sites

R. K. NEWSOM*

*Pacific Northwest National Laboratory, WA, USA

GRUAN 7th International Coordination Meeting, Matera, Italy, February 23-27, 2015
ARM Lidars

- ARM operates a number of lidar systems at its fixed and mobile sites around the globe.

- Systems include:
  - “Standard” systems operated at all sites
    - Micropulse lidars
    - Ceilometers
  - “Advanced” Systems operated at selected sites
    - Doppler Lidars
    - Raman Lidars
    - High Spectral Resolution Lidars (HSRLs)
ARM Doppler Lidar Measurements, and Current Deployment Locations

- **Measurements**
  - Clear-air vertical velocity, winds, turbulence, and aerosol backscatter
  - Maximum measurement height is 10 km, but mostly limited to atmospheric boundary layer (< 3km).

- **ARM currently operates 6 Doppler systems at the following sites:**
  - Southern Great Plains (SGP), Oklahoma, USA, 2011 to present
  - Tropical Western Pacific (TWP), Darwin, AU, 2010 through 2014
    - Moved to SGP in 2015
  - 1st ARM Mobile Facility (AMF1)
    - Nainital, India, June 2011 to March 2012
    - Cape Cod, MA, USA, July 2012 to July 2013
    - Manacapuru, Brazil, January 2014 to present
  - North Slope of Alaska (NSA), Barrow, Alaska, USA, 2014 to present
  - 3rd ARM Mobile Facility (AMF3)
    - North Slope of Alaska (NSA), Oliktok Point, Alaska, USA, 2014 to present
  - Eastern North Atlantic (ENA), Graciosa Island, Azores, 2014 to present
ARM Doppler Lidar Deployment Locations
ARM Doppler Lidar Specs

- Manufacturer: Halo Photonics (UK)
- Specs
  - Wavelength: 1.5 μm
  - Pulse width: 150ns (22.5m)
  - Pulse Energy: ~100 μJ
  - Pulse repetition Frequency: 15 kHz
  - Max Measurement Range: 10 km
  - Typical range: ~2-4 km
  - Velocity precision: ~10cm s⁻¹
  - Full upper hemispheric scanning capability
  - Sensitive to aerosol backscatter
- Measurements and Operation modes
  - Vertical staring and PPI scans once every 15 min
  - Typical resolution: 1 sec, 30 m
  - Direct Measurements
    - Radial Velocity
    - SNR
  - Derived Measurements
    - Attenuated aerosol backscatter
    - Winds
    - Vertical velocity statistics
ARM Doppler Lidar Data Products

Vertical Velocity Variance, Skewness and Kurtosis

(a) $<w^2>$ $(m^2 s^{-2})$ for sgolnpt 20140618

(b) Skewness for sgolnpt 20140618

(c) Kurtosis for sgolnpt 20140618

Wind Profiles (15 min, 25 m)
ARM Raman Lidar

- Built by John Goldsmith at Sandia Labs, Livermore, CA, USA
- Specs
  - Transmitter
    - Tripled Nd:YAG (Manufacturer: Continuum)
    - Wavelength: 355 nm
    - Pulse Energy ~300 mJ
    - PRF 30 Hz
    - Pulse width ~5 ns
    - Beam Diameter 13 cm
    - Beam Divergence 0.1 mrad
  - Receiver
    - Primary Telescope diameter 61 cm, f/9.3
    - Field of view: 2 mrad for Wide (WFOV) and 0.3 for narrow (NFOV)
    - PMTs: Electron Tubes 9954B
    - Detection Electronics: Licel Transient Data Recorders
    - 9 Detection channels
      - WFOV unpolarized elastic @ 354.71nm (bandwidth = 0.3 nm)
      - NFOV co-polarization elastic @ 354.71nm (bandwidth = 0.3 nm)
      - NFOV depolarization elastic @ 354.71nm (bandwidth = 0.4 nm)
      - WFOV H2O @ 407.45nm (bandwidth = 0.3 nm)
      - NFOV H2O @ 407.45 nm (bandwidth = 0.3 nm)
      - WFOV N2 @ 386.69 nm (bandwidth = 0.3 nm)
      - WFOV N2 @ 386.69 nm (bandwidth = 0.3 nm)
      - WFOV Rotational Raman 1 @ 353.27nm (bandwidth = 0.2 nm)
      - WFOV Rotational Raman 2 @ 354.27nm (bandwidth = 0.2 nm)
ARM Raman Lidar Specs
ARM Raman Lidar Measurements and Current Deployment Locations

- **Raman Lidars**
  - **Measurements**
    - Water vapor mixing ratio, temperature, aerosol backscatter, aerosol extinction, linear depolarization ratio.
    - Maximum measurement height is ~30 km
    - Incomplete overlap limits the measurement accuracy below ~1 km.
  - **ARM currently operates 3 Raman systems at the following sites:**
    - Southern Great Plains (SGP), Oklahoma, USA, 1996 to present
    - Tropical Western Pacific (TWP), Darwin, AU, 2010 through 2014
      - Moved to ENA in 2015
    - 3rd ARM Mobile Facility (AMF3)
      - North Slope of Alaska (NSA), Oliktok Point, Alaska, USA, 2014 to present
ARM Raman Lidar Deployment Locations
ARM Raman Lidar Data Products

- **Raw Data**
  - Resolution: 7.5 m, 10 sec
  - PMT Analog voltage
  - Photon Counts
  - Photon counting rates from merging analog and photon counts

- **Derived Data Products**
  - Water Vapor Mixing Ratio (75 m, 10 sec and 10 min)
  - Temperature (300 m, 10 and 60 min)
  - Aerosol (75 m, 1 or 2 and 10 min)
    - Extinction coefficient
    - Volume backscatter coefficient
    - Linear Depolarization Ratio
ARM Raman Lidar Data Products

2006

2007

2008

Raman lidar moisture data
14 Nov 2006

16 Nov 2008

Relative humidity

Mixing ratio

Julian Day
ARM High Spectral Resolution Lidar

- Built by Ed Eloranta and team at Space Sciences and Engineering Center, University of Wisconsin, Wisconsin, USA

- Major Specs:
  - Wavelength = 532 nm
  - Min/Max range = 100 m to 30km
  - Time resolution: 2.5 sec
  - Range resolution: 7.5 m
  - Autonomous, 24/7 mode of operation
ARM HSRL Measurements and Current Deployment Locations

- **Measurements**
  - Aerosol backscatter, aerosol extinction, aerosol depolarization ratio.
  - Maximum measurement height is ~30 km
  - In complete overlap limits the measurement accuracy below ~2 km.

- **ARM currently operates 2 HSRL systems at the following sites:**
  - North Slope of Alaska, Barrow, Alaska, USA, 2011 to present
  - 2nd ARM Mobile Facility (AMF2)
    - Steamboat Springs, Colorado, USA, 2010-2011
    - Gan Island, Maldives, 2011-2012
    - Ship-based between CA and HI, USA, 2012-2013
    - Hyytiälä Finland, 2014
    - Ship-based between CA and HI, USA, 2015
HSRL Volume Backscatter Coefficient

NSA log$_{10}$ Particulate backscatter cross section per unit volume at C1 on 20141129

Image provided by the ARM Data Quality Office: 20141202
HSRL Circular Depolarization Ratio

Image provided by the ARM Data Quality Office 20141202
Questions?