ARM Cloud-Aerosol-Precipitation Experiment (ACAPEX)

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Organizing Committee:
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Translating Process Understanding to Improve Climate Modeling
CLIVAR Webinar 23 March 2016
The ARM Climate Research Facility

Atmospheric Radiation Measurement (ARM) is an observation user facility to support DOE’s Climate and Environmental Mission

ARM Mission

Use 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.

www.arm.gov
How much precipitation?

Wind speed, moisture amount, and atmospheric stability are important ingredients for producing heavy precipitation.

- Do models get them right for short term forecasting and projections of future changes?

Observation

Model simulation

NOAA Ron Brown
DOE AMF2
NOAA G-IV
Rain or snow?

Dust is a determinant of rain vs. snow

Snowpack provides water supply in summer

Atmospheric rivers or aerosols?

DOE G1

NOAA P-3

NASA ER-2
Objective: Improve understanding and modeling of the role of atmospheric rivers and aerosols on precipitation in California.
Calwater 2015 key science questions

► Atmospheric rivers
  ▪ How much water vapor is transported by atmospheric rivers and what are their sources?
  ▪ What processes control precipitation at landfall?

► Aerosol-cloud-precipitation interactions
  ▪ What are the distribution, characteristics, and sources of aerosols affecting winter precipitation in California?
  ▪ How do aerosols influence precipitation in different storm environments?

► Atmospheric river – aerosol connections
  ▪ How may aerosols influence the evolution and structure of atmospheric rivers?

► How well can models capture all of the above?
ACAPEX observing platforms

ARM Mobile Facility (AMF) on NOAA Ron Brown

ARM Aerial Facility (AAF)
Instruments on AMF2

- Aerosol Observing System (AOS)
- Clouds:
  - Vertically pointing W-band cloud radar (WACR)
  - Ka-band zenith pointing radar (KAZR)
  - Microwave radiometer (MWR)
  - Ceilometer, micropulse lidar (MPL), and high spectral resolution lidar (HSRL)
  - 3-channel microwave radiometer (MWR3C)
- Meteorology:
  - Radar Wind Profiler (RWP)
  - Atmospheric Sounder
  - Meteorological instruments (MET) and atmospheric profiling (SONDE)
- Portable Radiation Measurement Package (PRP2) and sun pyranometer (SPN)
- Bulk aerodynamics fluxes (BAF)
G-1 payload (~ 40 instruments)

- Aircraft and Atmospheric State Parameters
- Cloud Properties
  - Liquid water, total water, ice water content
  - Size Distribution (2 µm to 2 cm)
- Aerosol Properties (interstitial and residual)
  - Total Concentration
  - Size Distribution (60 nm – 50 µm)
  - Optical Properties (absorption, scattering)
  - Physico-chemical composition (single particle)
  - Cloud Condensation Nuclei Concentration
  - Ice Nuclei Concentration
- Trace Gases
  - H₂O, CO, O₃, N₂O
## CalWater 2015 platform activities

<table>
<thead>
<tr>
<th>January</th>
<th>February</th>
<th>March</th>
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<tbody>
<tr>
<td>15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31</td>
<td>1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28</td>
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- **NOAA RHB**
- **DOE AMF2**
- **DOE G-I**
- **NOAA G-IV**
- **NOAA P-3**
- **NASA ER-2**
- **UCSD/NSF BBY**
- **NOAA HMT**

| C = Coordinated Platform Activities |
| 2 = Two flight day |
G-1 flew a total of 28 flights:

- 8 flights in atmospheric rivers (over the ocean, along the coast, and in Sierra Nevada)
- 6 flights in coastal stratus and stratocumulus
- 4 flights in frontal orographic clouds
- 10 flights to characterize aerosols, CCN, INP from local sources and long range transport
- Of the 28 flights, 6 were coordinated with NASA ER-2, of which 2 were also coordinated with NOAA G-IV and P-3 for comprehensive moisture, cloud, and aerosol measurements

AMF2 on Ron Brown:

- Deployed from Jan 15 – Feb 9 from Honolulu to San Francisco; measured atmosphere, aerosols/clouds, and surface fluxes in 3 atmospheric rivers
February 5: Stratiform clouds of an AR

- Multiple measurements to constrain or evaluate simulations of cloud macrophysical and microphysical properties for mixed-phase clouds
February 5: Stratiform clouds of an AR
Orographic clouds on February 6 - 8

**February 6**
- Above Lake Tahoe
- Flooded area in Central Valley

**February 7**
- Above Lake Tahoe

**February 8**
- Above Sugar Pine Reservoir
February 6: orographic cloud properties

Water content (Liquid or Ice)

<table>
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<tr>
<th>Time [UTC]</th>
<th>Liquid [g/m³]</th>
<th>Ice [g/m³]</th>
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</thead>
<tbody>
<tr>
<td>23:15</td>
<td>0.5</td>
<td>1.0</td>
</tr>
<tr>
<td>23:25</td>
<td>0.2</td>
<td>0.8</td>
</tr>
<tr>
<td>23:33</td>
<td>1.0</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Temperature [°C]

Altitude [km]
February 6: aerosol properties and sources

CCN (SS = 0.30%)

Ice Clouds: 23:40~23:55

Ice Clouds: 23:40~23:55

Backward trajectories ending at 0000 UTC 07 Feb 15
GFSG Meteorological Data

Source H at 38.77°N 120.58°W

Meters AGL
February 7

**Flight Track**

19:16-19:55
19:55-20:34
20:34-21:12
21:12-21:51
21:51-22:30
22:30-23:09

**2DS:**
Droplet concentration (#/L/µm)

**FCDP:**
Droplet concentration (#/L/µm)

**PCASP:**
Aerosol concentration (#/cm³/µm)

**CCN (SS = 0.30%)**

Time [UTC]

Temperature [°C]

Altitude [km]
February 7: orographic cloud properties

**Water content (Liquid or Ice)**

- **WCM**
- **Ice [gm^-3]**
- **Liquid [gm^-3]**
- **CSL [gm^-3]**

**Temperature [°C]**

- **Altitude [km]**

**FCDP [gm^-3]**

**20:28**

**1.28 mm**

**21:06**

**21:50**

**21:23**
February 7: aerosol properties

- Measurements of aerosol chemical composition, BC concentration, and light absorption suggest the presence of aerosols with low hygroscopicity.

**Aerosol chemical composition**

- BB-sulfate
- ECOC-sulfate
- Sulfate
- HMOC
- Sea salt

**BC concentration**

- Super-cooled liquid: 21:18~21:28
- Super-cooled liquid: 21:50~22:00

**Light absorption coefficient**

- Super-cooled liquid: 21:50~22:00
February 8: orographic cloud properties
February 8: aerosol properties and sources

CCN (SS = 0.30%)

BC concentration

Light absorption coefficient

Ice Clouds: 22:35~22:55
CCN and IN impacts on supercooled liquid and cloud phase

- Increasing CCN increases supercooled water (SCW), decreases cloud glaciation temperature (CGT) and expands the mixed-phase zone.

- Increasing INP for immersion freezing more dramatically reduces SCW, increases CGT and narrows the mixed-phase zone.

- SCW is less sensitive to INP for warm than cold mixed-phase clouds.
Dust transported along with AR

(Creamean et al. 2013)
Summary

► ARM campaign:
  - http://www.arm.gov/sites/amf/acx/news

► ARM feature story:

► CalWater 2015 field campaign, including the daily weather forecasts, can be found in:
  - http://mead.ucsd.edu/?page_id=400

► ARM data repository

► AGU 2015 sessions (Precipitation, Weather, and Climate: Atmospheric Rivers and Aerosol-Cloud-Interaction Studies (A44C: Oral; A51L: Poster)
Aerosol and cloud microphysical data were collected before, during, and after a landfalling AR between February 5 – 8, 2016.

Generally low CCN of 10 – 100 per cc, low INP ~ 0.1 – 1 per L, cloud drop concentrations ~ 10 – 50 per cc per µm, and cloud drop size < 10 – 50 µm.

Despite low concentrations, aerosols have absorbing properties with chemical composition of organics and dust, and are likely transported over long range across the Pacific Ocean.

Because of low CCN hygroscopicity and low concentration of INP, very small supercooled cloud drops exist at low temperature and the mixed phase zone is large.

Important data for studying the impacts of CCN and IN on supercooled liquid and cloud phase, ice nucleation mechanisms, and precipitation forming mechanisms.