Overview of Calwater / ACAPEX

L. Ruby Leung, PNNL
Kim Prather, UCSD
Marty Ralph and Chris Fairall, NOAA/ESRL
# Core Scientific Steering Group

<table>
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<td>US Geological Survey</td>
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<td>US Geological Survey</td>
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<td>Science and Technology Corporation</td>
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<tr>
<td>D. E. Waliser</td>
<td>NASA Jet Propulsion Laboratory</td>
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Information on CalWater 2

Website

CalWater2

Observation Platforms

Terrain Bath Map

Announcements

Water Cycle Observables

Precipitation, Aerosols, and Pacific Atmospheric Rivers Experiment

A continuing effort to improve weather and climate prediction systems and develop better decision support tools for water resources management.

White paper

CalWater 2: Impacts of Pacific Atmospheric Rivers and Aerosols on Extreme Precipitation Events

Presents overview, goals, and experimental design of CalWater 2

GEWEX newsletter
Science and socio-economic issues

- Variability of water supply
- Incidence of extreme precipitation events along the West Coast of the United States
- Flood damages averaged $10 B/yr in the 2000s, up from $5 B/yr in the 1980s

Key phenomena addressed

- Atmospheric rivers (ARs) deliver much of the water associated with major storms along the U.S. West Coast
- Aerosols, from local sources as well as those transported from remote continents, can affect western U.S. precipitation.
- Effects of climate variability and change on these phenomena
CalWater & HMT-West Observing Systems
Winter 2009 - 2011 in California
Experiments documenting ARs and Aerosols

G-1 Research aircraft for CalWater (DOE/PNNL)
1 Feb – 7 mar 2010

SKYWATER Radar

C-band scanning radar (NOAA/PSD)

Three S-Prof precipitation profilers (NOAA/PSD)

449 MHz wind profiler

GPS IWV & balloon Sounding Systems

Seven 915 MHz wind profilers (NOAA/PSD)
Flooding on California’s Russian River: Role of atmospheric rivers

Ralph, F.M., P. J. Neiman, G. A. Wick, S. I. Gutman, M. D. Dettinger, D. R. Cayan, A. White


Russians River floods are associated with atmospheric rivers - all 7 floods over 8 years.

Flooding in Western Washington: The Connection to Atmospheric Rivers

Paul J. Neiman, Lawrence J. Schick, F. Martin Ralph, Mimi Hughes, and Gary A. Wick

*J. Hydrometeorology* (2011)

Of 48 annual peak daily flows on 4 watersheds, 46 were associated with the land-fall of atmospheric river conditions.
Atmospheric Rivers, Floods and the Water Resources of California
by Mike Dettinger, Marty Ralph, Tapash Das, Paul Neiman, Dan Cayan
*Water, 2011*

25-35% of annual precipitation in the Pacific Northwest fell in association with atmospheric river events.

An average AR transports the equivalent of 7.5 times the average discharge of the Mississippi River, or ~10 M acre feet/day.

35-45% of annual precipitation in California fell in association with atmospheric river events.
Landfalling storm 14-16 February 2011
- Multi-Doppler scanning-radar retrievals
- Multi-wind-profiler time series diagnostics
- Balloon soundings

Observing network clearly monitored both the AR and SBJ during two sub-periods within the 2-day IOP
- SBJ western edge detected
- SBJ deepened toward the north
- AR rode up and over the SBJ
Global Hawk AR Flight, 11-12 Feb 2011, IVT

- 403 km wide
- 186x10^6 kg/s flux
- ~11 “Mississippis”
- 10 Million Acre Feet/day
CalWater 2011 field observations showed days with dust and bioparticles experienced extensive snowfall.
Removing dust reduces precipitation (mainly snowfall) by up to 20%, with larger effects under polluted conditions.

Pollution aerosols (CCN) suppress precipitation by about 5% without dust, but when dust is present, CCN enhance precipitation.

(Fan et al. 2013, ACP, submitted)
Key Science Gaps

- **Evolution and structure of ARs**, including quantifying the water vapor transport budget (air-sea flux, rainout, frontal convergence, entrainment from tropics)

- **Prediction of aerosol burdens and properties** during intercontinental transport from remote source regions to the U.S. West Coast

- **Aerosol interactions with ARs and the impact on precipitation**, including locally generated aerosol effects on orographic precipitation along the U.S. West Coast
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**Facility Status**

- **Committed**
- **Requested**
- **To be developed**
- **Hypothetical**
CalWater 2 /ACAPEX Observational Strategy
Winter 2014-15

SSM/I satellite observations of IWV showing a strong atmospheric river on 12 Dec 2010
(from Ralph and Dettinger BAMS 2012)

Hawaii

Aerosol Profiling
- NOAA WP-3D
- Aerosols, trace gases

Water Vapor Budget Boxes
- NOAA G-IV or NASA Global Hawk
- Dropsondes and radar

Ship
- DOE AMF2
- Small UAS
- Air-sea fluxes
- Precipitation estimates

Ground
- NOAA HMT
- UCSD ATOFMS

DOE G-1
- Aerosols
- Microphysics

Remote aerosol plume (schematic)

Sierra Nevada, Shasta, and Coast Ranges (white bars)

Operations bases
- NOAA WP-3D (Monterey)
- DOE G-1 (Monterey)
- Global Hawk (NASA Dryden) or NOAA G-IV (Monterey)

Courtesy of F. M. Ralph, NOAA Earth System Research Laboratory
CalWater 2 Air-Sea Interaction and AR dynamics in Mid-latitude Pacific Storms

- Ships (Brown and/or UNOLS Class I)
- Aircraft (NOAA P-3, NOAA G-IV?)
- Field Duration – 30 days
- Ship location – Nominally 35-40 N 130 W
- Modeled after DYNAMO Revelle field program – joint air/sea obs.

DYNAMO
- Undisturbed U=4, Net heat 100 W/m^2
- Storm U=7 (Max=17) m/s, Net heat -75 W/m^2
- Biggest effect on Solar flux

CalWater2
- Undisturbed U=7, Net heat -50 W/m^2
- Storm U=13 (Max U=20) m/s, Net heat -250 W/m^2
- Biggest effect on Latent heat flux
- Storms will have strong stress with buoyancy forcing changing from small negative (warm sector) to very large positive (cold air, post frontal)
CALWATER2 Air-Sea Science Objectives

- Interface, near-surface
  - Strong emphasis on aerosol/gas fluxes
  - Fluxes in strong wind forcing with varying heat flux
    - Warm sector vs post frontal
  - Wave aspects – breaking, aerosol production, wave-pressure, high frequency wave slope (saturation spectrum)

- Boundary layer and Frontal dynamics
  - BL coupling to surface properties – updrafts/downdraft, precipitation effects on aerosol/chemistry
  - Links to mesoscale, Low-level jet effects
  - Synoptic – mostly aerosol/chemistry

- Ocean mixing processes
  - Mixing/entrainment strong forcing with deep ML
  - Possible feedback to air-sea fluxes?
CALWATER2
Ship-based Sensors

- C-band Radar – CSU (Rutledge)
- DOE AMF2 - PNNL (Leung)
  - Aerosols, microwaves, lidars, wind profilers, …
- Fluxes and Near-Surface Meteorology-ESRL/PSD (Fairall)
- Marine aerosol production - PMEL (Bates/Quinn)
- Surface waves (IR/polarization imaging)– LDEO (Zappa)
- Wave dissipation (SWIFT buoys) – Thompson (UW/APL)
- Ocean mixing (AMP array) – UW/APL (Sanford, Kunze)
- Bubble/aerosol dynamics – SIO (Deane, Stokes)
- Gliders – SIO (Rudnick)
Science questions

► What are the key physical processes (e.g., rainout, vapor convergence, air-sea interaction, evaporation) that control the water vapor transport budget in ARs over the ocean and at landfall?

► To what extent different types of aerosols and their microphysical environment influence precipitation efficiency in ARs

► What is the role of ARs in providing precipitation that ends drought conditions in key regions?

► What are the impacts of absorbing aerosols (e.g., dust and black carbon) deposited on snow on the hydrological cycle in the western U.S.? To what extent do different types of aerosols and varying origins influence this process?
Modeling and analysis

Process Modeling

► L. R. Leung – aerosol-cloud-precipitation interactions, spectral bin microphysics, AR modeling
► M. Hughes – AR modeling, WRF downscaling
► R. B. Pierce – aerosol and chemistry transport modeling

Weather and Climate Modeling

► M. Dettinger – ARs, hydrology perspective
► L. R. Leung – Model intercomparison experiments of aerosol effects and AR
► D. Waliser – AR phenomena/processes, tropical connections, prediction and predictability
► G. Stephens – high-capability, high-performance modeling of extreme precipitation events
► M. Hoerling – ARs, extreme precipitation events, pattern perspective
Experimental execution, coordination, and data sharing

- Coordination among NOAA (aircraft, ship), DOE (aircraft, AMF), and NASA (potentially Global Hawk), UCSD (ATOFMS), other PIs (e.g., DeMott – CFDC) in 2014/15

- Flight coordination: Manned aircraft (NOAA WP-3D and later NASA DC-8) and a large UAS (NASA GH) all flying in the Pacific Ocean

- NOAA data sharing policy

- DOE ARM data sharing policy: http://www.arm.gov/data/docs/policy