



U.S. DEPARTMENT OF  
**ENERGY**

Office of  
Science



**Pacific Northwest**  
NATIONAL LABORATORY

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# Overview of Calwater / ACAPEX

L. Ruby Leung, PNNL

Kim Prather, UCSD

Marty Ralph and Chris Fairall, NOAA/ESRL

# Core Scientific Steering Group

Investigator	Affiliation
F. M. Ralph (Co-Lead)	NOAA Earth System Research Laboratory
K. A. Prather (Co-Lead)	Scripps Institution of Oceanography, University of California San Diego
D. Cayan (Co-Lead)	Scripps Institution of Oceanography, University of California San Diego US Geological Survey
M. Dettinger	Scripps Institution of Oceanography, University of California San Diego US Geological Survey
C. Fairall	NOAA Earth System Research Laboratory
L. R. Leung	Pacific Northwest National Laboratory
D. Rosenfeld	The Hebrew University of Jerusalem
S. Rutledge	Colorado State University
J. R. Spackman	NOAA Earth System Research Laboratory Science and Technology Corporation
D. E. Waliser	NASA Jet Propulsion Laboratory

# Information on CalWater 2

## Website

U.S. Department of Commerce | National Oceanic & Atmospheric Administration | NOAA Research

**Earth System Research Laboratory**  
Physical Sciences Division

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### CalWater2

Precipitation, Aerosols, and Pacific Atmospheric Rivers Experiment

Home | Overview | Steering Group | Events | Partners | Related Links

CalWater2 is a field campaign focusing on two key phenomena that play key roles in the variability of the water supply and the incidence of extreme precipitation events along the West Coast of the United States. These phenomena include the role of:

- Atmospheric Rivers (ARs)** in delivering much of the water vapor associated with major storms along the U.S. West Coast, and
- Aerosols** from local sources as well as those transported from remote continents—and their modulating effects on western U.S. precipitation.

**Observation Platforms**

The CalWater 2/ACAPEX observational strategy will use high- and low-altitude aircraft, a ship with the ARM2, and a ground-based network.

**Terrain Base Map**

Terrain base map of northern California showing wind profiler sites and S-PROF radar operation during the HMT and CalWater field campaigns (pink circles and red triangles, respectively).

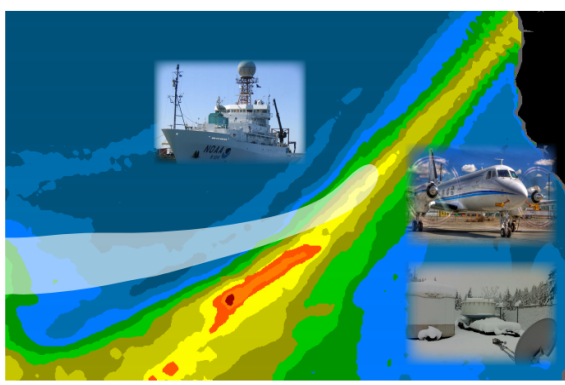
**Announcements**

- 22 Apr 2013 – The CalWater2 White Paper is now available
- 22 March 2013 – CalWater2 featured in the February 2013 issue of GEWEX News
- 28 February 2013 – New Study Finds Dust/Biological Particles Travelling from Sahara and Asia Influence Precipitation on West Coast

U.S. Department of Commerce | National Oceanic & Atmospheric Administration | NOAA Research  
Earth System Research Laboratory | Physical Sciences Division  
<http://www.esrl.noaa.gov/psd/calwater/index.html>

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## White paper



# CalWater 2

## 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.

National Oceanic & Atmospheric Administration  
U. S. Department of Energy

California Energy Commission  
Scripps Institution of Oceanography

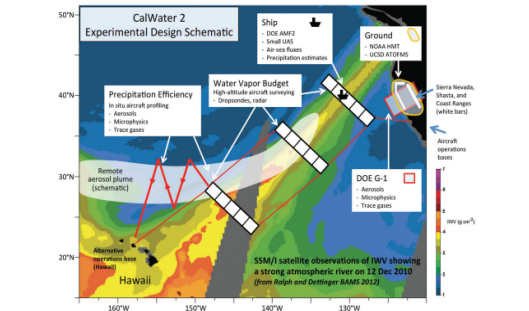
## GEWEX newsletter

**GEWEX** Global Energy and Water Exchanges  
WCRP **NEWS**

Vol. 23, No. 1 February 2013

WCRP | ICSU

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



The CalWater 2 observational strategy shown above will employ high- and low-altitude aircraft platforms, a ship equipped with the ARM Mobile Facility 2, a ground-based network that includes the NOAA Hydrometeorology Testbed assets, and the aerosol time-of-flight mass spectrometer from Scripps Institution of Oceanography. The experimental design is superimposed on SSM/I satellite observations from a strong atmospheric river (AR) event described in Ralph and Dettlinger (2012). An Asian aerosol plume is shown schematically in the context of the AR to conceptually show the sampling strategy for both the AR (transsects and water vapor flux boxes) and aerosol (profiling to the north and west of the AR) objectives. During such an AR event, the ship would be vectored along an aircraft transect of an AR to coordinate the observations. As the parent storm moves to the east, the AR would move to the south and east toward the G-1 research aircraft sampling region in the diagram. See article by Ryan Spickman et al. on page 5. Figure courtesy of F. M. Ralph, NOAA Earth System Research Laboratory.

**Also Inside**

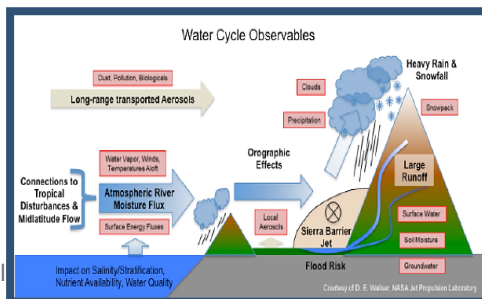
- Commentary by K. Trenberth: *The New Normal* (Page 2)
- New GEWEX SSG Members: Rene Garreaud and Richard Anyah (Page 4)
- 1<sup>st</sup> GDAP Meeting Highlights Panel Results and Progress on the Integrated GEWEX Data Product (Page 11)

**Now Available**

**Radiative Flux and Global Cloud Data Assessments**

About: (Page 4)  
Results: (Page 11)

## Presents overview, goals, and experimental design of CalWater 2



## Science and socio-economic issues

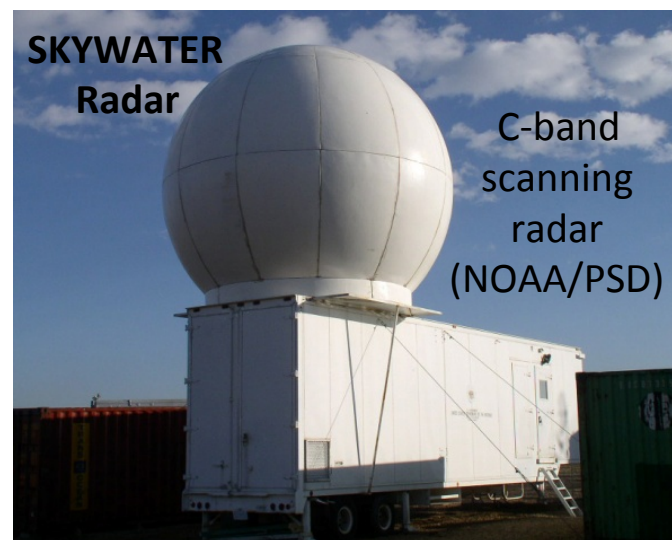
- ▶ Variability of water supply
- ▶ Incidence of extreme precipitation events along the West Coast of the United States
- ▶ Flood damages averaged \$10 B/yr in the 2000s, up from \$5 B/yr in the 1980s

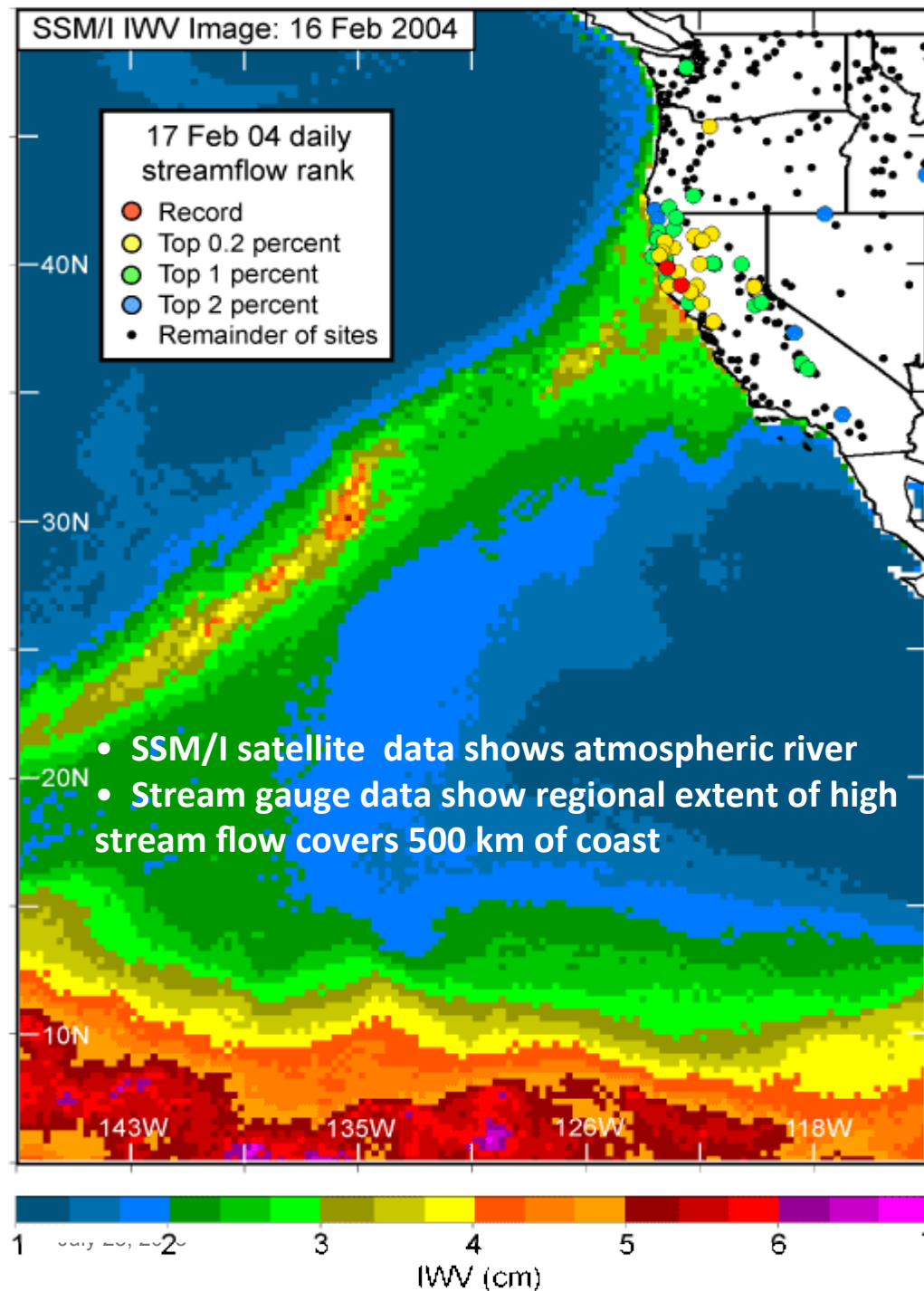
## Key phenomena addressed

- ▶ 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





## 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

*Geophys. Res. Lett.*, 2006

**Russian 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

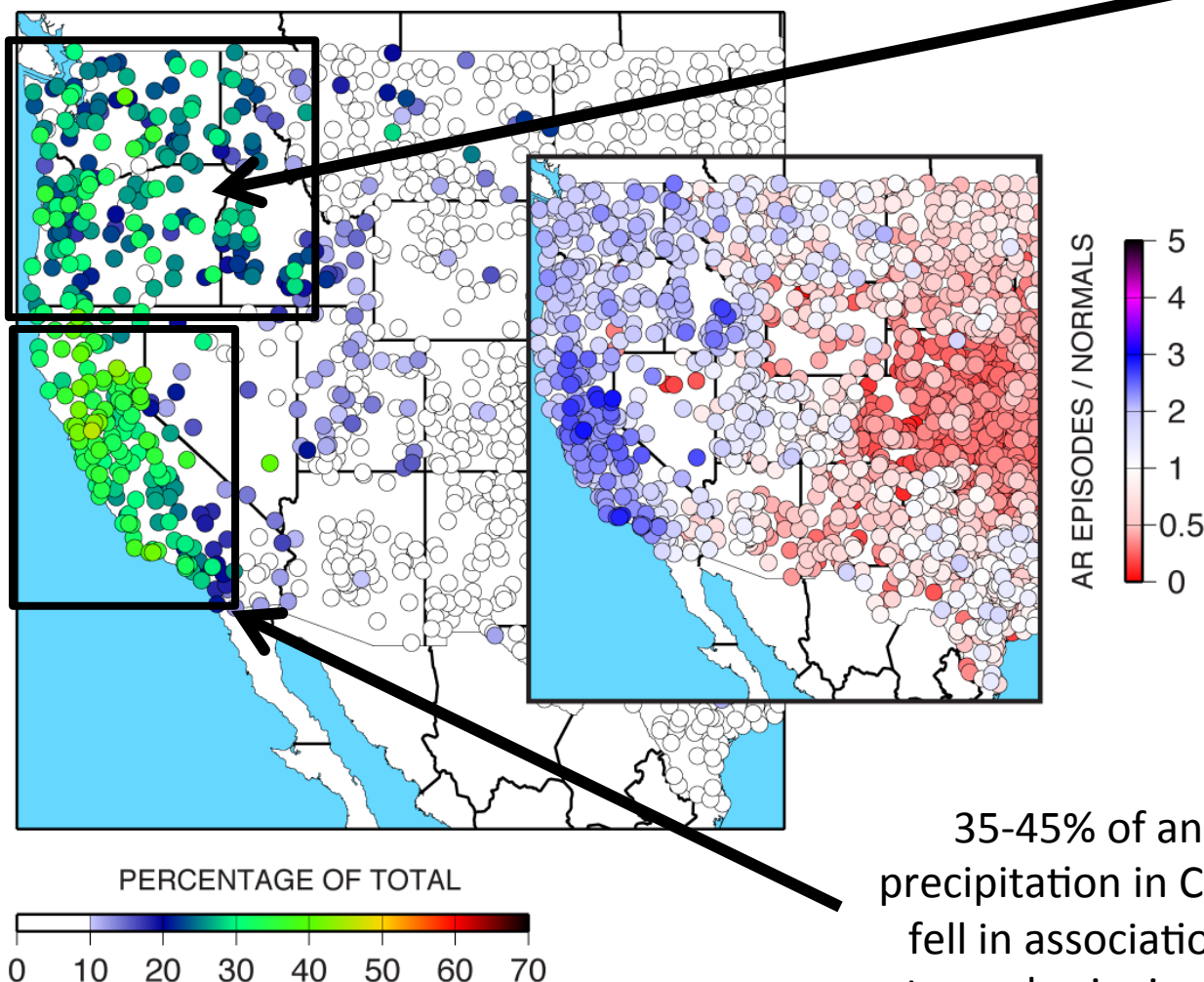
*Water, 2011*



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CONTRIBUTIONS OF ALL AR EPISODES (days 0 to +1)  
TO TOTAL PRECIPITATION, WY 1998-2008



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**

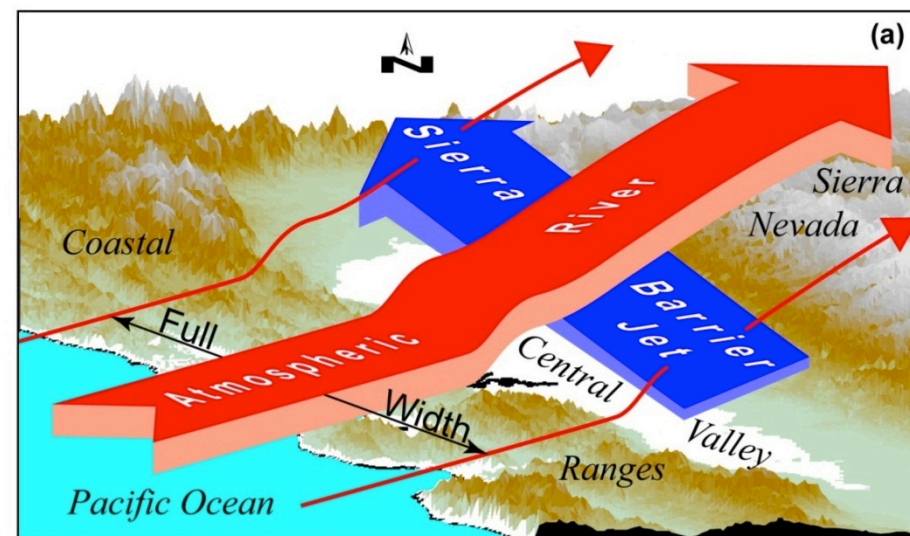
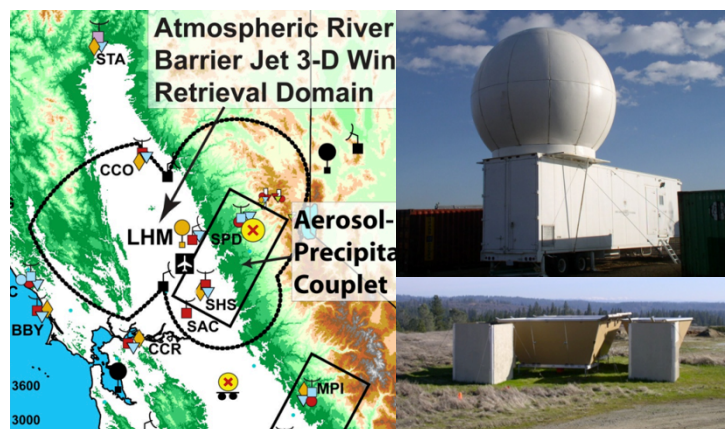
35-45% of annual  
precipitation in California  
fell in association with  
atmospheric river events

# Kinematic and Thermodynamic Structures of Sierra Barrier Jets and Overrunning Atmospheric Rivers during a Land-falling Winter Storm in Northern California



Kingsmill, Neiman, Moore, Hughes, Yuter and Ralph  
*Journal of Hydrometeorology*, 2013 *In Press*

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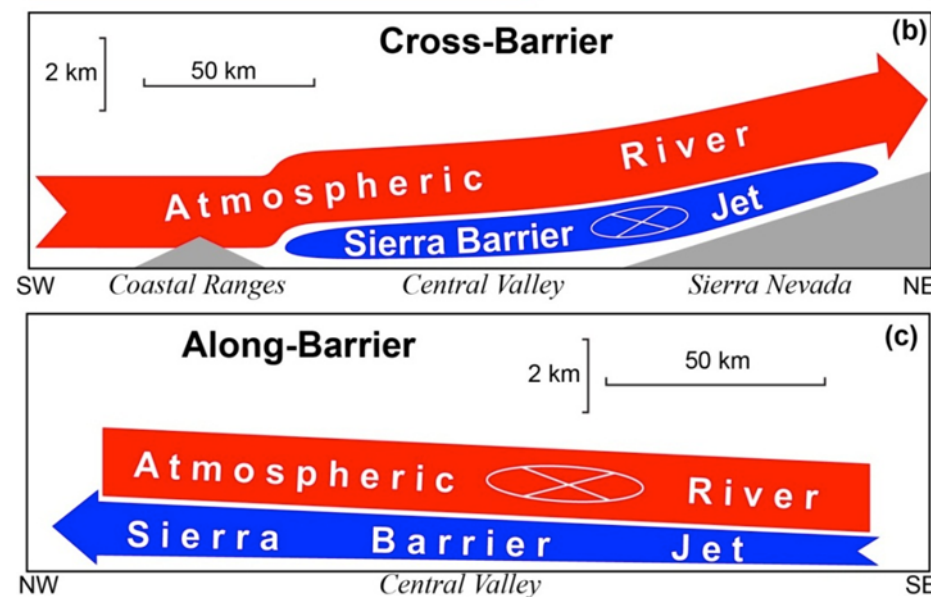
## Landfalling storm 14-16 February 2011

- 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

July 25, 2013



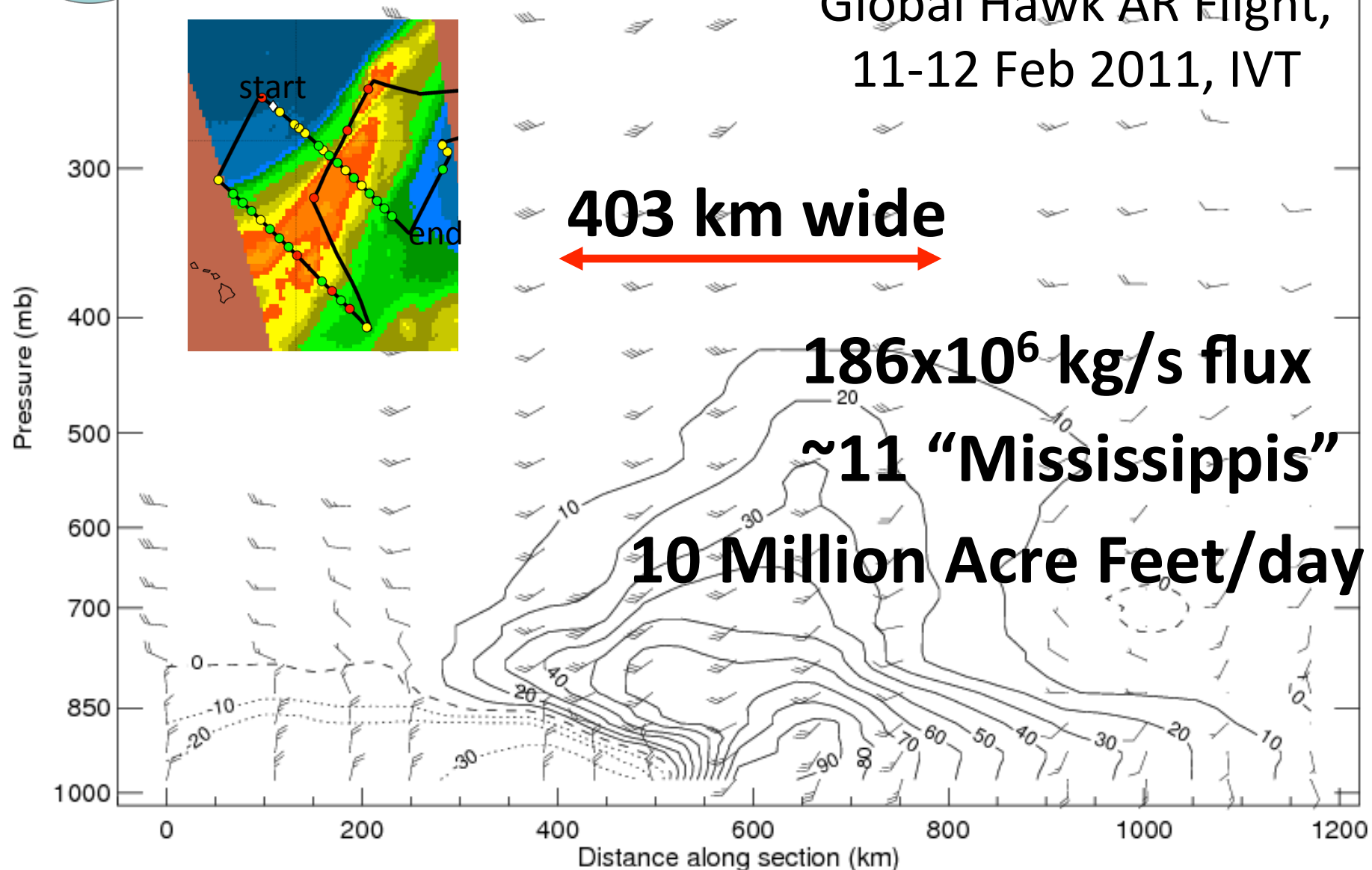




# WINTER STORMS AND PACIFIC ATMOSPHERIC RIVERS (WISPAR)

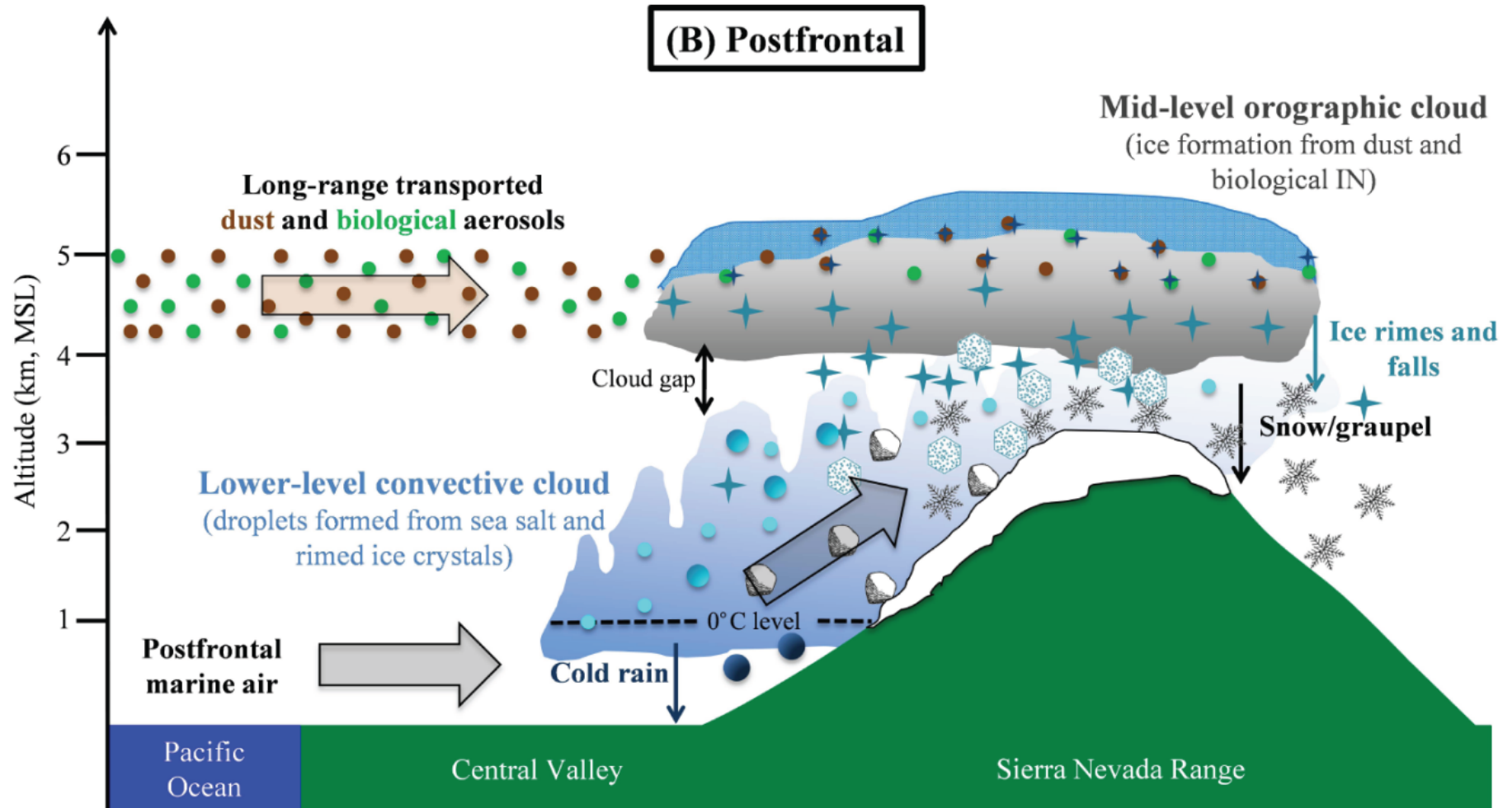


Global Hawk AR Flight,  
11-12 Feb 2011, IVT



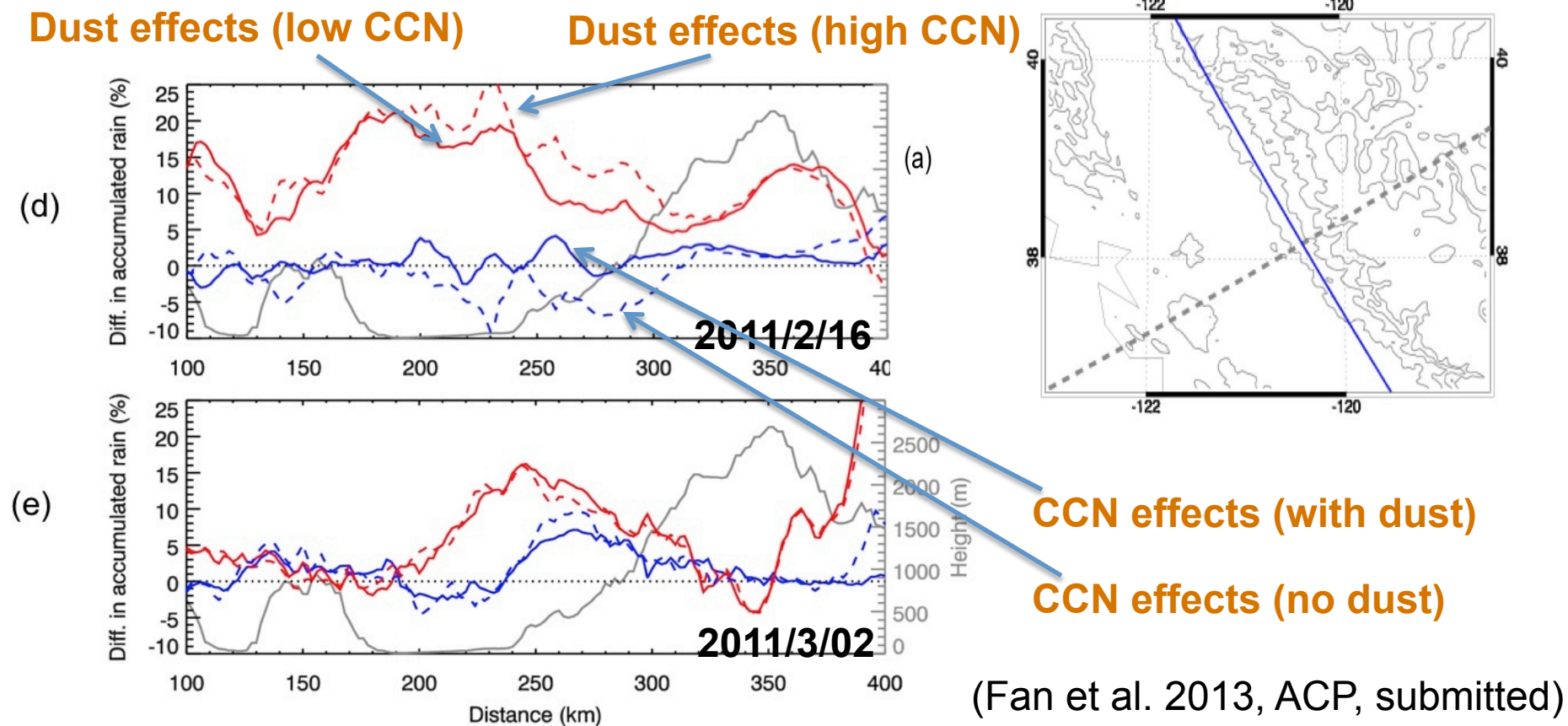
# Dust and Biological Aerosols from the Sahara and Asia Influence Precipitation in the Western U.S.

Creamean, et al., Science, 2013



CalWater 2011 field observations showed days with dust and bioparticles experienced extensive snowfall

# Modeling of aerosol effects



- ▶ 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



# 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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Major Platforms	CY 2014				CY 2015				CY 2016				CY 2017				CY 2018			
NOAA HMT/CADWR Network																				
DOE ACAPEX AMF2 + G-1																				
NOAA or NSF ship																				
NOAA P-3 Chang/Fairall																				
OLYMPEX NASA DC-8 & other facilities																				
Global Hawk Risk Reduc. NOAA NASA																				
NSF other facilities (radar, G-V...)																				
AREX NASA Global Hawk																				
AREX NASA DC-8																				

Facility Status

Committed

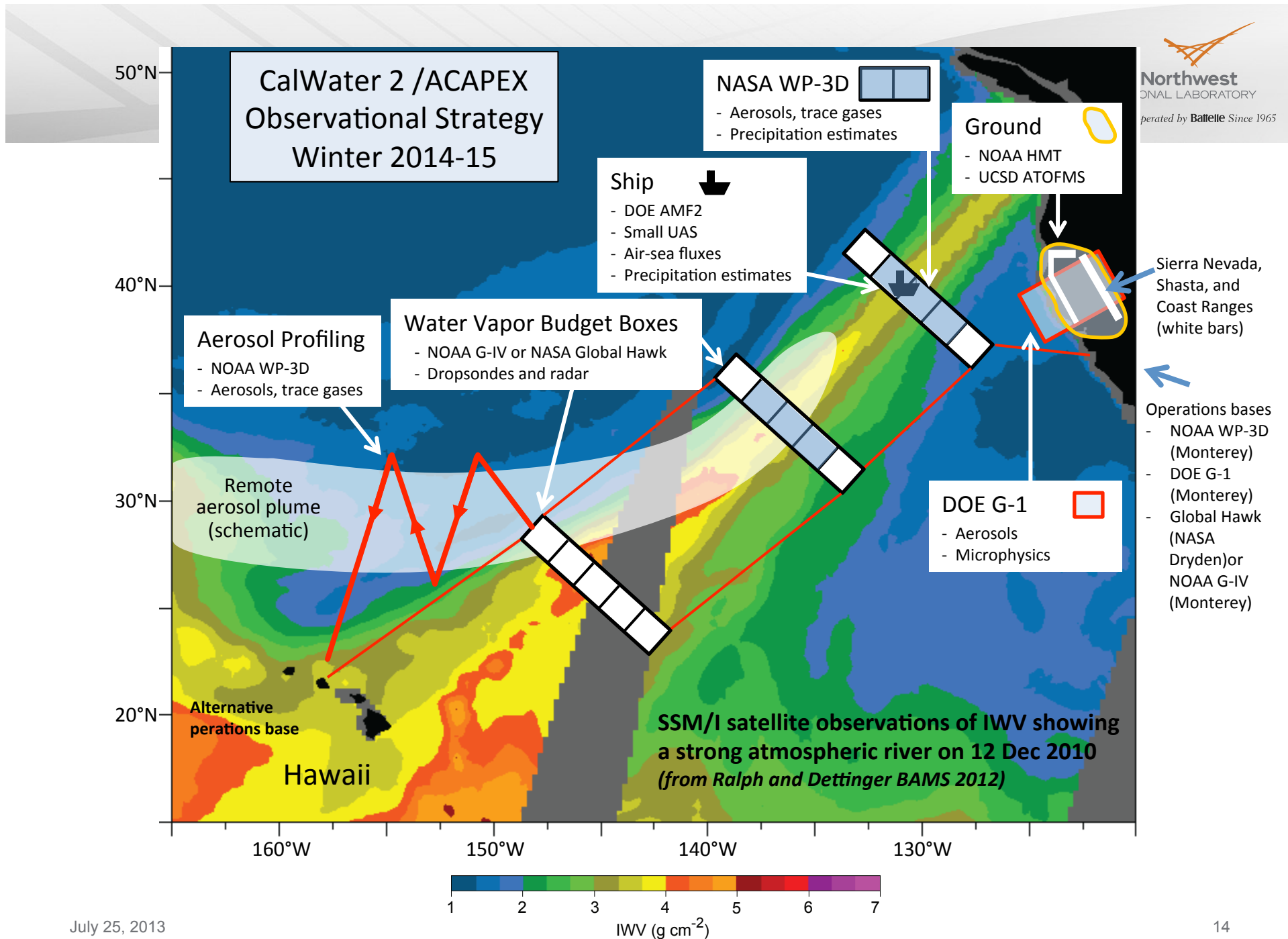
Requested

To be developed

Hypothetical

Jul

13



July 25, 2013

14

Courtesy of F. M. Ralph, NOAA Earth System Research Laboratory



# CalWater 2 Air-Sea Interaction and AR dynamics in Mid-latitude Pacific Storms

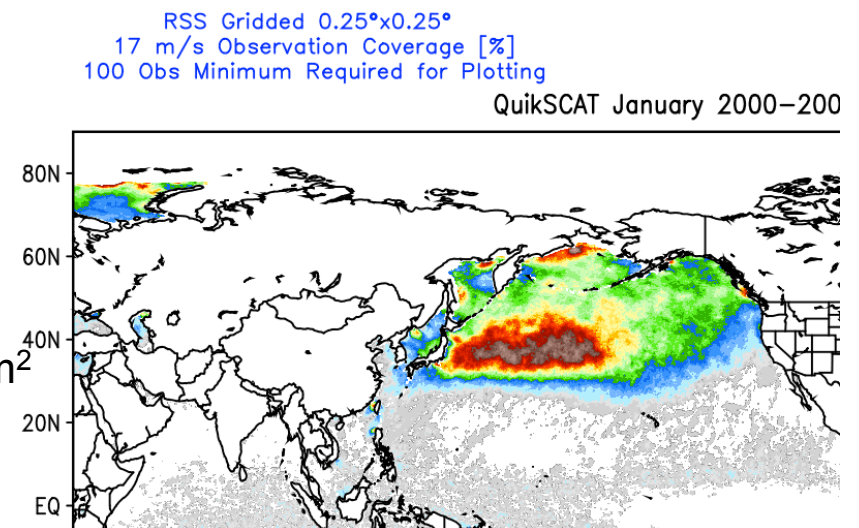
- ▶ Ships (Brown and/or UNOLS Class I)
- ▶ Aircraft (NOAA P-3, NOAA G-IV?)
- ▶ Field Duration – 30 days
- ▶ Time Window – Dec 1, 2014 – Mar 31, 2015
- ▶ Ship location – Nominally 35-40 N 130 W
- ▶ Modeled after DYNAMO Revelle field program – joint air/sea obs.

## DYNAMO

- ▶ Undisturbed  $U=4$ , Net heat  $100 \text{ W/m}^2$
- ▶ Storm  $U=7$  (Max=17) m/s, Net heat  $-75 \text{ W/m}^2$
- ▶ Biggest effect on **Solar flux**

## CalWater2

- ▶ Undisturbed  $U=7$ , Net heat  $-50 \text{ W/m}^2$
- ▶ Storm  $U=13$  (Max  $U=20$ ) m/s, Net heat  $-250 \text{ W/m}^2$
- ▶ 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)



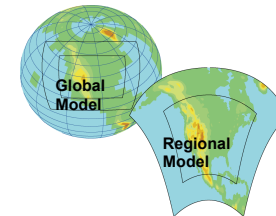
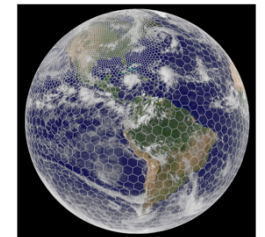
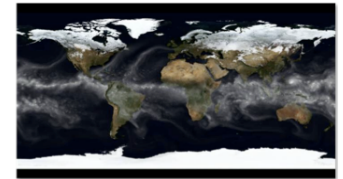
# Science questions

- ▶ 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](http://www.arm.gov/data/docs/policy)