U.S. DEPARTMENT OF ENERGY | Office of Science

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Overview of Calwater / ACAPEX

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Kim Prather, UCSD
Marty Ralph and Chris Fairall, NOAA/ESRL

Core Scientific Steering Group

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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

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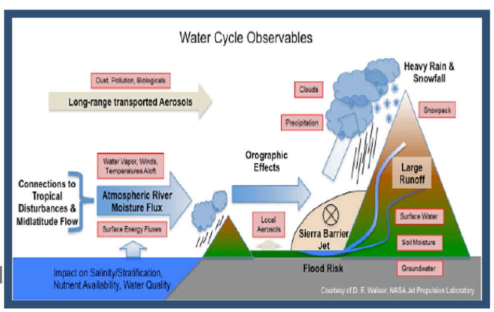
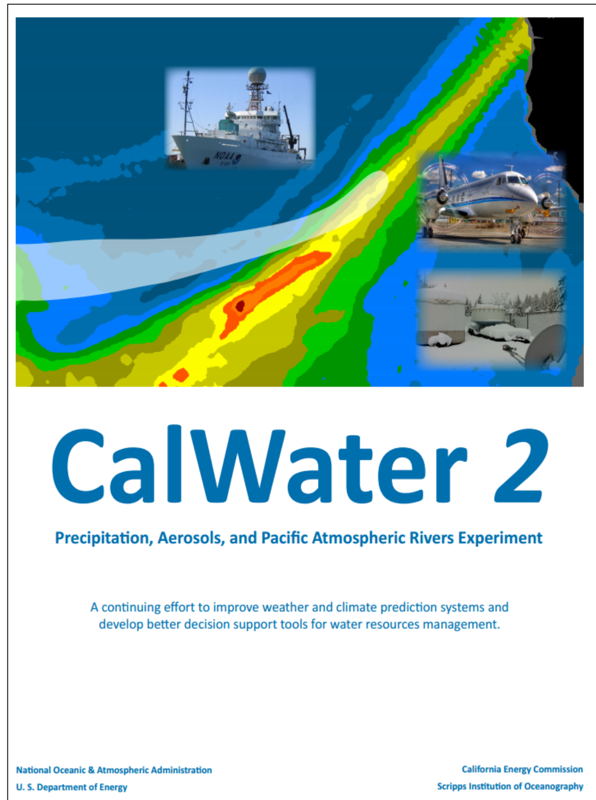
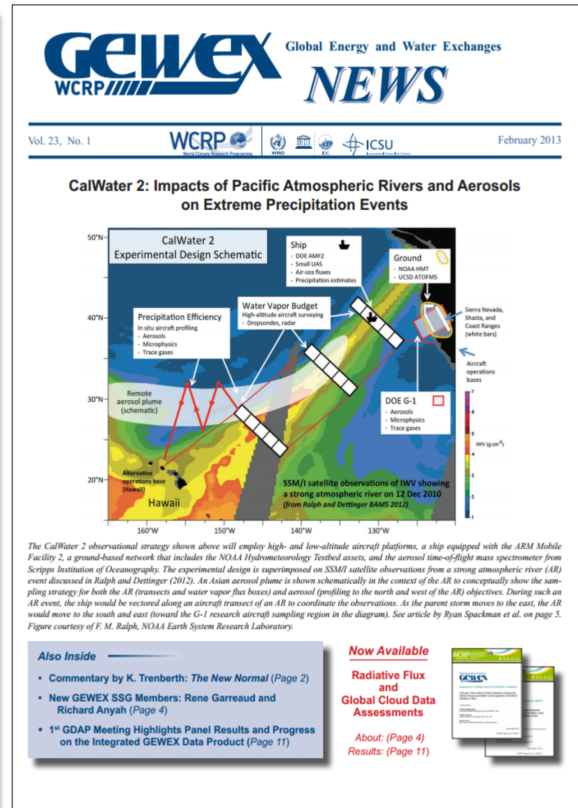
Website



White paper



GEWEX newsletter



Presents overview, goals, and experimental design of CalWater 2

Drivers and Phenomena

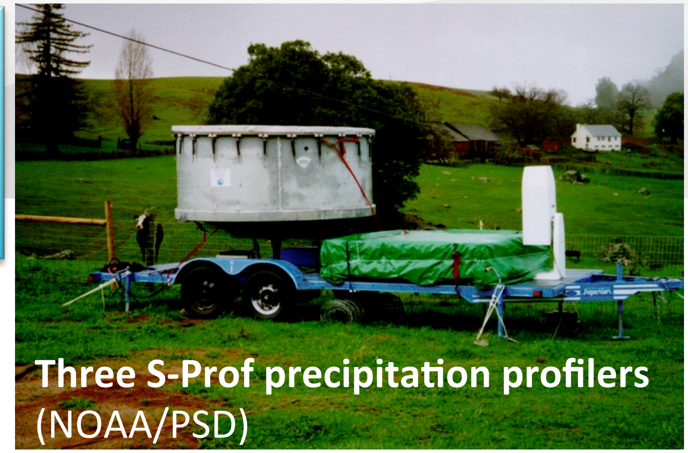
Science and socio-economic issues

- 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

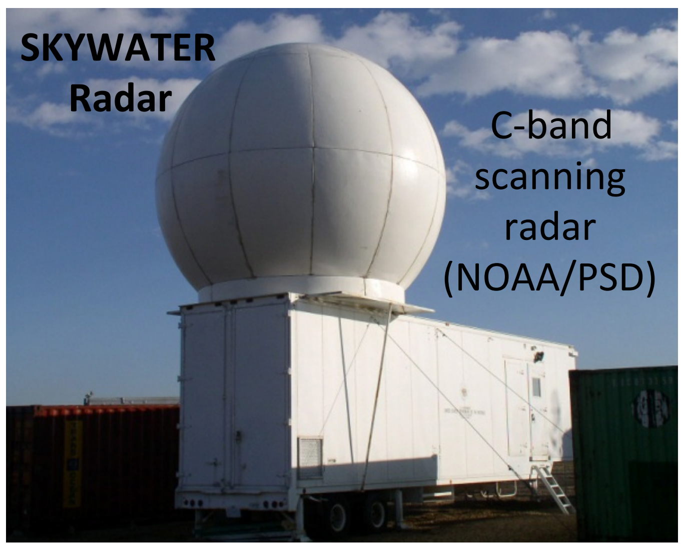


Three S-Prof precipitation profilers (NOAA/PSD)

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

449 MHz wind profiler

GPS IWV & balloon Sounding Systems



SKYWATER Radar

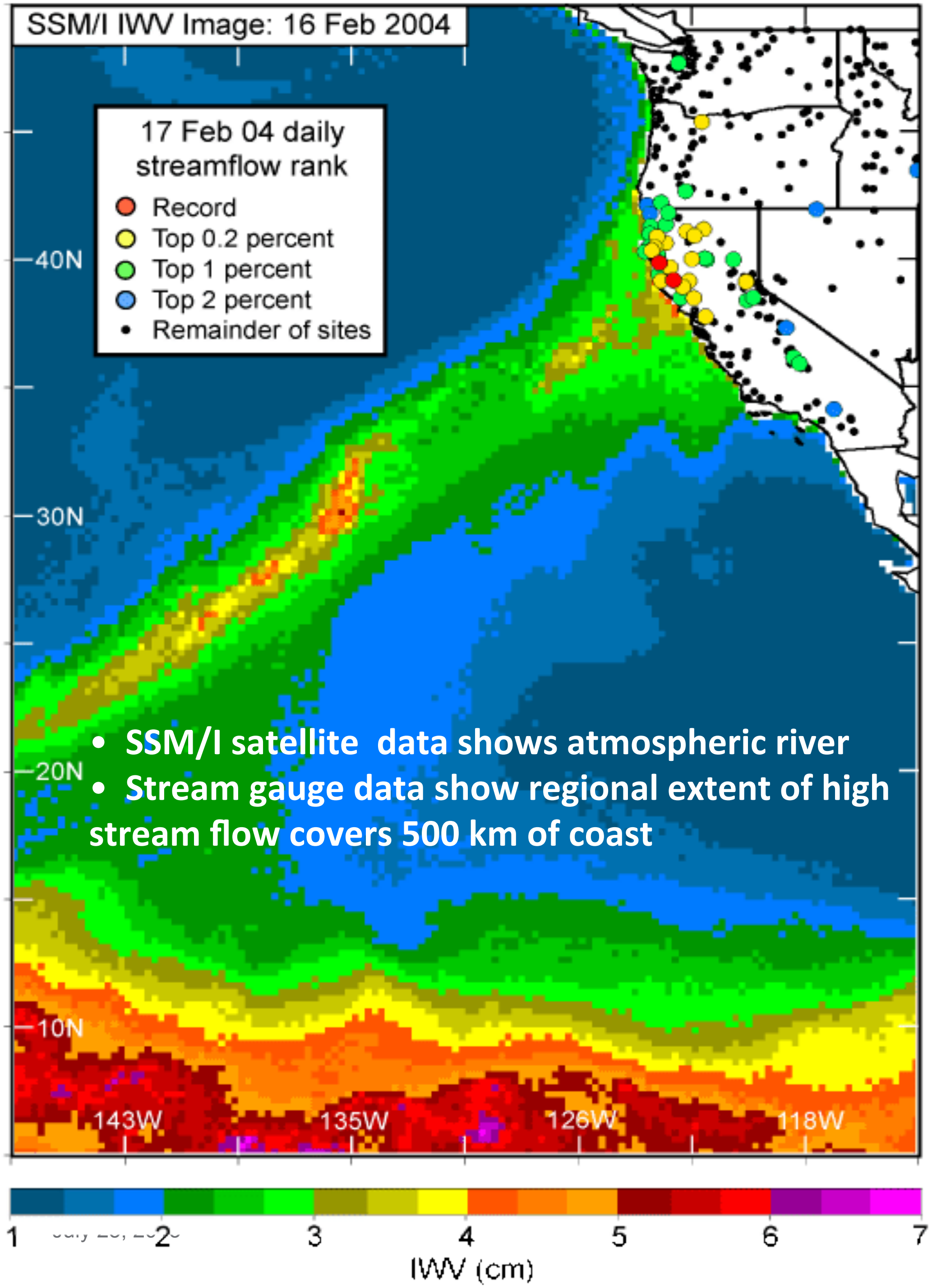
C-band scanning radar (NOAA/PSD)

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

Geophys. Res. Lett., 2006



- **SSM/I satellite data shows atmospheric river**
- **Stream gauge data show regional extent of high stream flow covers 500 km of coast**

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

Flooding in Western Washington: The Connection to Atmospheric Rivers

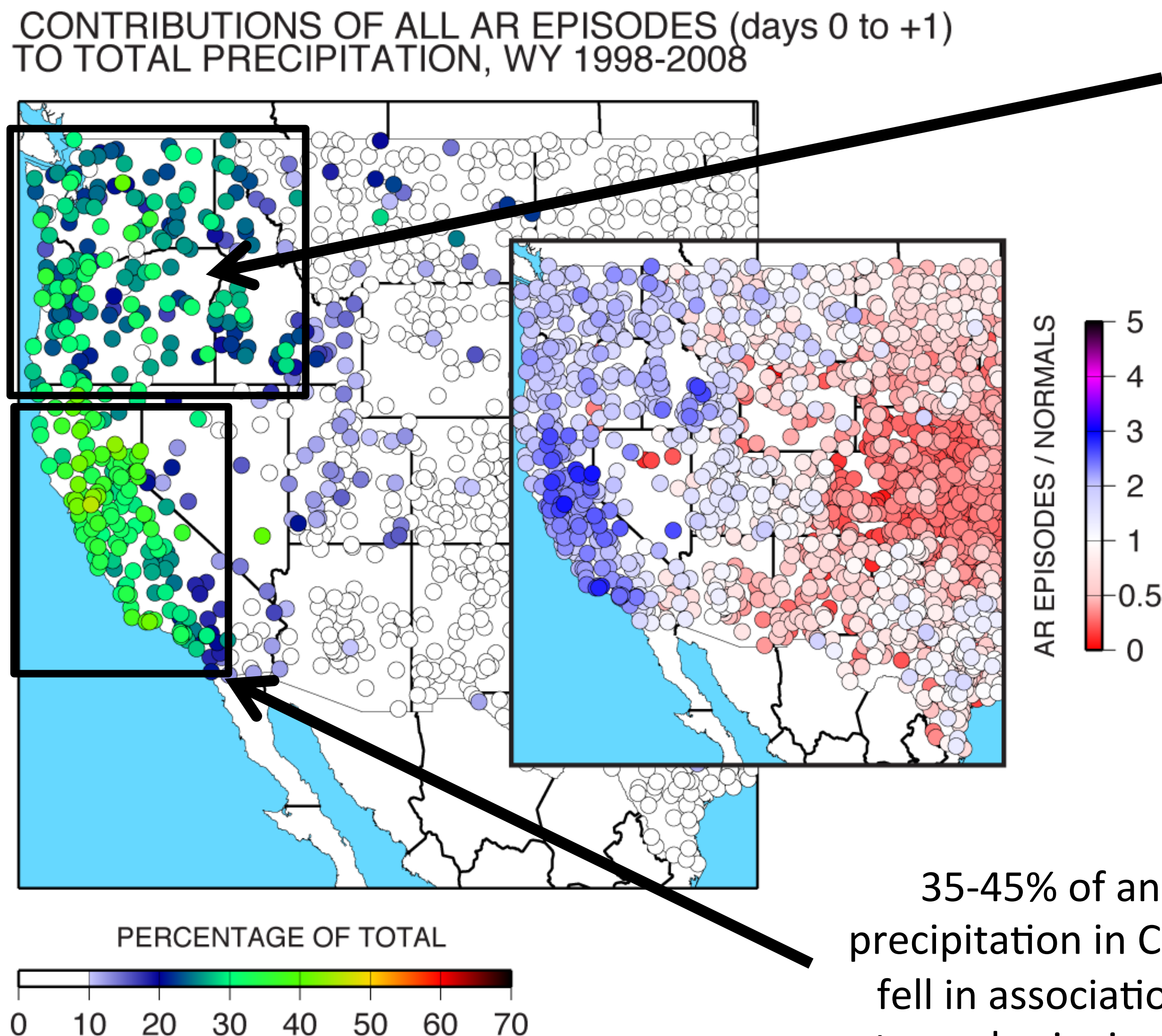
Paul J. Neiman, Lawrence J. Schick, F. Martin Ralph, Mimi Hughes, and Gary A. Wick
J. Hydrometeorology (2011)

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



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

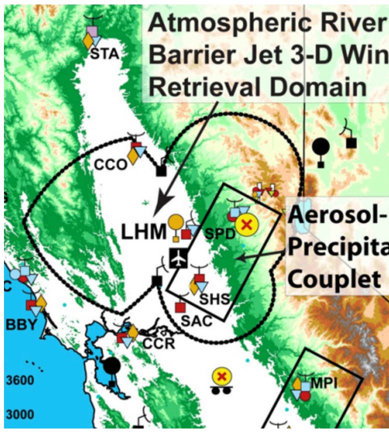
An average AR transports the equivalent of 7.5 times the average discharge of the Mississippi River, or ~10 M acre feet/day

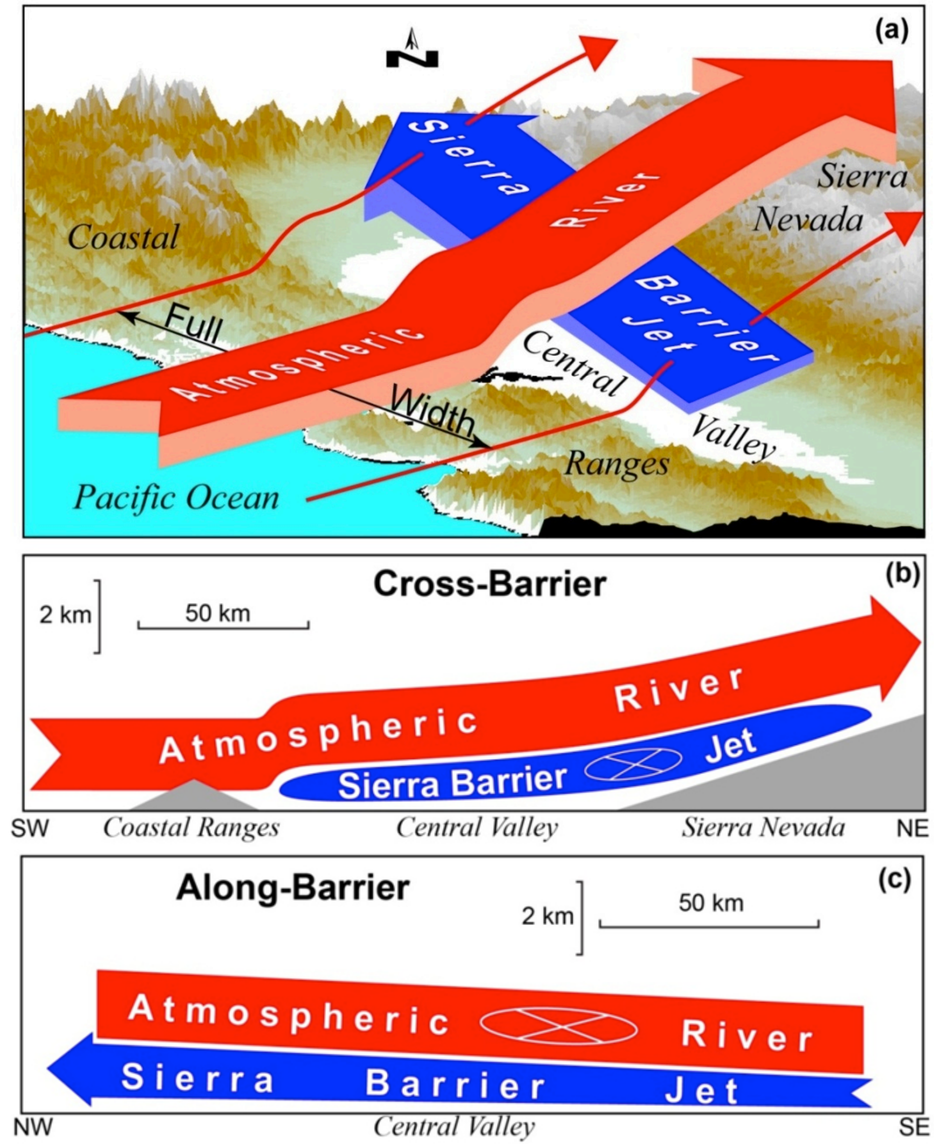
35-45% of annual precipitation in California fell in association with atmospheric river events

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





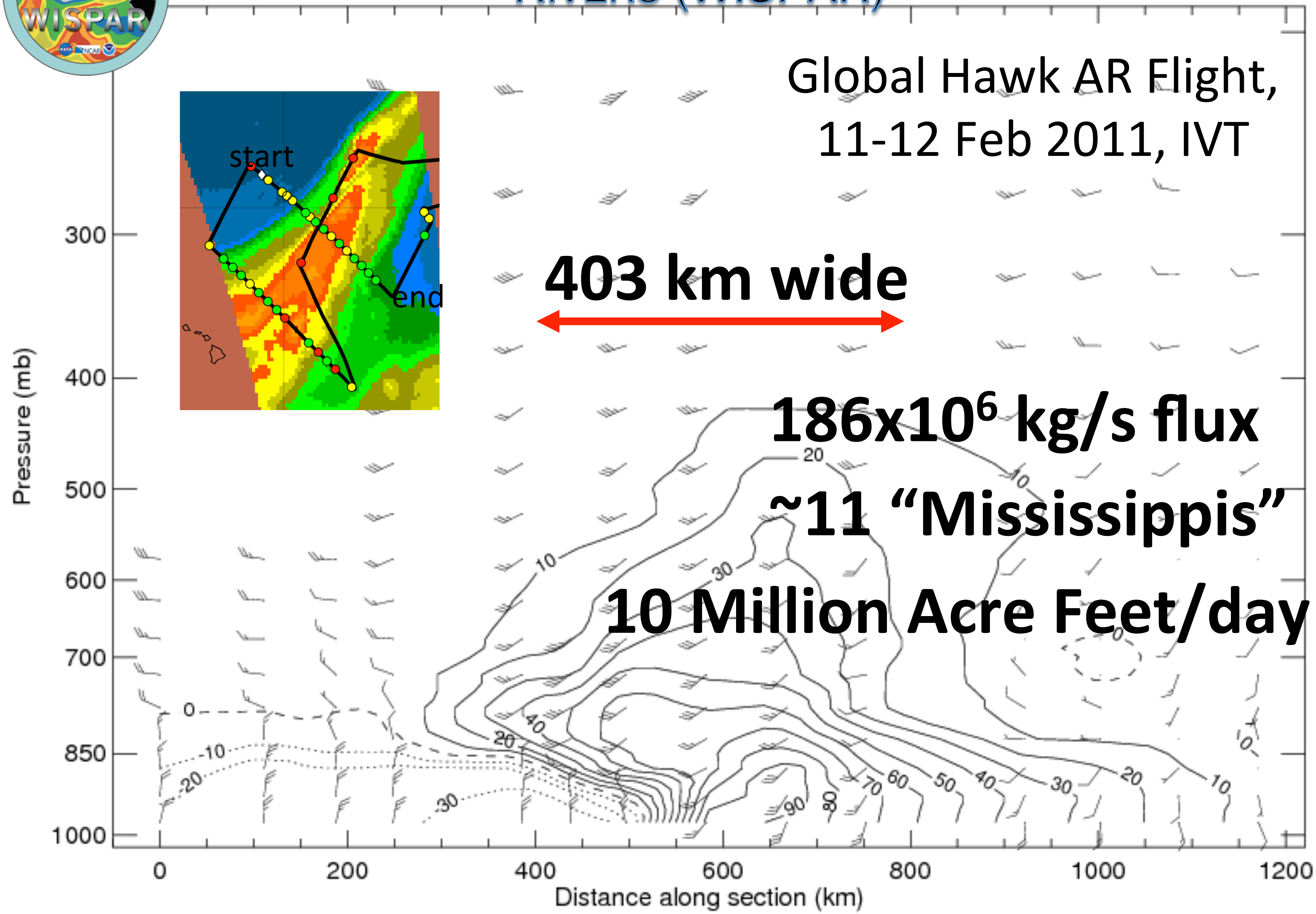
Landfalling storm 14-16 February 2011

- 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

Winter Storms and Pacific Atmospheric Rivers (WISPAR)



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

403 km wide

186×10^6 kg/s flux

~11 "Mississippis"

10 Million Acre Feet/day

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

Creamean, et al., Science, 2013

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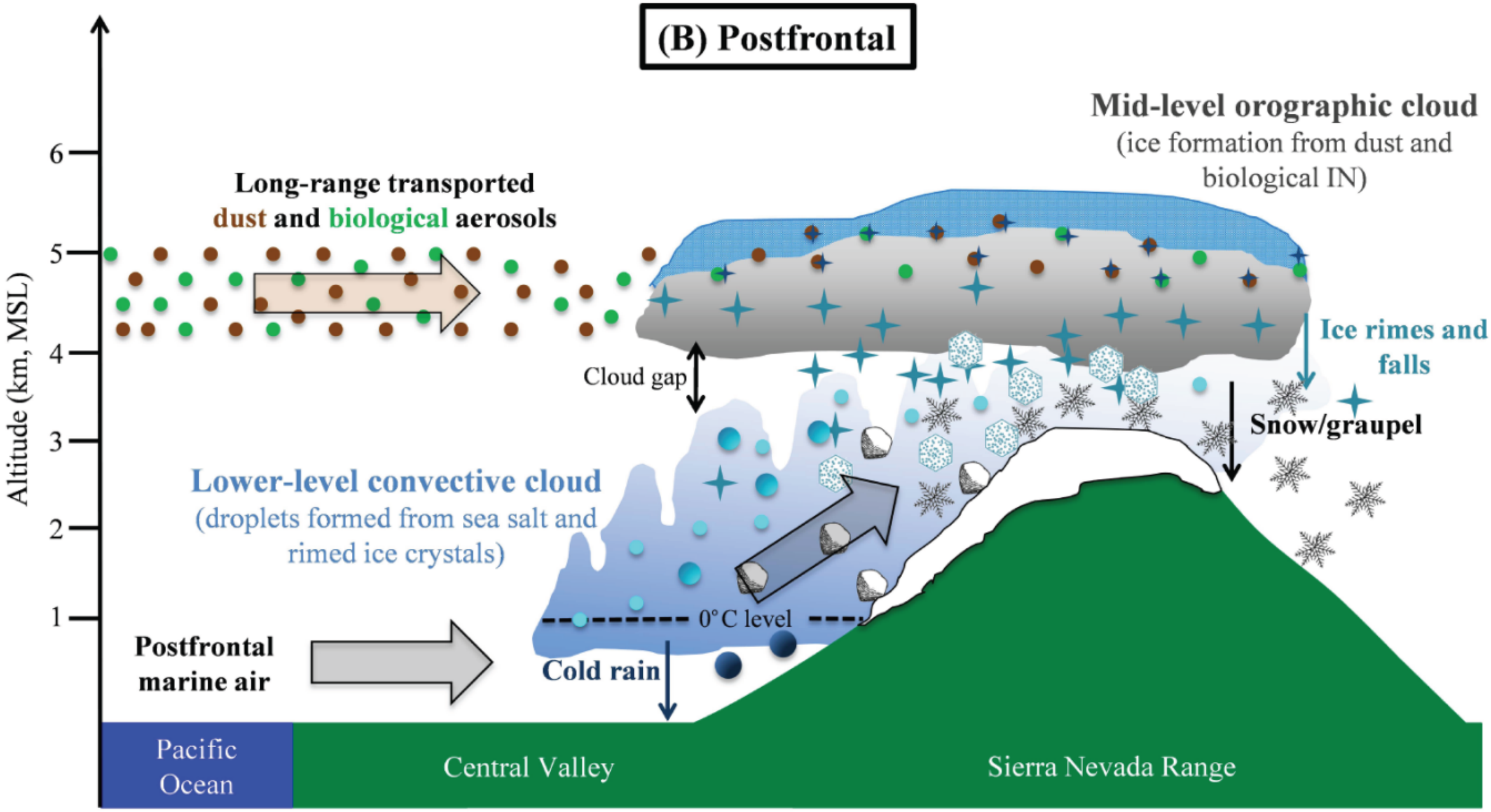

CalWater 2011 field observations showed days with dust and bioparticles experienced extensive snowfall

Modeling of aerosol effects

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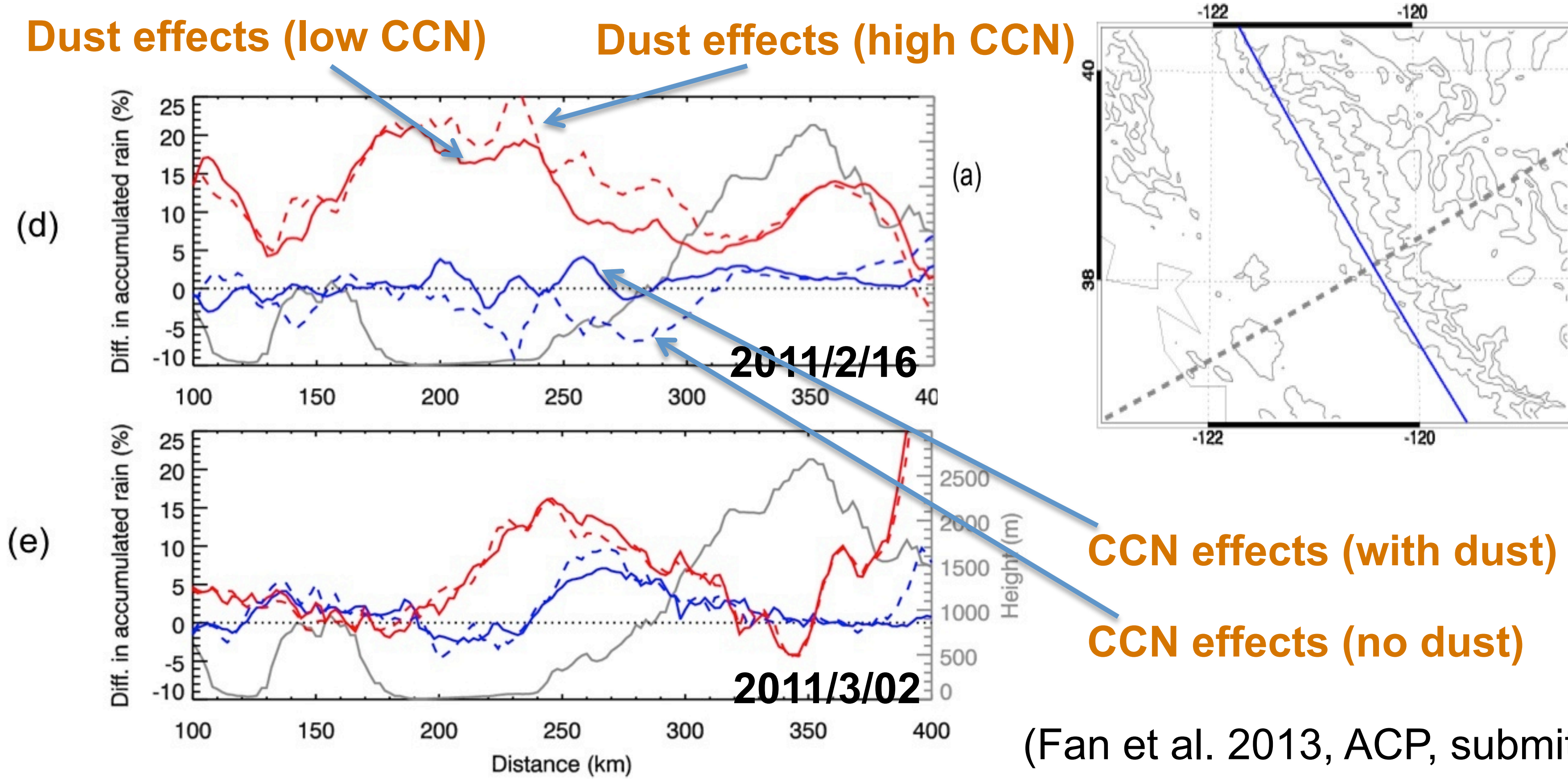


(Fan et al. 2013, ACP, submitted)

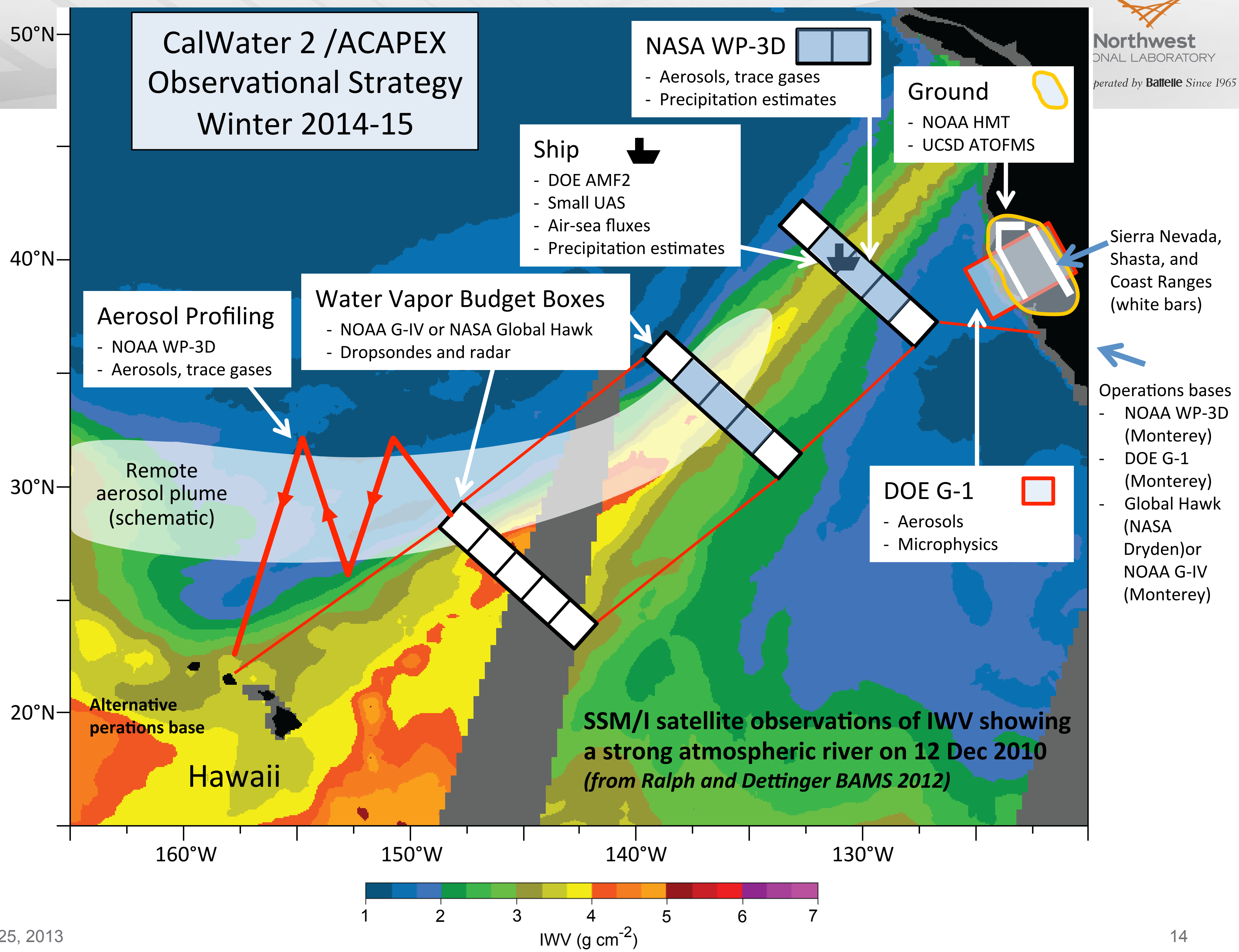
- Removing dust reduces precipitation (mainly snowfall) by up to 20%, with larger effects under polluted conditions
- Pollution aerosols (CCN) suppress precipitation by about 5% without dust, but when dust is present, CCN enhance precipitation

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

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*



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

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

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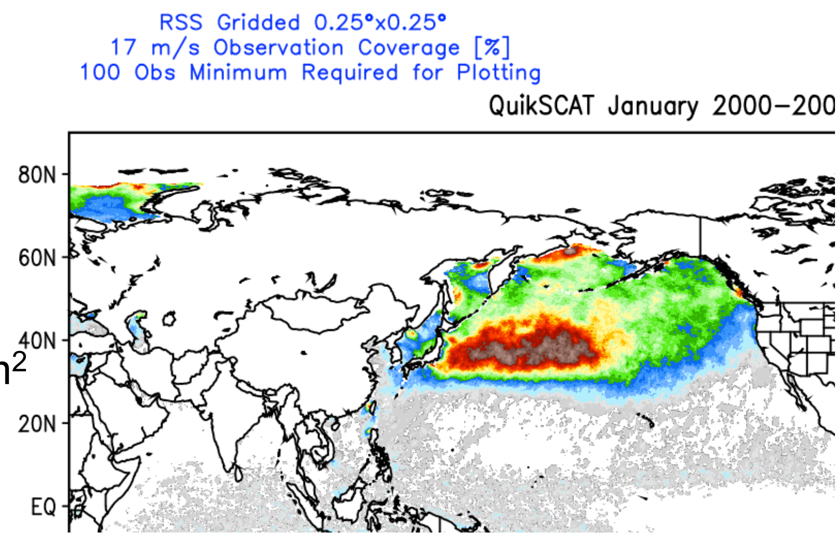
- Ships (Brown and/or UNOLS Class I)
- Aircraft (NOAA P-3, NOAA G-IV?)
- Field Duration – 30 days
- Time Window – Dec 1, 2014 – Mar 31, 2015
- Ship location – Nominally 35-40 N 130 W
- Modeled after DYNAMO Revelle field program – joint air/sea obs.

DYNAMO

- Undisturbed U=4, Net heat 100 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

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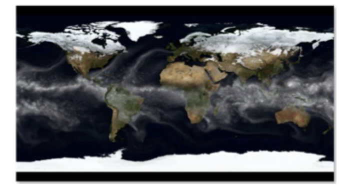
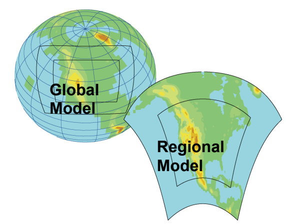
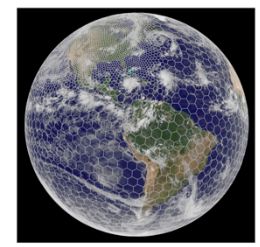
Process Modeling

- 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