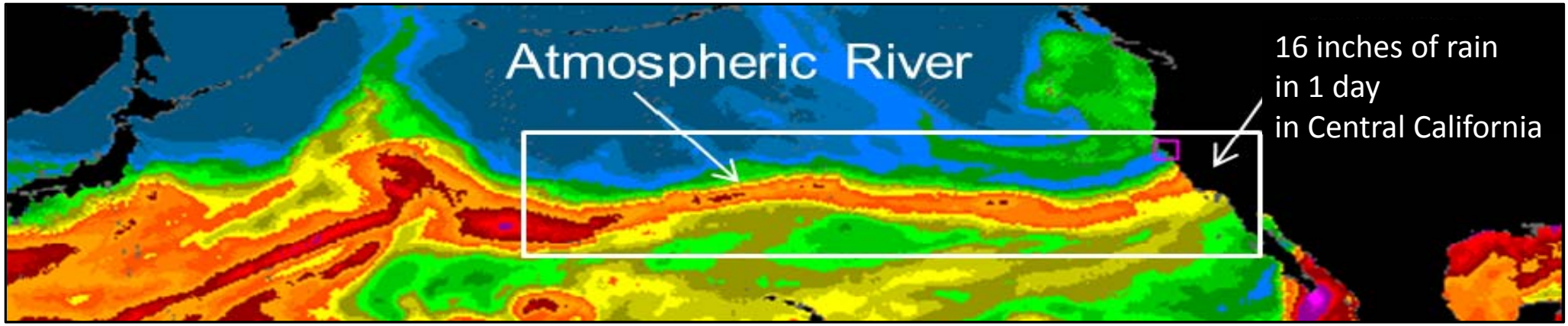


Anticipating Extreme Precipitation Events: Atmospheric Rivers and Scripps/CW3E Weather Modeling for the Bay Area

F. Martin Ralph

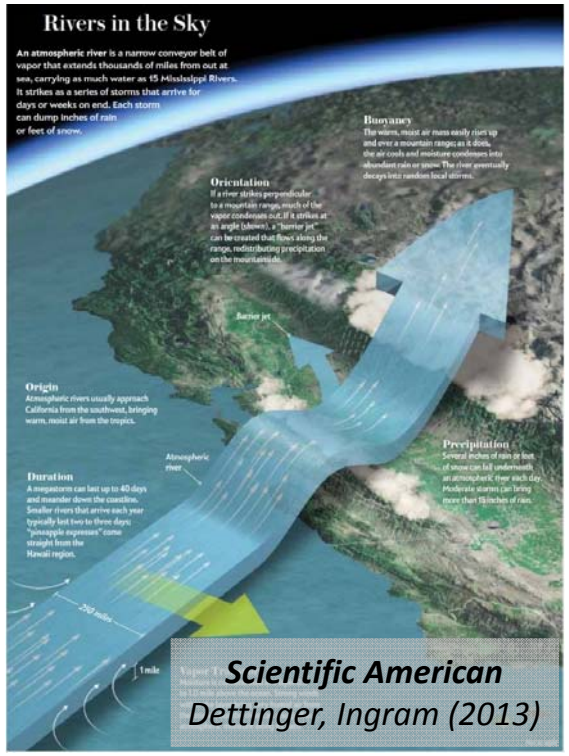
Center for Western Weather and Water Extremes – "CW3E"

at UC San Diego/Scripps Institution of Oceanography

CW3E.ucsd.edu

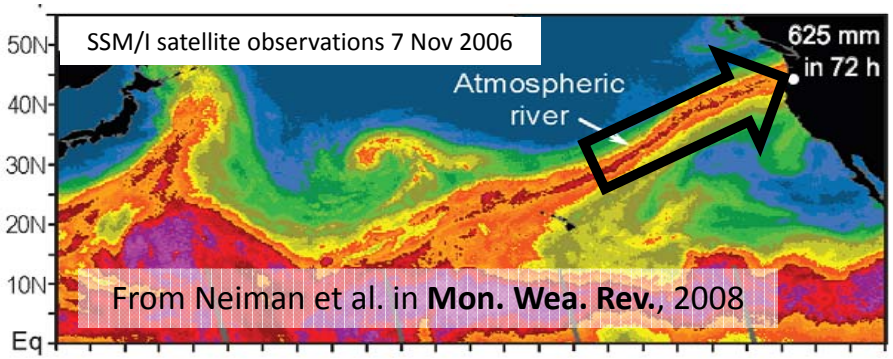
BAFPAA-CHARG panel "Climate Change: The New Normal"

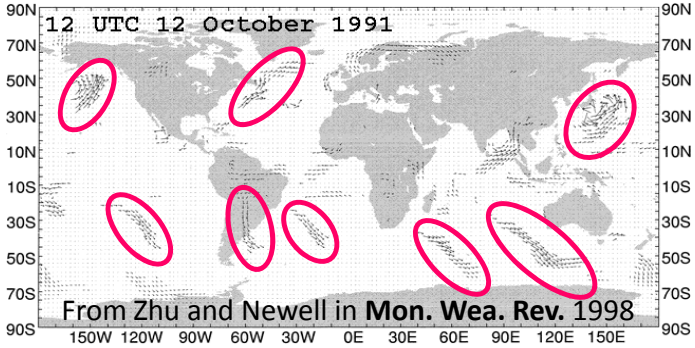
Oakland, California, 19 February 2015



Scientific American
Dettinger, Ingram (2013)

What are Atmospheric Rivers (AR)?



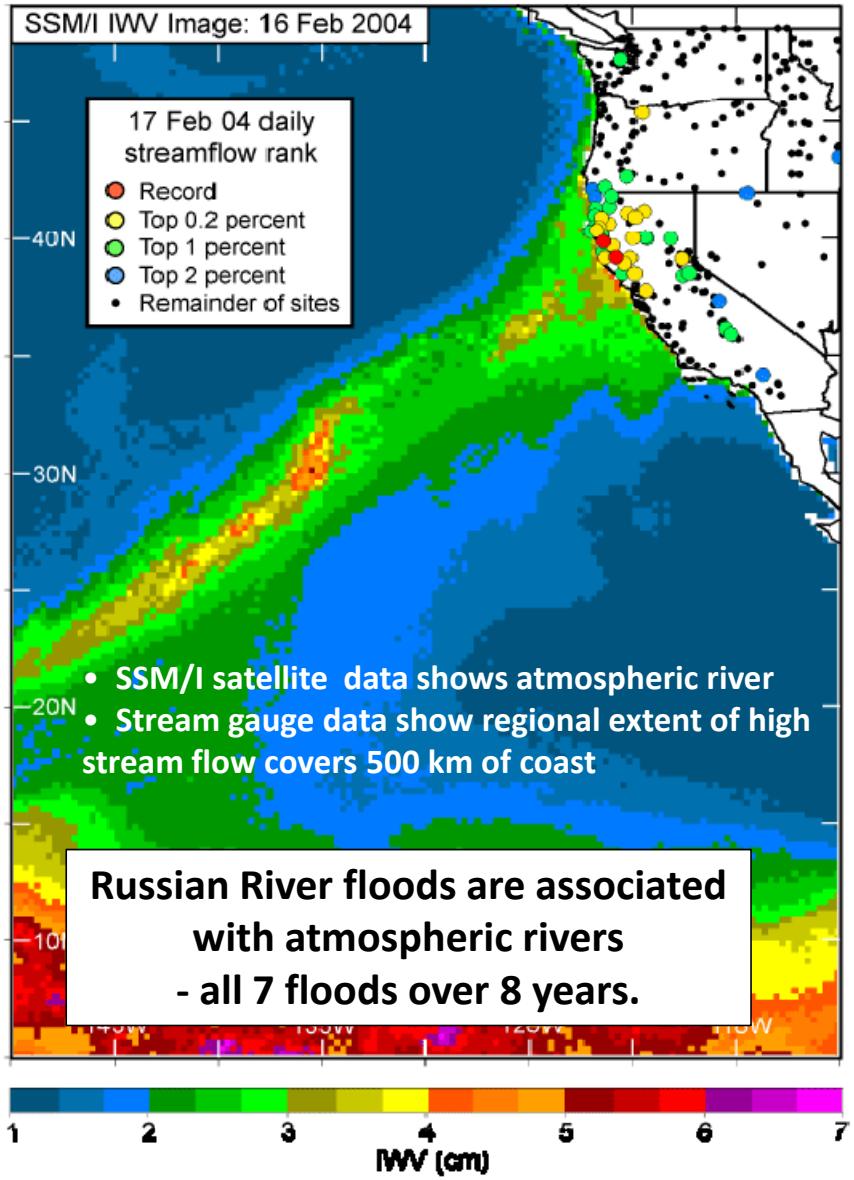


ARs are narrow region of strong winds and large amounts of water vapor. On average they are 400 km wide.

These regions provide the "fuel" (water vapor) for sometimes heavy rain or snow

Usually there are only a few present at one time

ARs are "narrow" regions in the atmosphere that perform >90% of the water vapor transport in earth's midlatitudes. They move with the larger storms they are part of and on average there are only 3-5 ARs in a hemisphere at one time.



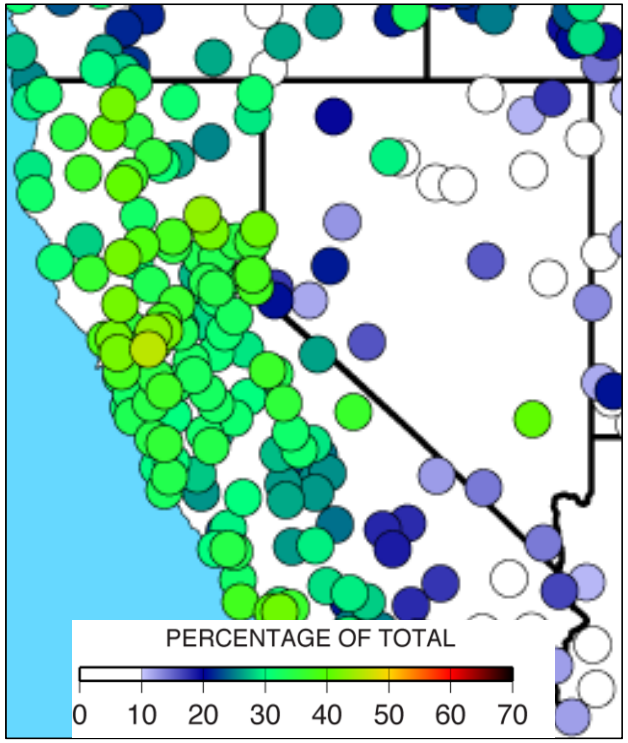
Flooding on California's Russian River: Role of atmospheric rivers

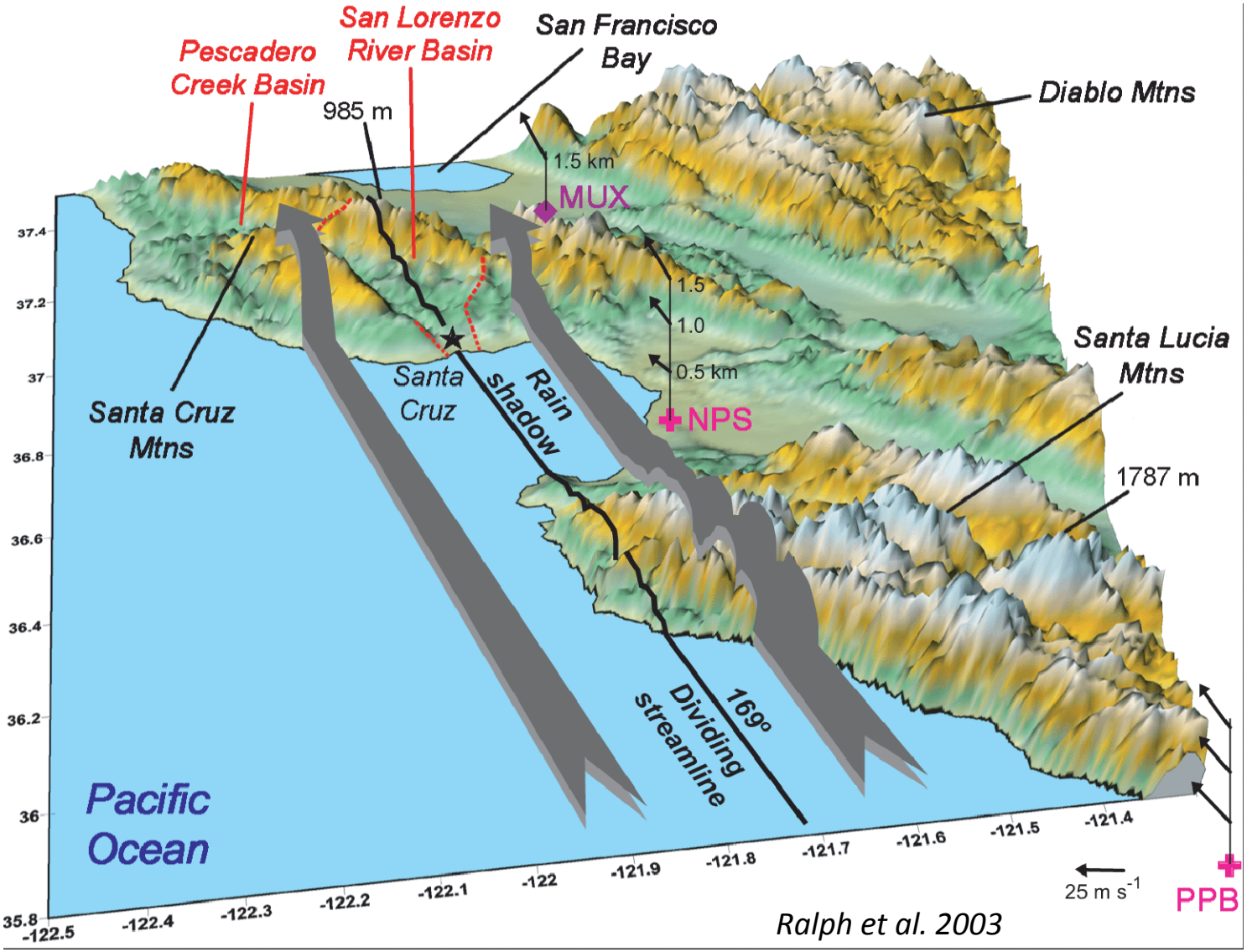
Ralph, F.M., P. J. Neiman, G. A. Wick, S. I. Gutman, M. D. Dettinger, D. R. Cayan, A. White (*Geophys. Res. Lett., 2006)*

ARs can CAUSE FLOODS and PROVIDE WATER SUPPLY

Atmospheric Rivers, Floods and the Water Resources of California

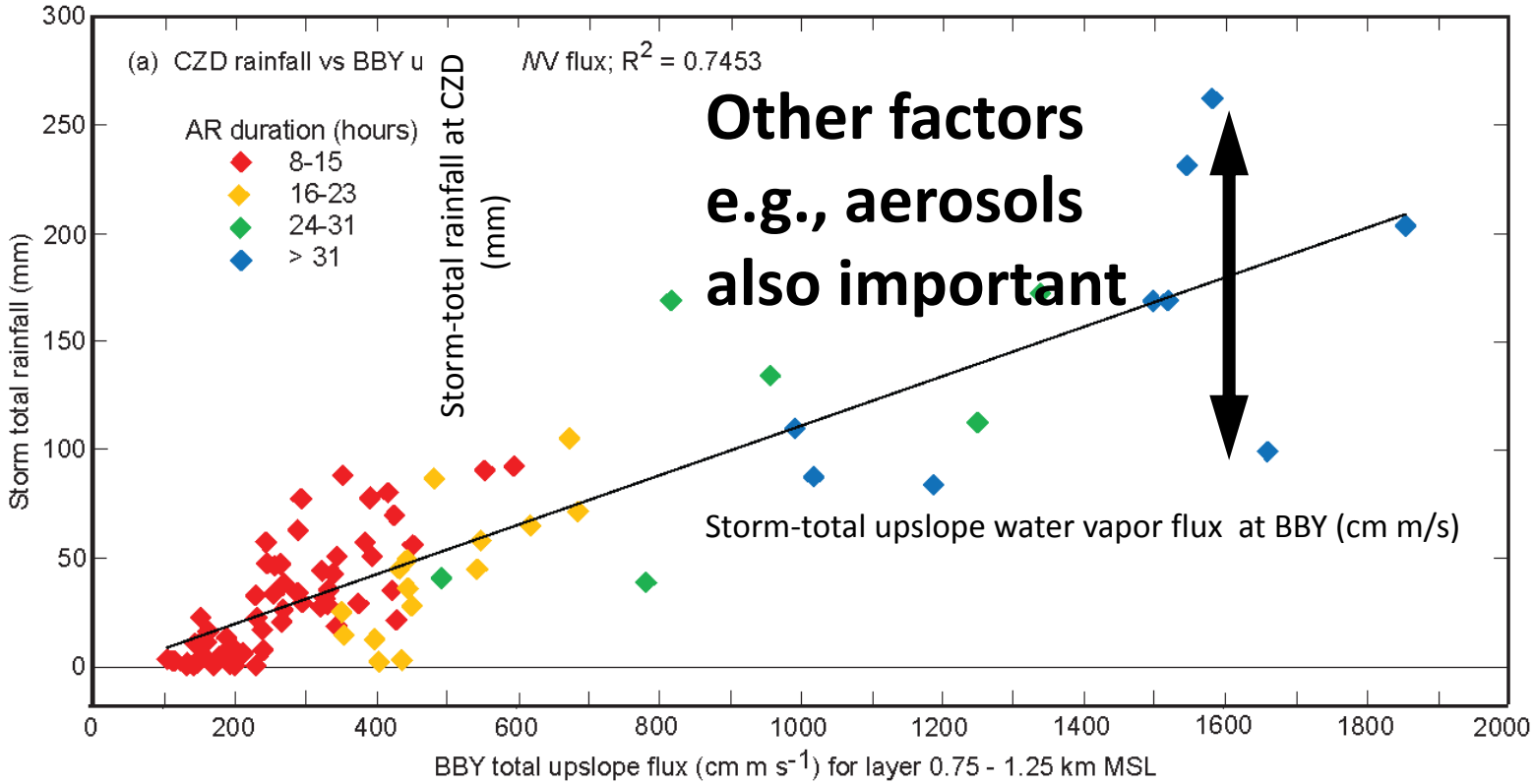
Mike Dettinger, M. Ralph, , T. Das, P. Neiman, D. Cayan *(Water, 2011*)





Ralph et al. 2003

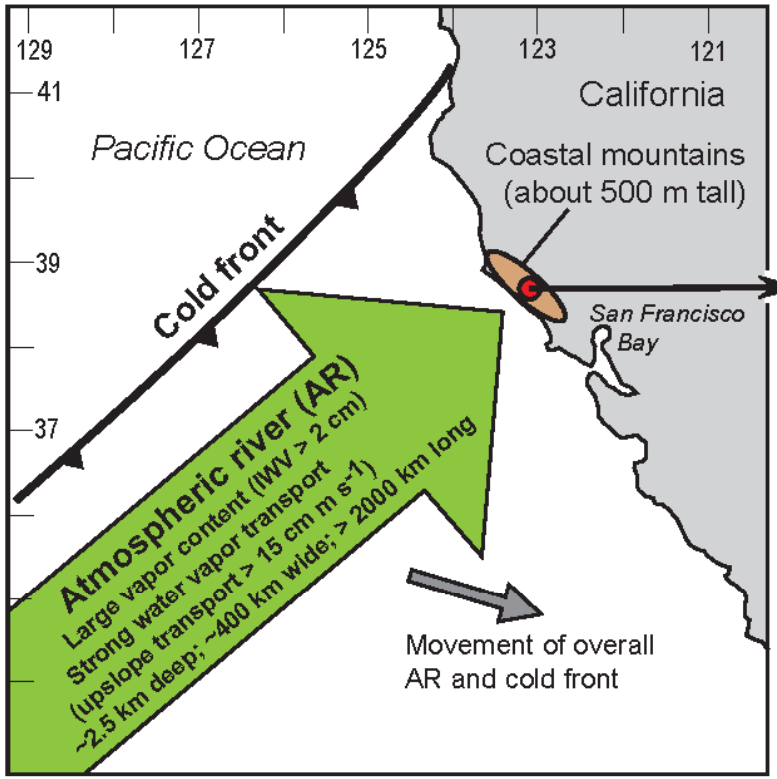
AR "Angle of Attack" can determine flooding in the Bay Area

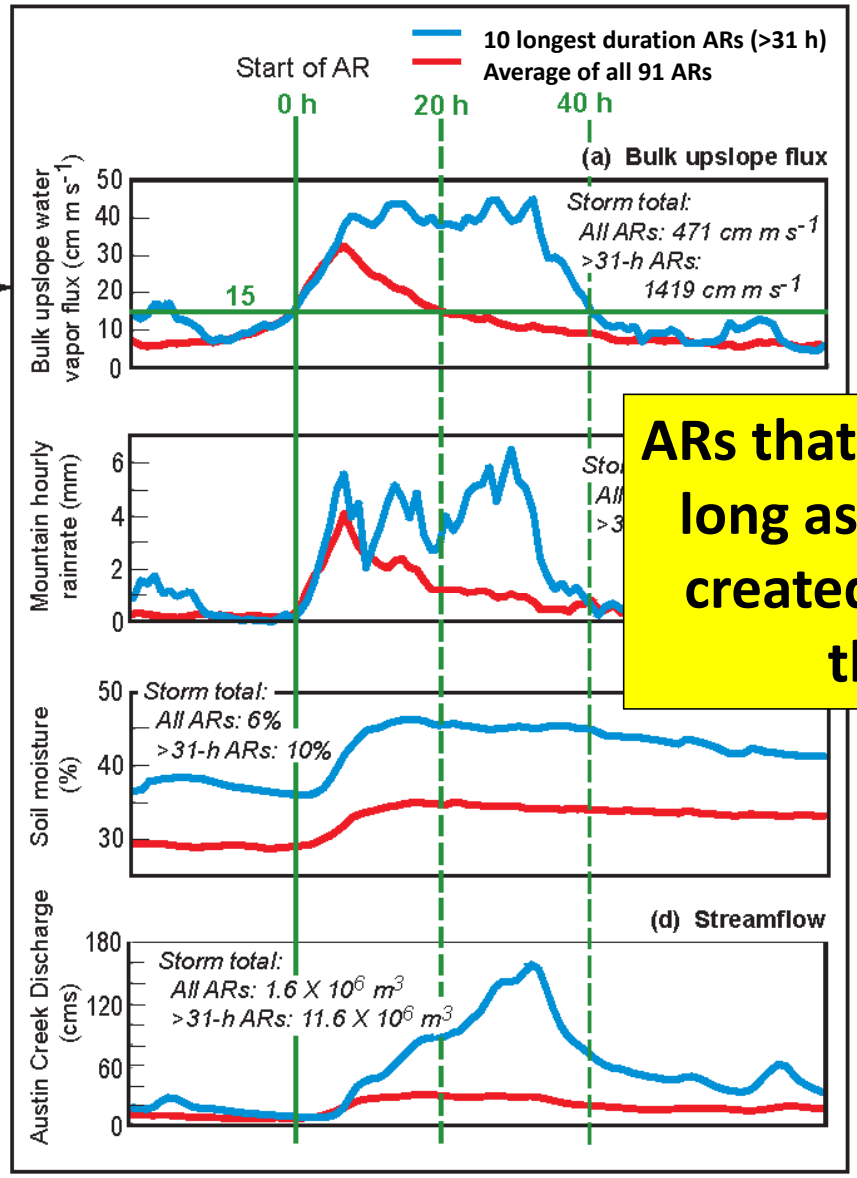


The greater the precipitation

The greater the AR strength and duration

From Ralph et al. 2013, *J. Hydrometeorology*





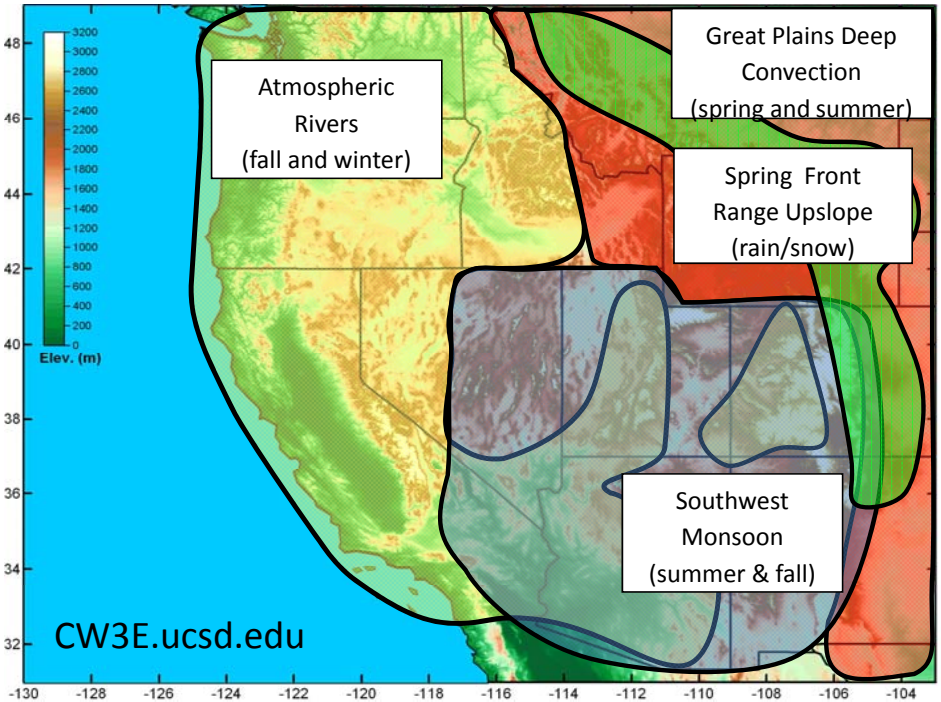
ARs that lasted TWICE as long as an average AR created SEVEN TIMES the runoff

Key conditions during 91 ARs observed at the Earth's surface and aloft north of San Francisco, WY2005-2010

The following attributes characterize the 10 longest-duration ARs, which produced the most extreme rainfall and streamflow:

- AR conditions persisted for > 31 h
- Coastal rainfall averaged 140 mm during AR conditions
- Wind direction between 180° to 240° at about 1 km MSL
- Storm-total Bulk Upslope IWV flux was > 1000 units
- Precursor soil moisture was > 36%
- Heavy rain was in DJF and transition seasons (SON, MAM)
- Extreme runoff was in December, January, February (DJF)

From Ralph et al. 2013, *J. Hydrometeorology*



Center for Western Weather & Water Extremes

Where: UC San Diego/Scripps Inst. Oceanography
La Jolla, California

When: Start - 2013

Who: F. M. Ralph (Director), Dan Cayan, Mike Dettinger, Dave Pierce, John Helly (SDSC), Sasha Gershunov, Mary Tyree, Sam Iacobellus, Kristin Guirguis, Andrew Martin (Post Doc), Dave Lavers (Post Doc), Julie Kalansky (Post Doc), Reuben Demirdjian (Gr. Student), R. Harnish, Duane Waliser (JPL), Ryan Spackman (NOAA & STC)
Collaborators B. Cornuelle, A. Miller, A. Evan, J. Kleissl (MAE)

Mission

Provide 21st Century water cycle science, technology and outreach to support effective policies and practices that address the impacts of extreme weather and water events on the environment, people and the economy of Western North America

Goal

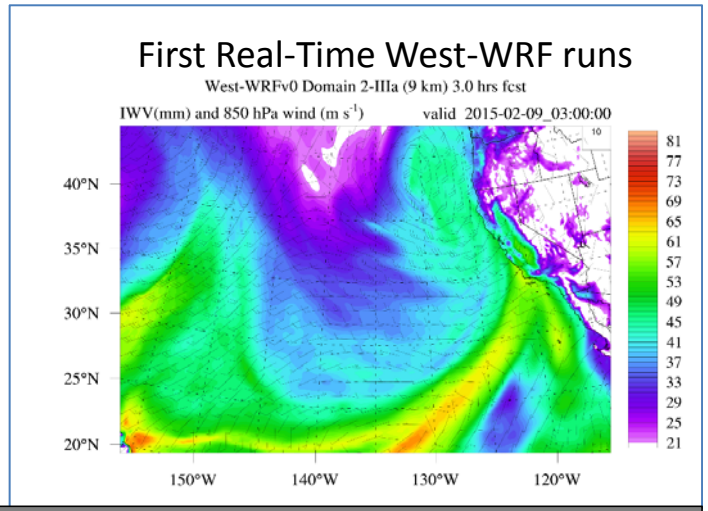
Revolutionize the physical understanding, observations, weather predictions and climate projections of extreme events in Western North America, including atmospheric rivers and the North American summer monsoon as well as their impacts on floods, droughts, hydropower, ecosystems and the economy

CW3E-SDSC Partnership

"West-WRF" Weather Model to Focus on Western U.S. Extreme Events

- ✓ SDSC Director and UCSD Physics Professor Mike Norman is fully-supportive of CW3E
- ✓ Contributing Staff time (J. Helly), computer time and disk storage on the *Gordon* supercomputer

- ✓ Interdisciplinary team of SIO & SDSC Scientists, post-docs and grad students
- ✓ Working to an integrated *research* and *operations* plan
- ✓ *West-WRF* implemented in < 6 months now supporting Calwater2 mission planning



CalWater Observations will be used to evaluate, explore and improve the physics in CW3E's West-WRF Model from air-sea interaction, to mesoscale dynamics, aerosols and cloud microphysics and data assimilation.

CalWater-2* "Early Start" field campaign

3-25 February 2014

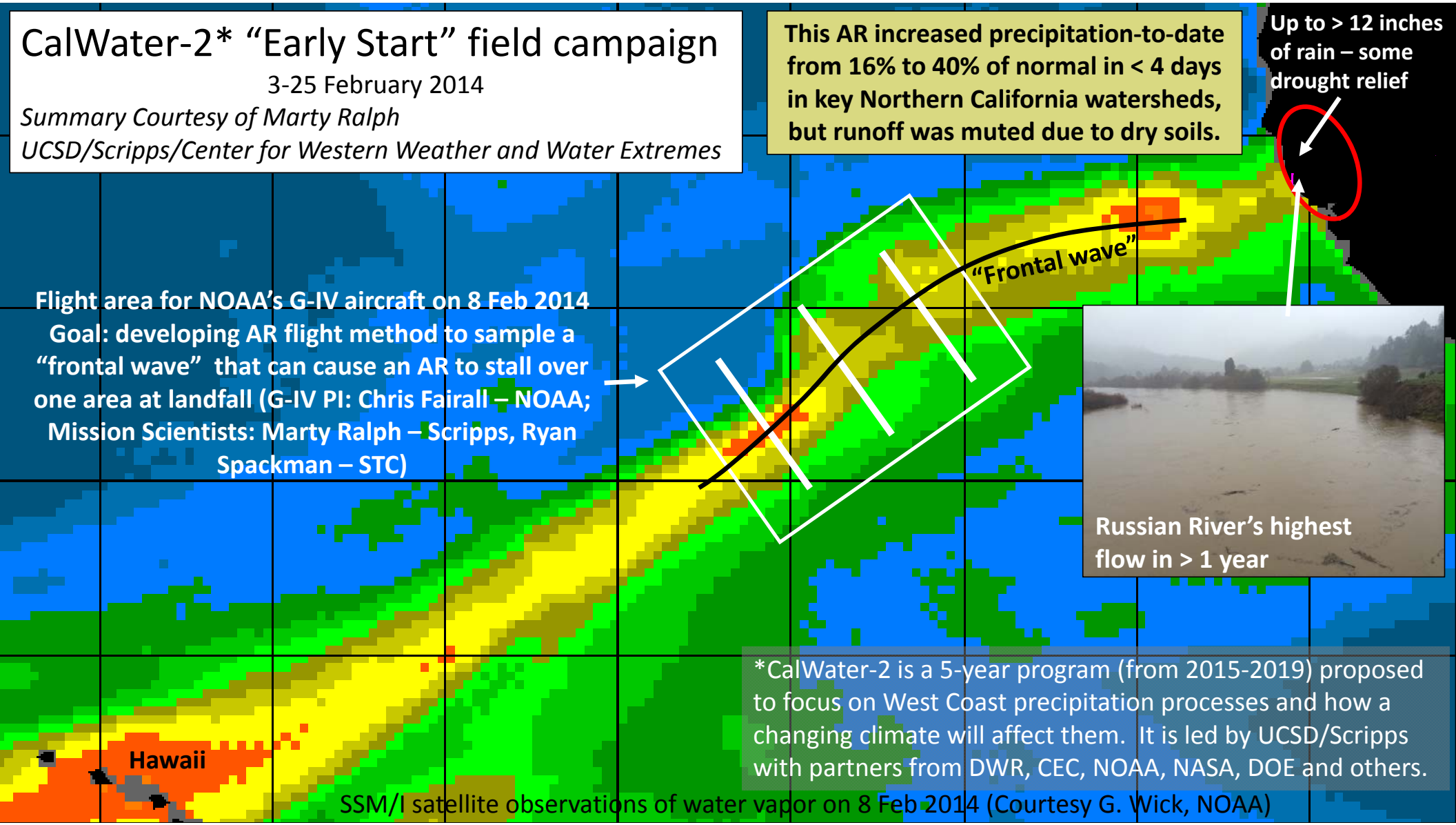
Summary Courtesy of Marty Ralph

UCSD/Scripps/Center for Western Weather and Water Extremes

This AR increased precipitation-to-date from 16% to 40% of normal in < 4 days in key Northern California watersheds, but runoff was muted due to dry soils.

Up to > 12 inches of rain – some drought relief

Flight area for NOAA's G-IV aircraft on 8 Feb 2014 Goal: developing AR flight method to sample a "frontal wave" that can cause an AR to stall over one area at landfall (G-IV PI: Chris Fairall – NOAA; Mission Scientists: Marty Ralph – Scripps, Ryan Spackman – STC)



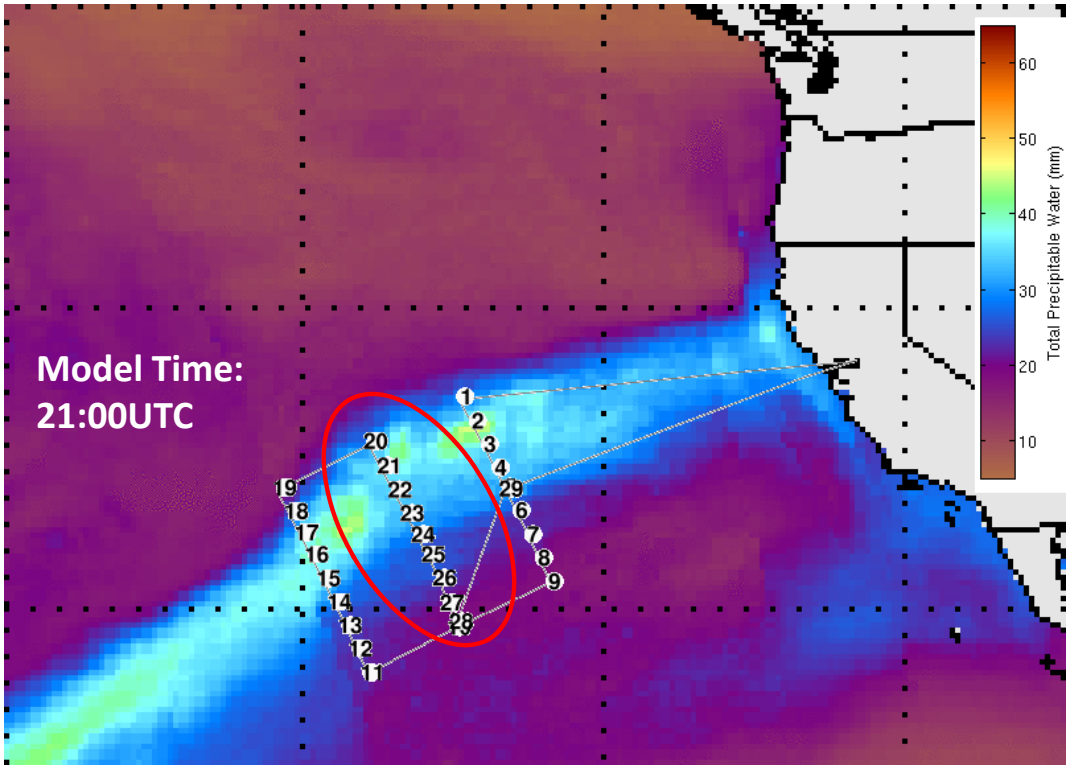
Russian River's highest flow in > 1 year

*CalWater-2 is a 5-year program (from 2015-2019) proposed to focus on West Coast precipitation processes and how a changing climate will affect them. It is led by UCSD/Scripps with partners from DWR, CEC, NOAA, NASA, DOE and others.

SSM/I satellite observations of water vapor on 8 Feb 2014 (Courtesy G. Wick, NOAA)

a3

Flight 2, February 8-9th, 2014



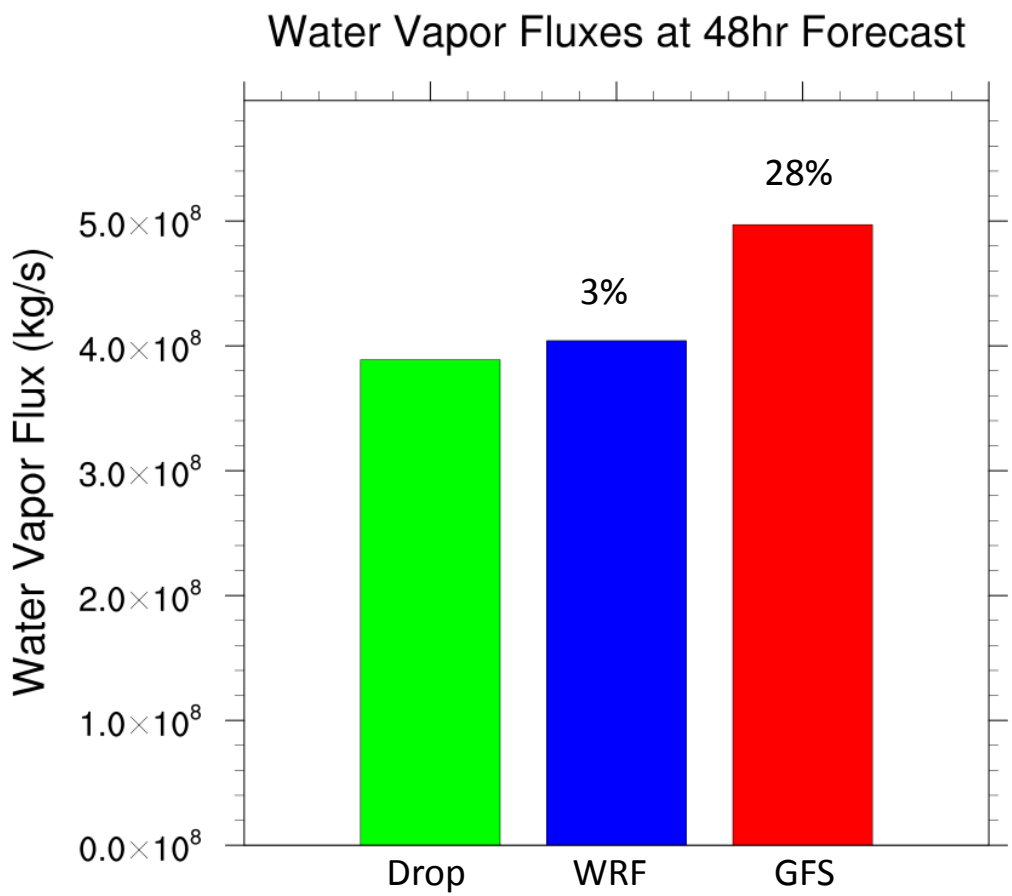
Sam Iacobellis

Slide 10

a3 This slide and the next are pretty redundant. How can he clean this up so that it bogs down the flow less? Maybe hand-draw the WRF and GFS transects over this image? PPL will want to see all three transects in the context of the IWV imagery.

amartin, 9/22/2014

Water Vapor Flux Through Transect



Summary of Model Error

	WRF	GFS	Forecast Time (hr)
Flight 2, T1, 1-9	9%	18%	45
Flight 2, T2, 11-19	0%	8%	48
Flight 2, T3, 20-28	3%	28%	48
Flight 3, T1, 4-33	2%	37%	51
Flight 4, T1, 1-10	17%	10%	72
Flight 4, T1, 1-10	52%	0%	138
Flight 5, T1, 1-23	5%	51%	99

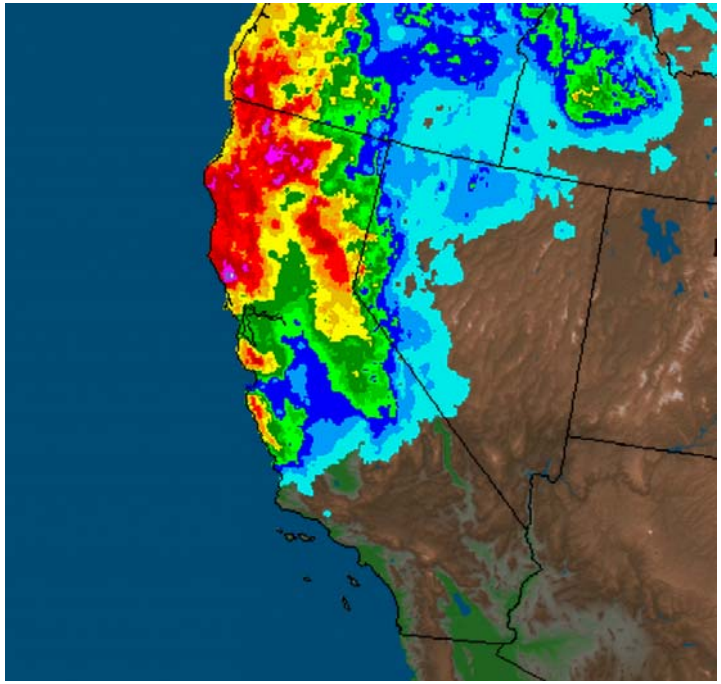
a12

$$\frac{WVFlux_{obs} - WVFlux_{model}}{WVFlux_{obs}}$$

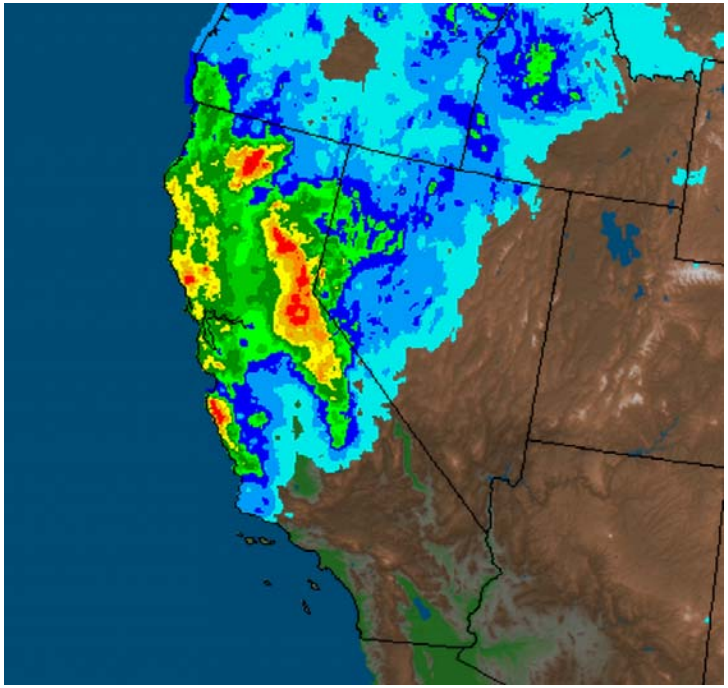
Slide 12

a12 Very good idea here, I would name this slide "Percent Error in Forecast WV Flux" I would also add a column which displays the length of forecast to validation time.
amartin, 9/25/2014

West-WRF and the Back-to-Back February ARs (02-05 through 02-08)

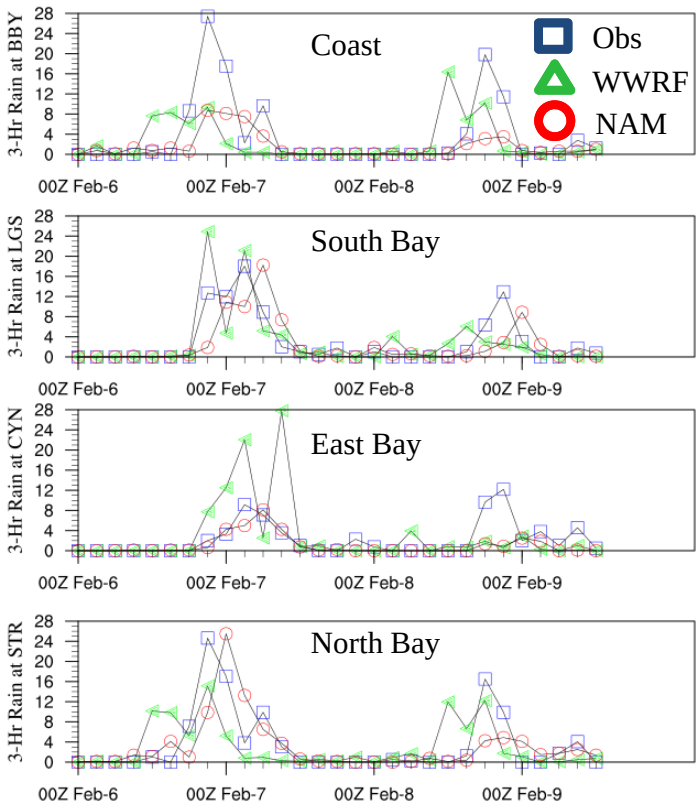


24 hour Precipitation ending
Feb. 7, 2015 @ 4 am PST



24 hour Precipitation ending
Feb. 9, 2015 @ 4 am PST

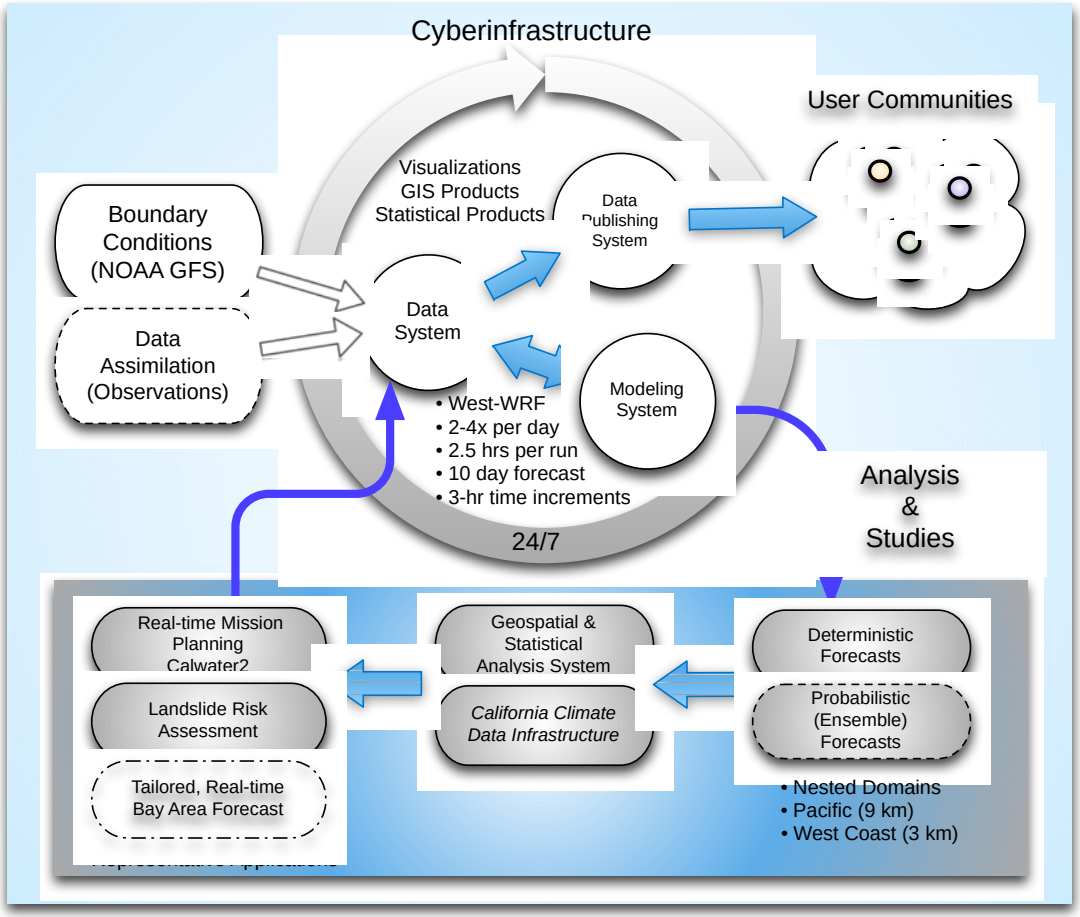
West Coast Focus and High Resolution Capture Observed Heavy Precipitation



Periods Exceeding 0.5 inch Rainfall

Observed	6
West-WRF Hits	2
NAM Hits	0

Calwater2 Real-time Mission Support Framework

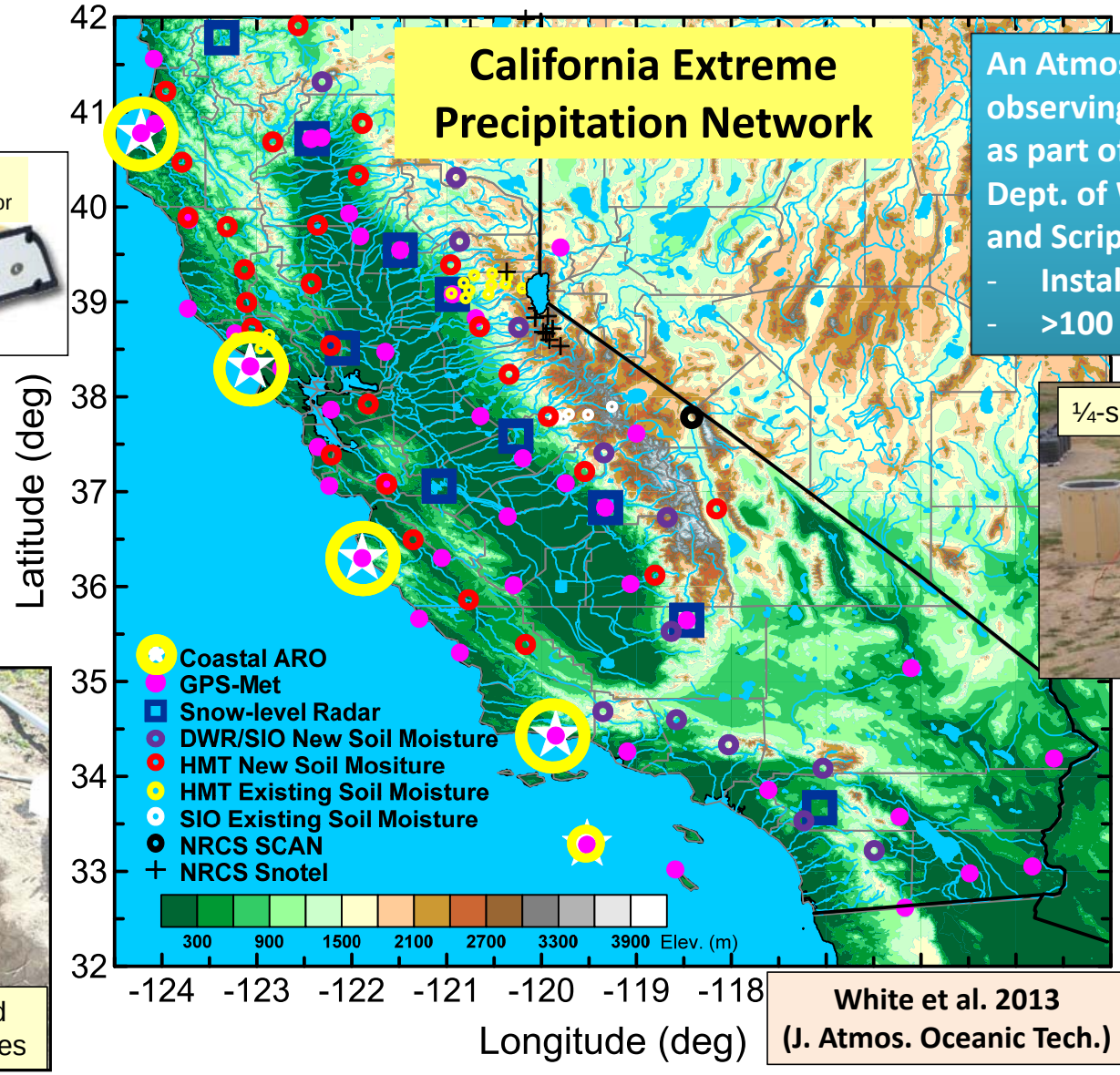


- West-WRF began running in mid-December 2014
- Calwater2 Real-time Mission Support began 4-Jan-2015 and continues

California Extreme Precipitation Network

An Atmospheric River-focused long-term observing network is being installed in CA as part of a 5-year project between CA Dept. of Water Resources (DWR), NOAA and Scripps Inst. Of Oceanography

- Installed 2008-2014
- >100 field sites

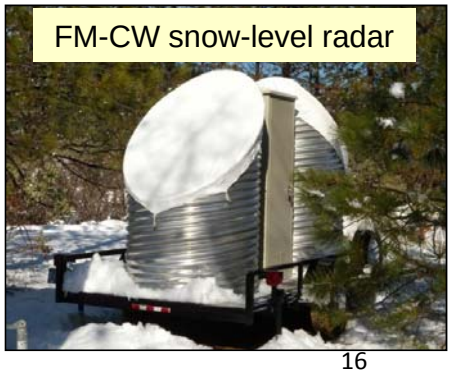


GPS receiver for integrated water vapor

¼-scale 449-MHz wind profiler with RASS

Soil Moisture and Temperature Probes

FM-CW snow-level radar



White et al. 2013
(J. Atmos. Oceanic Tech.)

CalWater 2

Precipitation, Aerosols, and Pacific Atmospheric Rivers Experiment

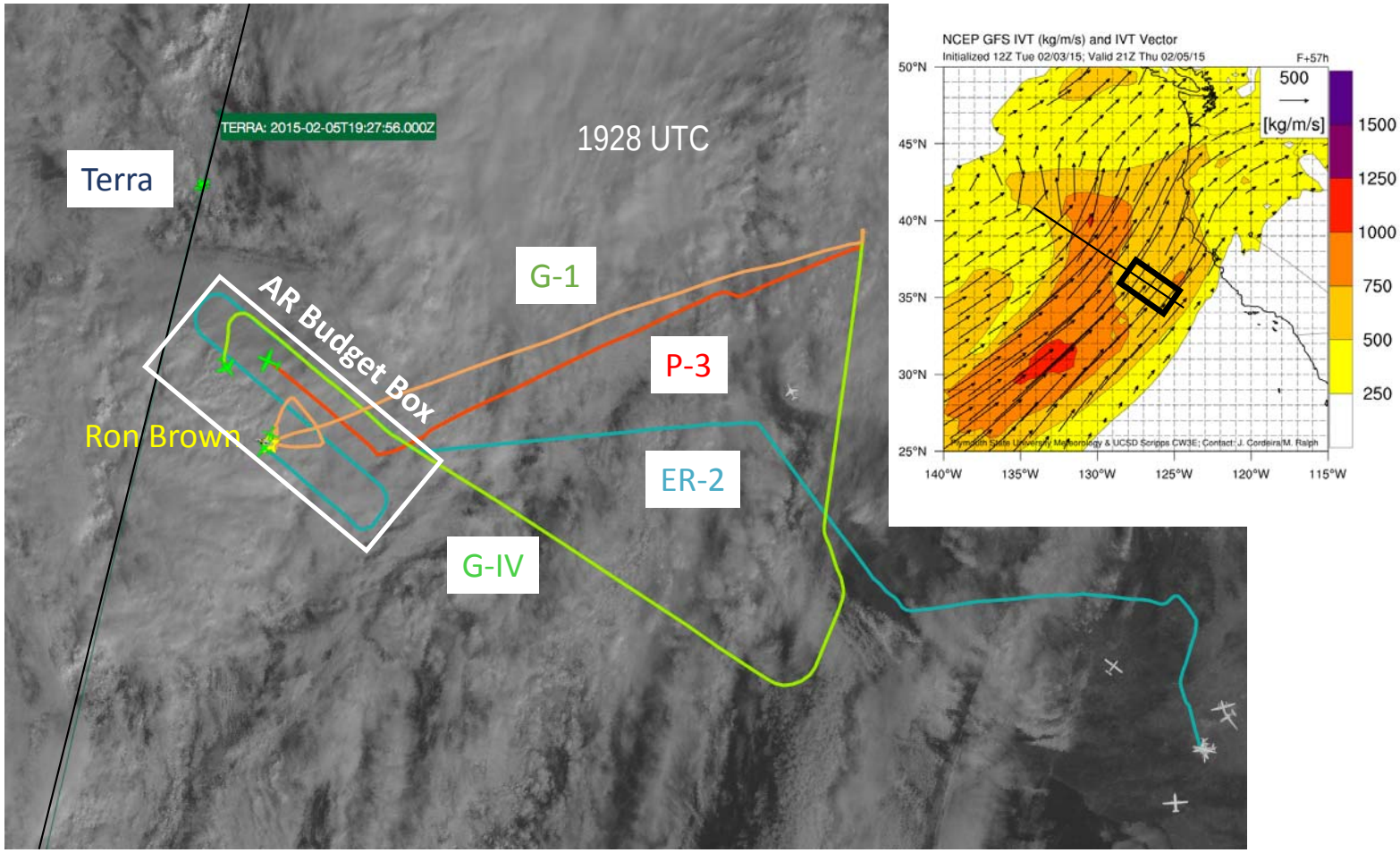
Scripps Inst. Oceanography Institutional Seminar – 12 Feb 2015

F. Martin Ralph
UC San Diego/Scripps Institution of Oceanography
Center for Western Weather and Water Extremes (CW3E)

Science Steering Committee

Marty Ralph, Kim Prather, Dan Cayan, Ryan Spackman, Paul DeMott, Mike Dettinger, Chris Fairall, Ruby Leung, Daniel Rosenfeld, Steven Rutledge, Duane Waliser, Allen White

Coordinated flights, February 5, 2015



Thank You

See cw3.ucsd.edu for

- Real-time data and products
- Up-to-date science and projects
- The "AR Portal"

Also see hmt.noaa.gov for mirrored products and other information.