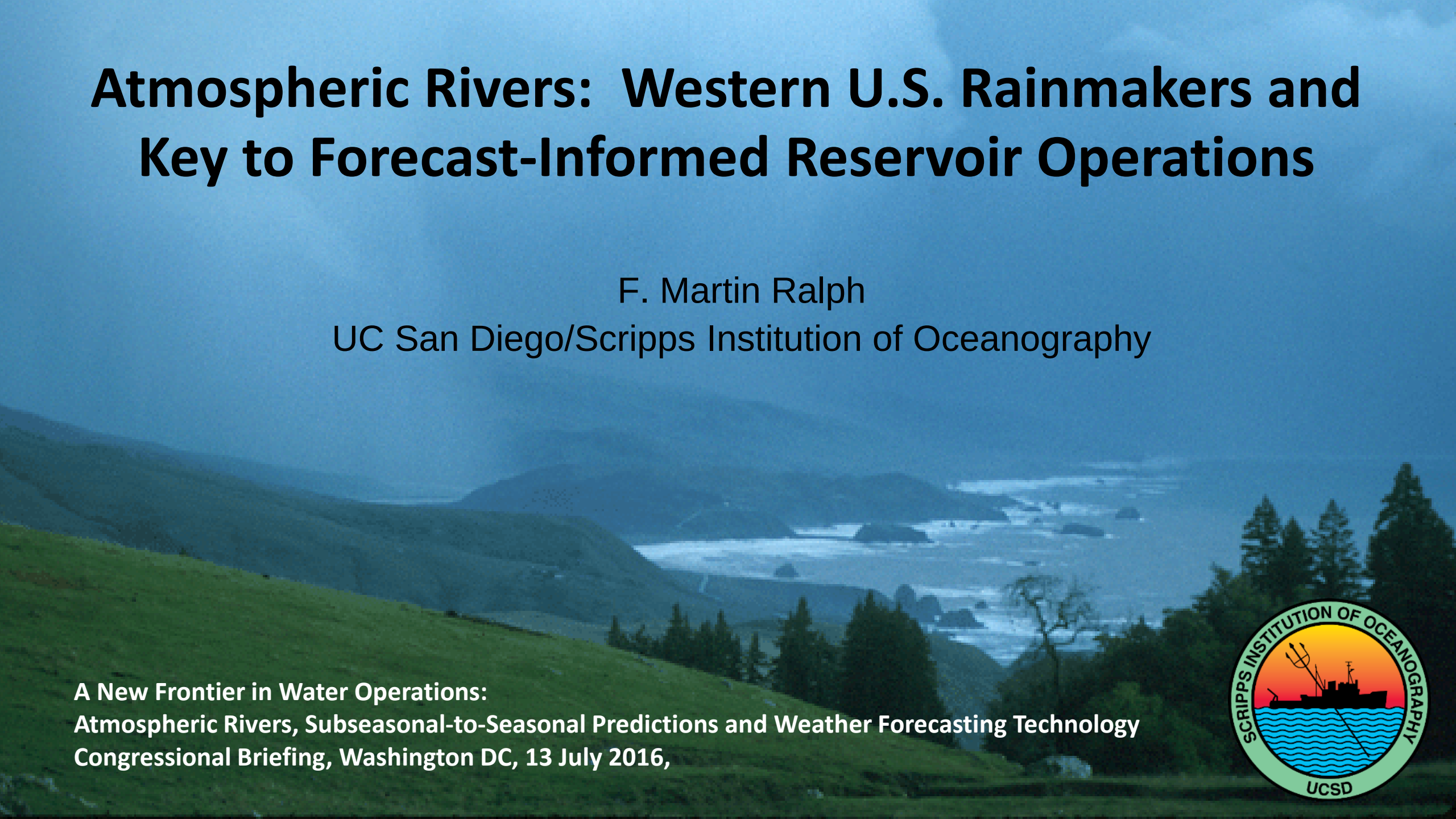
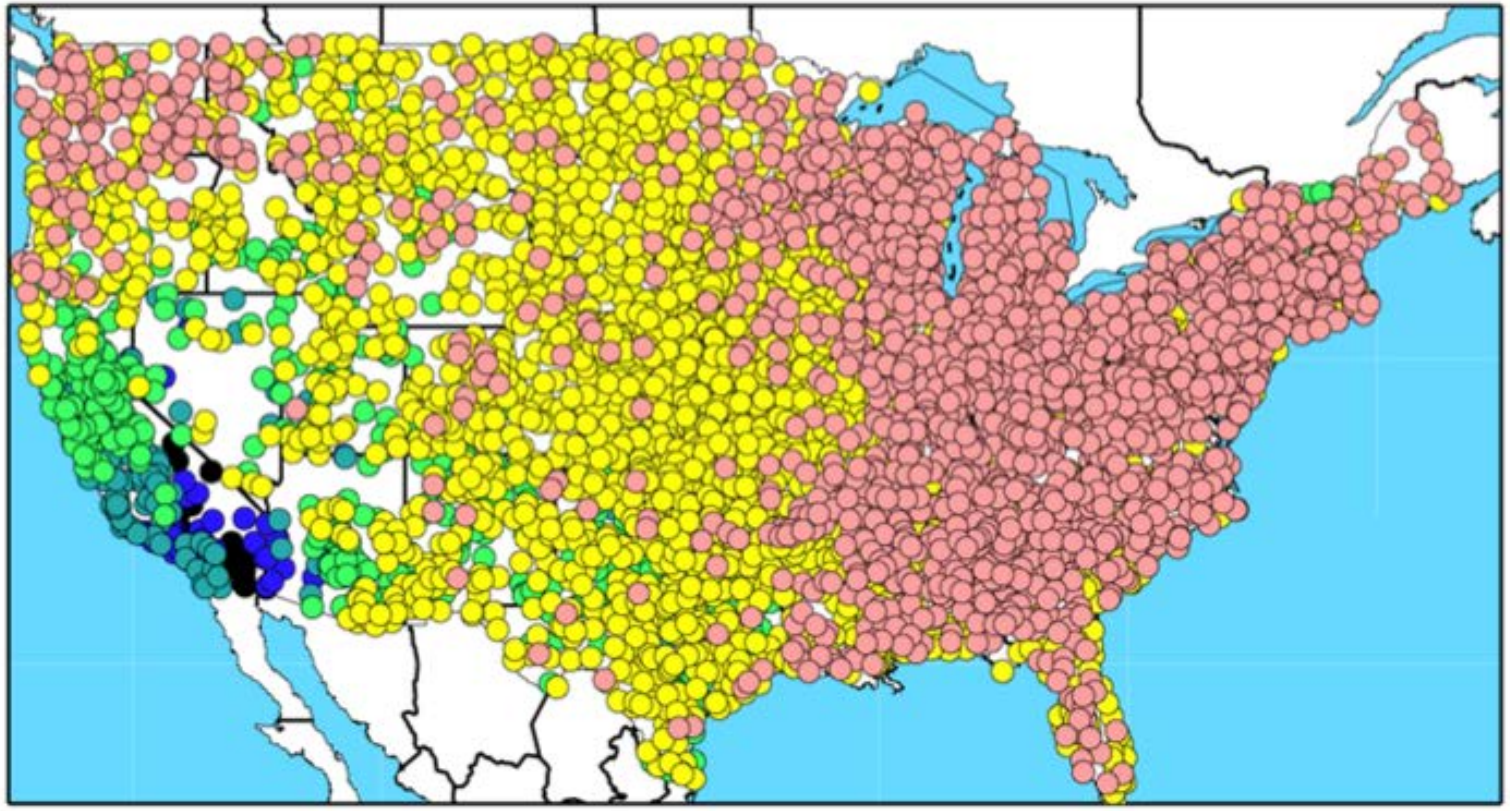
Atmospheric Rivers: Western U.S. Rainmakers and Key to Forecast-Informed Reservoir Operations

F. Martin Ralph
UC San Diego/Scripps Institution of Oceanography

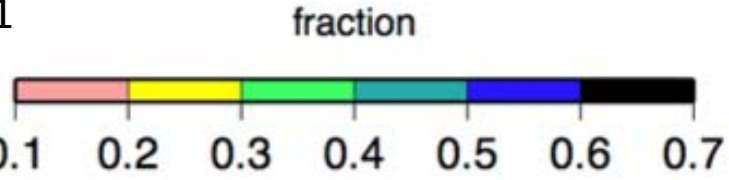


A New Frontier in Water Operations:
Atmospheric Rivers, Subseasonal-to-Seasonal Predictions and Weather Forecasting Technology
Congressional Briefing, Washington DC, 13 July 2016,

Variability of Annual Precipitation



Dettinger et al. 2011

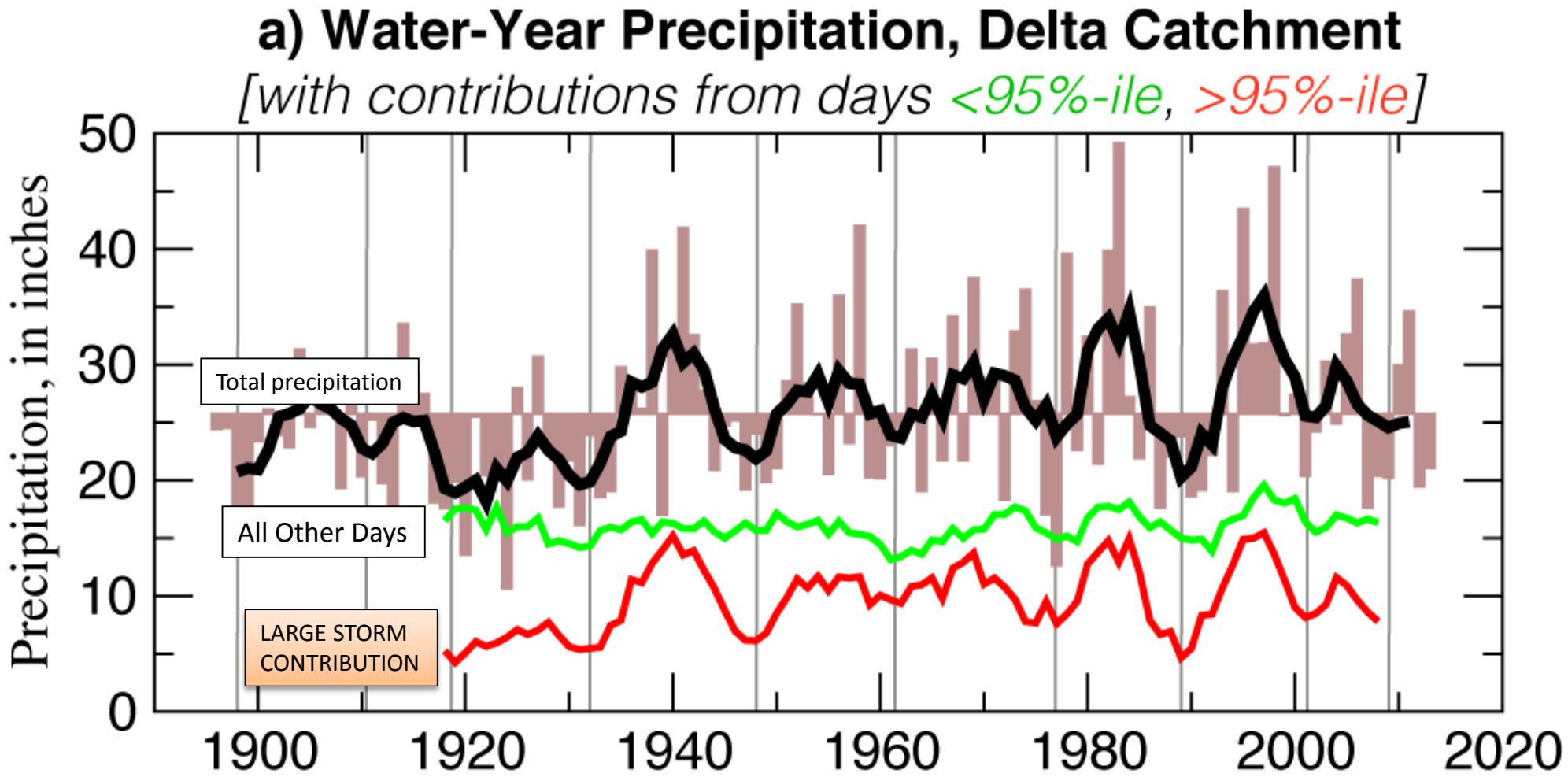


Coefficient of variation for annual precipitation 1950-2008

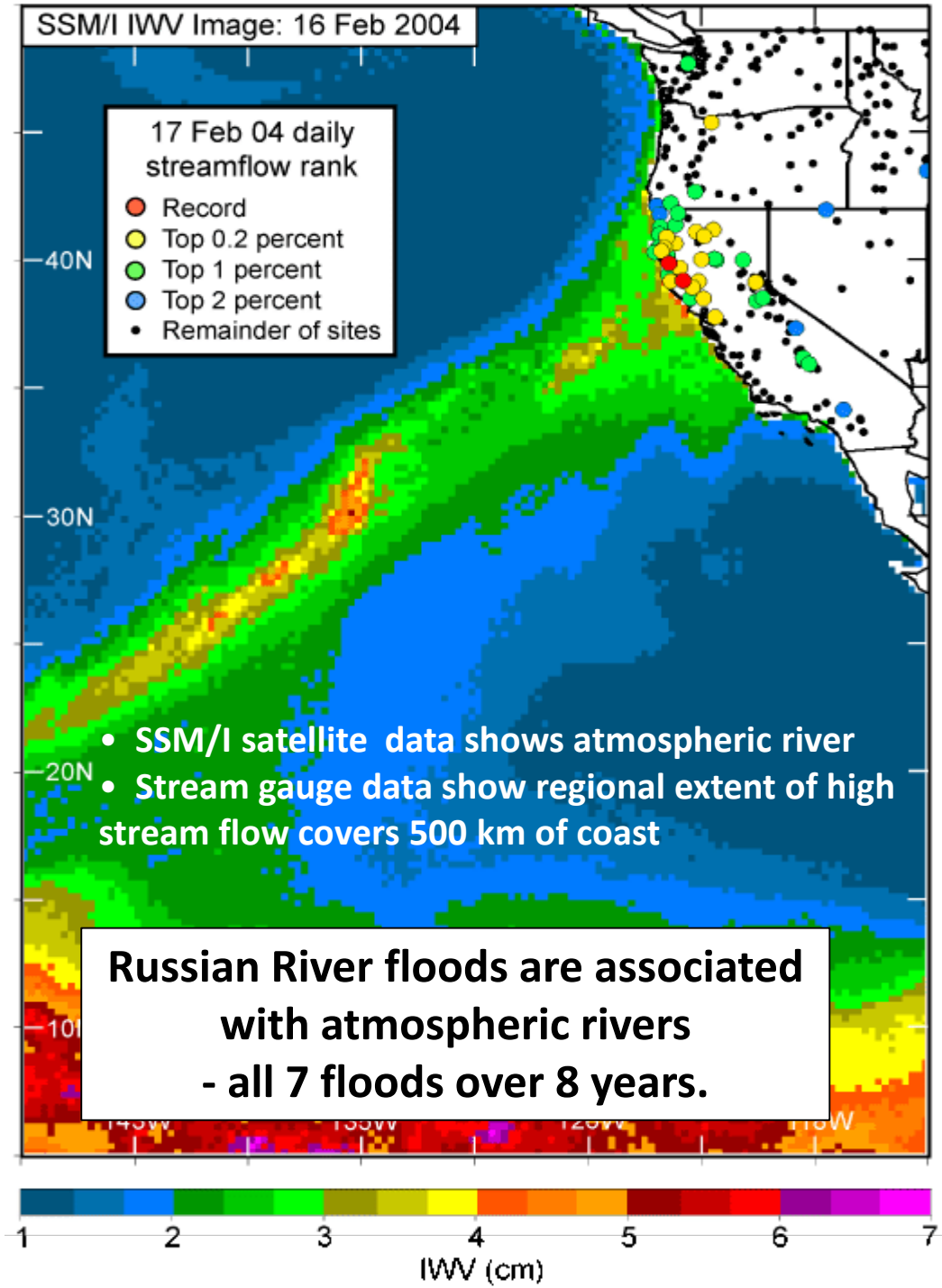
- CA has the largest year to year precipitation variability in the US.
- CA variability is on the order of half the annual average.
- The year to year variability in CA is largely caused by the wettest days (ARs).

A few large storms (or their absence)

account for a disproportionate amount of California's precipitation variability



Dettinger and Cayan **Drought and the Delta—A Matter of Extremes**
San Francisco Estuary and Watershed Science, April 2014



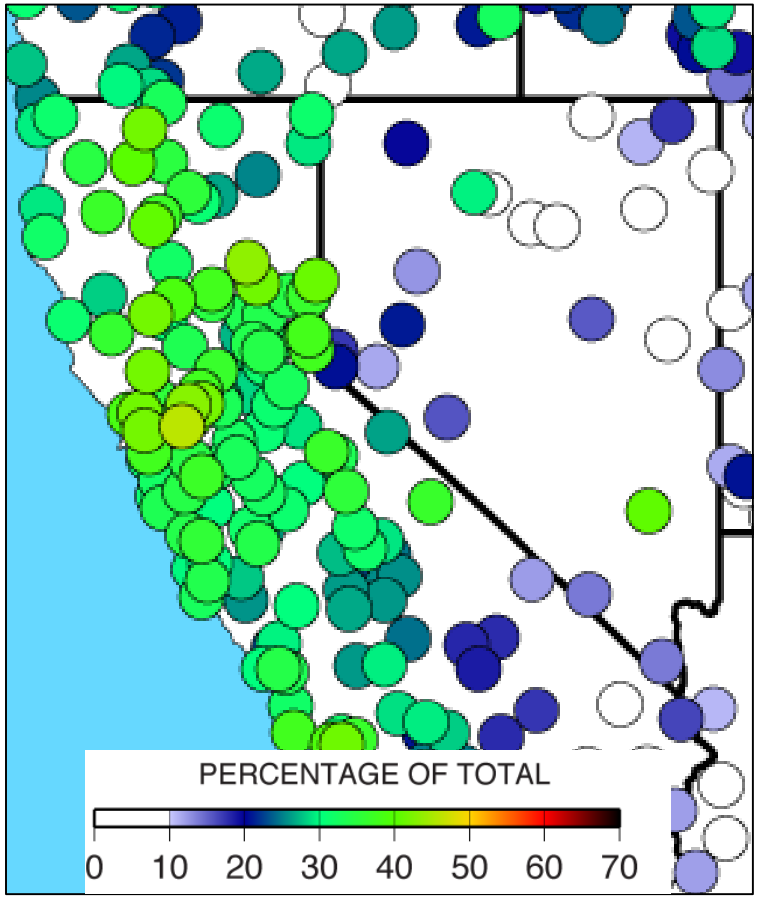
Flooding on California's Russian River: Role of atmospheric rivers

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

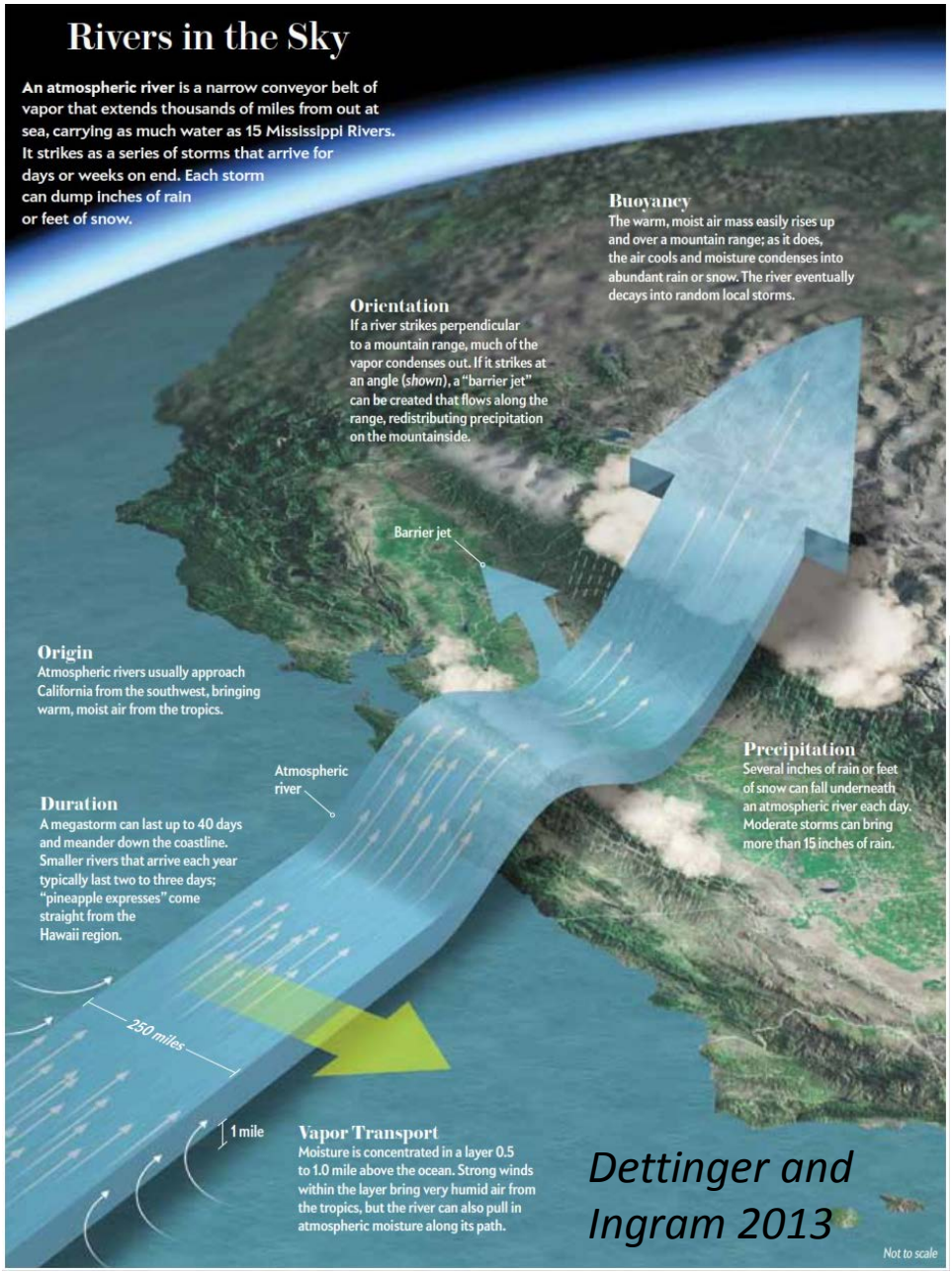
ARs can CAUSE FLOODS and PROVIDE WATER SUPPLY

Atmospheric Rivers, Floods and the Water Resources of California

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

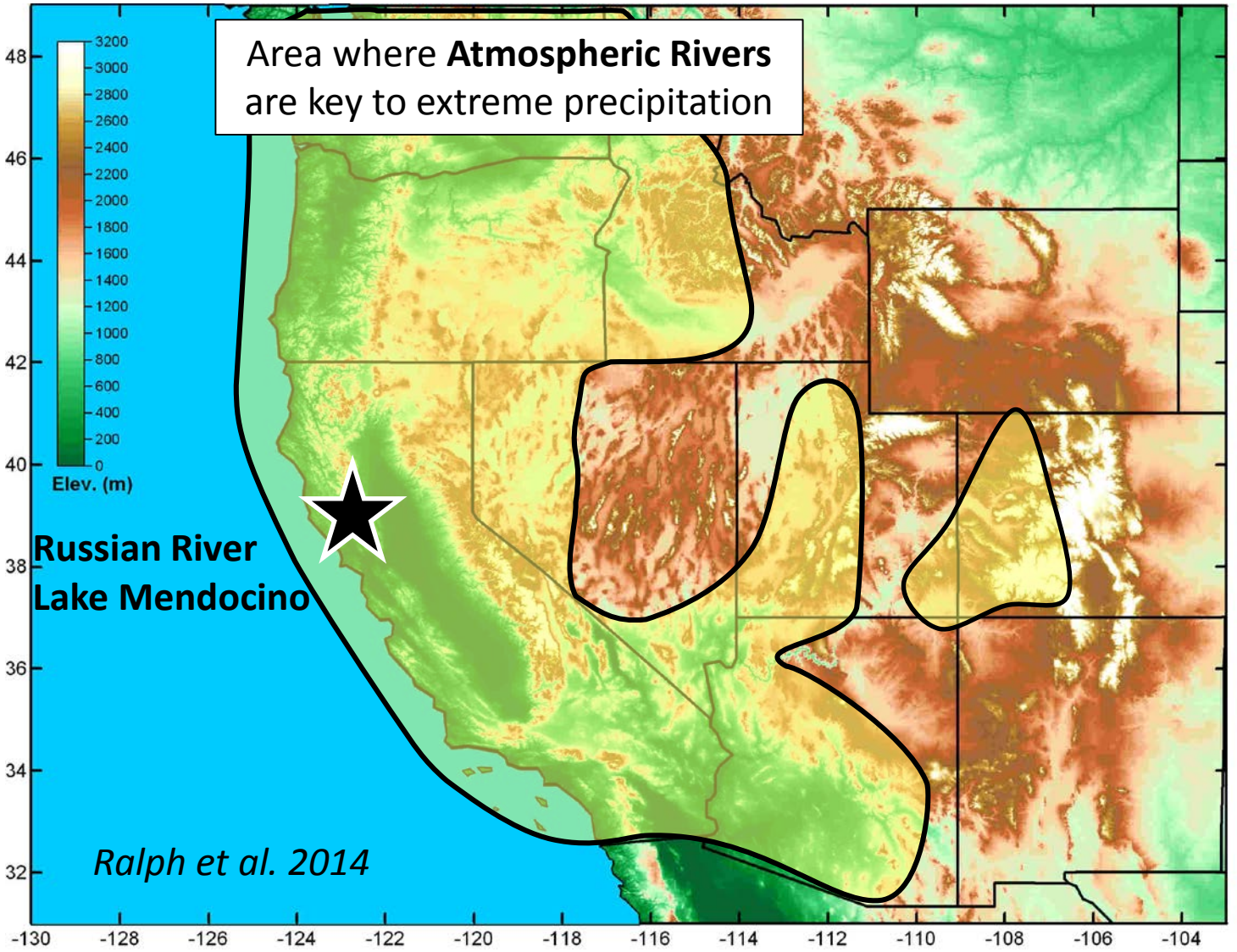


Rivers in the Sky



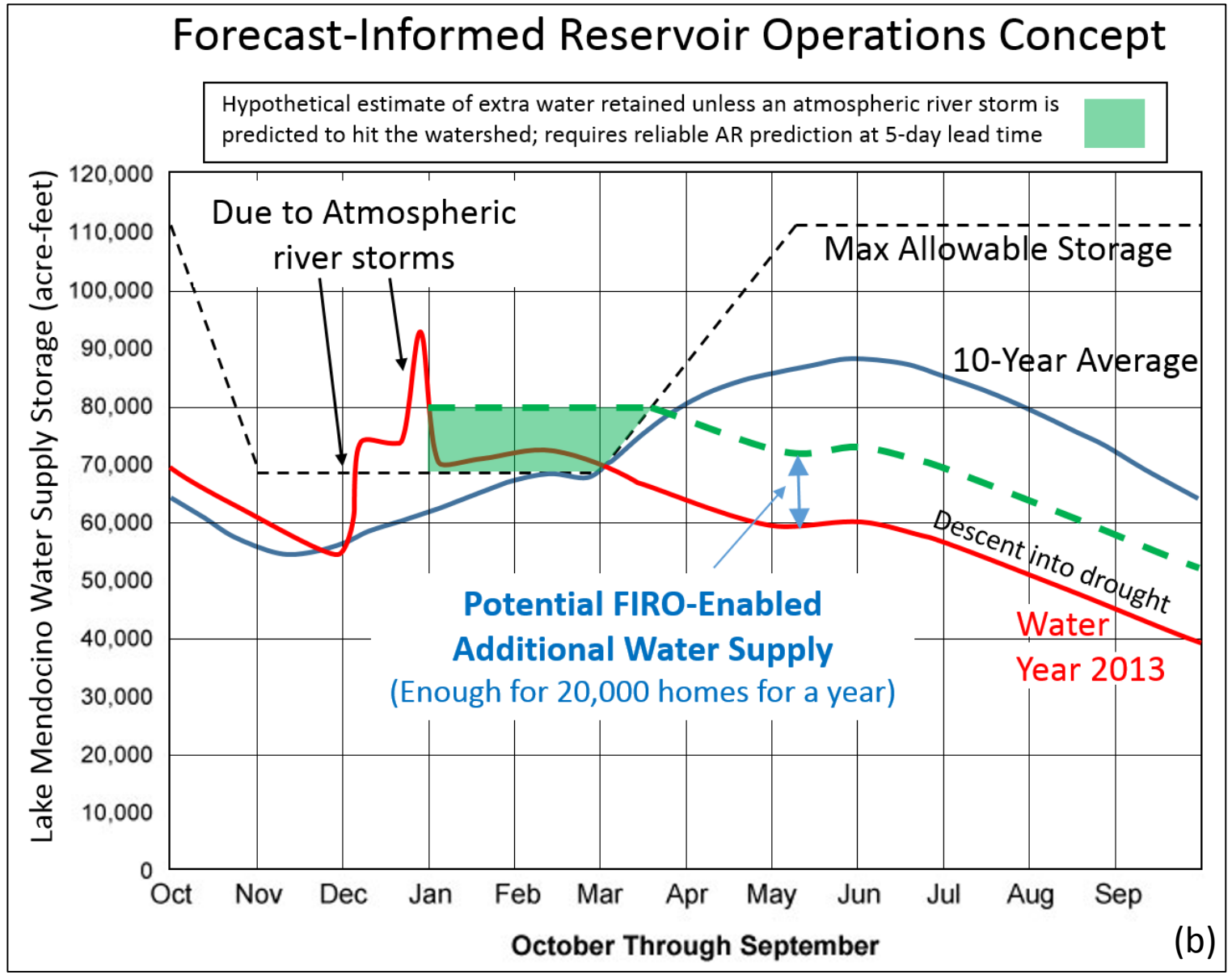
Dettinger and Ingram 2013

ARs Affect Large Areas of the U.S. West



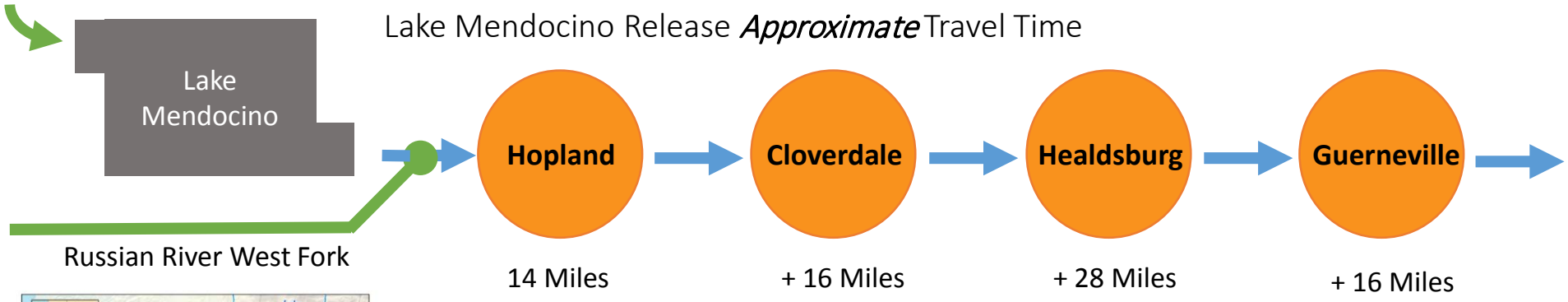
Ralph et al. 2014


Lake Pillsbury
PG&E Potter Valley Project
Lake Mendocino
Flow travel time from Lake Mendocino to Guerneville: 1-3 days
MENDOCINO COUNTY
Lake Mendocino
Max. allowable storage 110,000 acre-feet (summer), 68,000 acre-feet (winter)
LAKE COUNTY
SONOMA COUNTY
Lake Sonoma
Russian River Watershed
0.95 million acres, 1.6 million acre-feet annual discharge
PACIFIC OCEAN
NAPA COUNTY
Guerneville
0 2.5 5 10 15 20 Miles
(a)


Forecast-Informed Reservoir Operations Concept
Hypothetical estimate of extra water retained unless an atmospheric river storm is predicted to hit the watershed; requires reliable AR prediction at 5-day lead time
Lake Mendocino Water Supply Storage (acre-feet)
120,000
110,000
100,000
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Due to Atmospheric river storms
Max Allowable Storage
10-Year Average
Descent into drought
Water Year 2013
Potential FIRO-Enabled Additional Water Supply
(Enough for 20,000 homes for a year)
Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep
October Through September
(b)

How much forecast lead time is required to enable FIRO on Lake Mendocino?

10,000 AF could be released at 2500 cfs, which would take **2 days**



Total travel time ranges from 26hrs to 85hrs depending on flow rate (74miles traveled)*

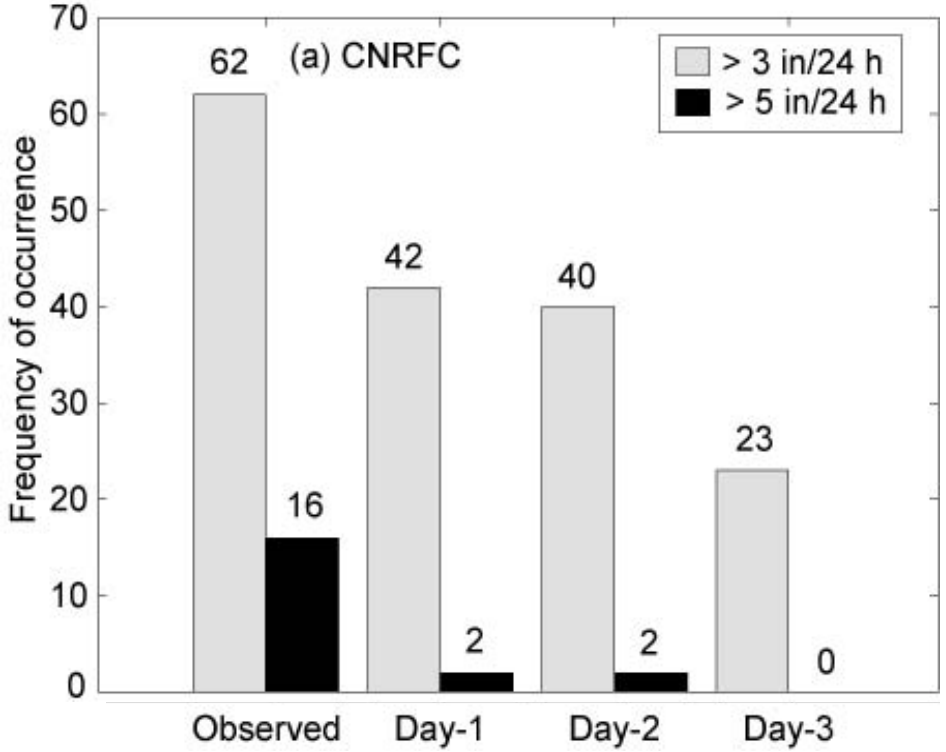
Bottom Line: It takes 2 days to release 10,000 AF at 2500 cfs, plus 1.1 to 3.5 days for water released from Lake Mendocino to get past vulnerable communities downstream. In situations this would be needed, travel times will be on the short end of range.

- This sets a forecast lead time requirement of <u>3-5 days</u> to predict landfalling atmospheric rivers.

*Uses information from Coyote Valley Dam and Lake Mendocino Water Control Manual (1986)

The Forecasting Challenge

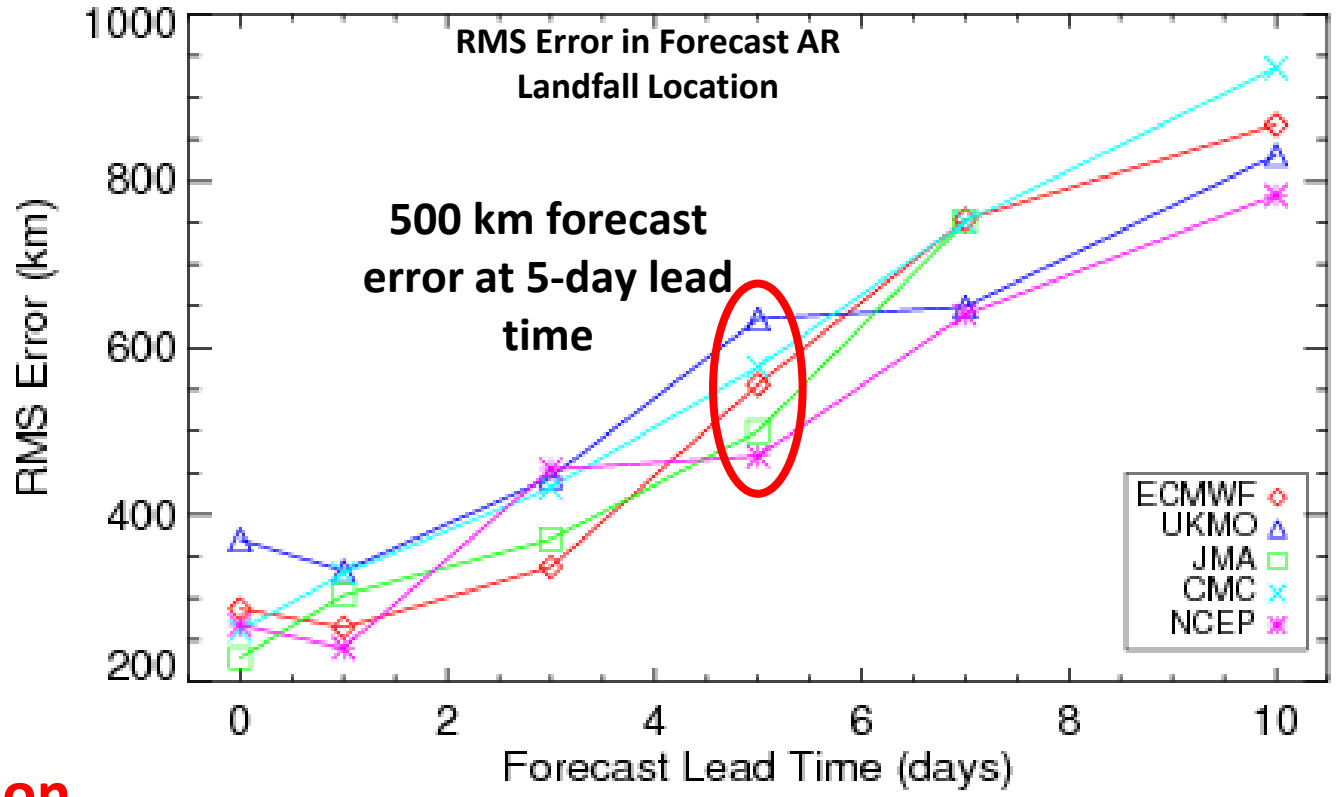
Forecasting large precipitation amounts is difficult



Of the 20 dates with >3 inches of precipitation in 1 day, 18 were associated with ARs.

Ralph et al. 2010

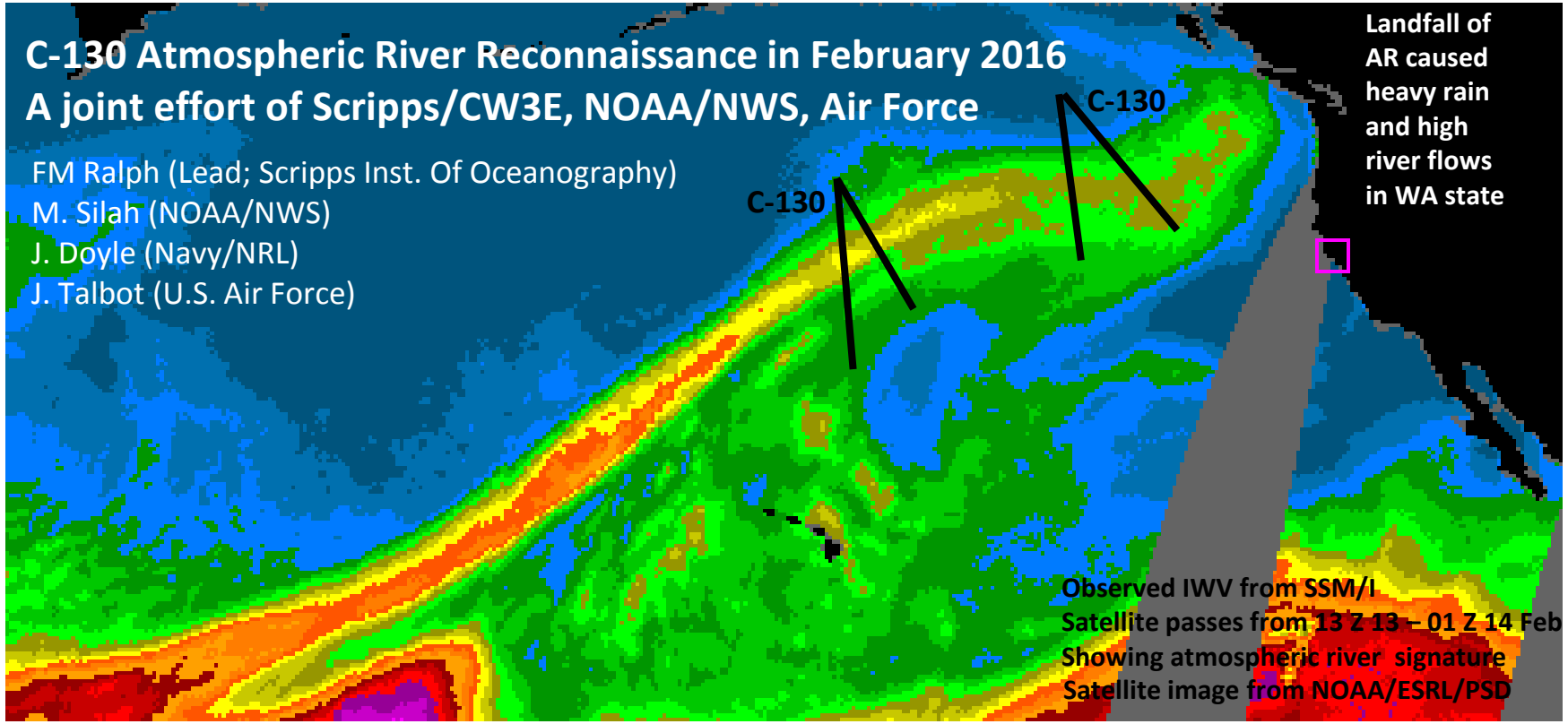
Forecasting AR landfall includes position errors larger than watersheds



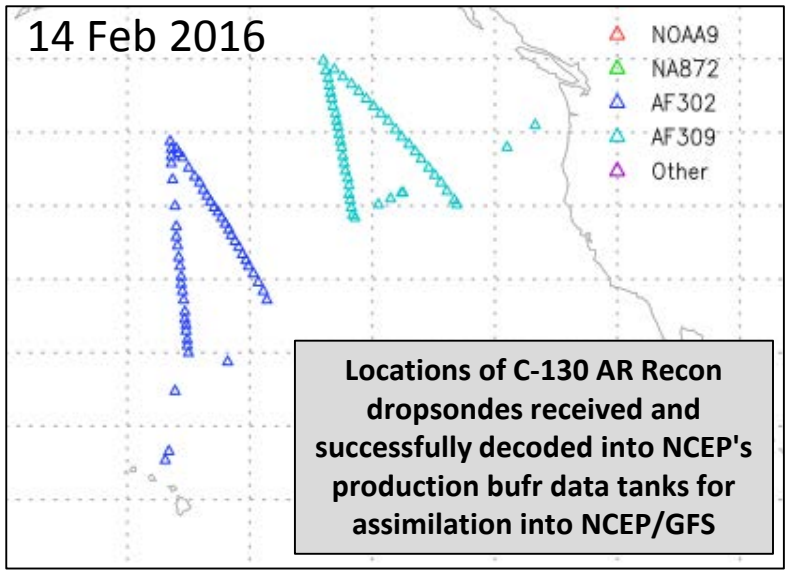
Wick et al. 2013

C-130 Atmospheric River Reconnaissance in February 2016
A joint effort of Scripps/CW3E, NOAA/NWS, Air Force

FM Ralph (Lead; Scripps Inst. Of Oceanography)
M. Silah (NOAA/NWS)
J. Doyle (Navy/NRL)
J. Talbot (U.S. Air Force)



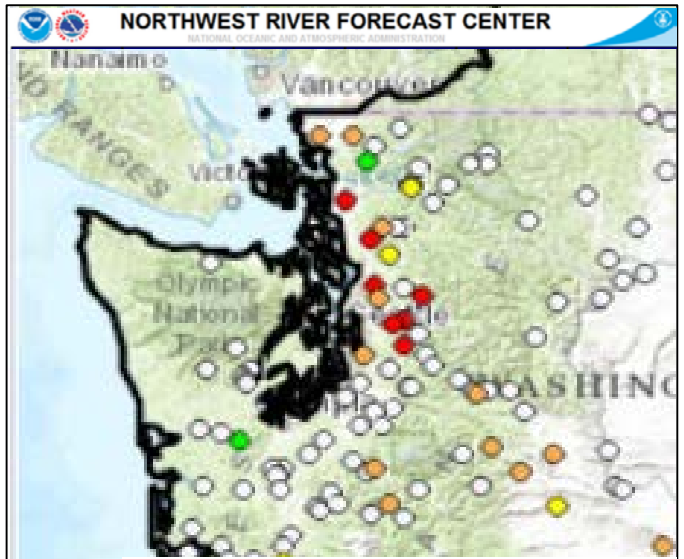
1st C-130 AR Recon Mission
13-14 Feb 2016
Dropsondes released for the 0000 UTC 14 Feb 2016 GFS data assimilation window



Locations of C-130 AR Recon dropsondes received and successfully decoded into NCEP's production bufr data tanks for assimilation into NCEP/GFS

Air Force C-130 Aircraft – Weather Recon' Squadron

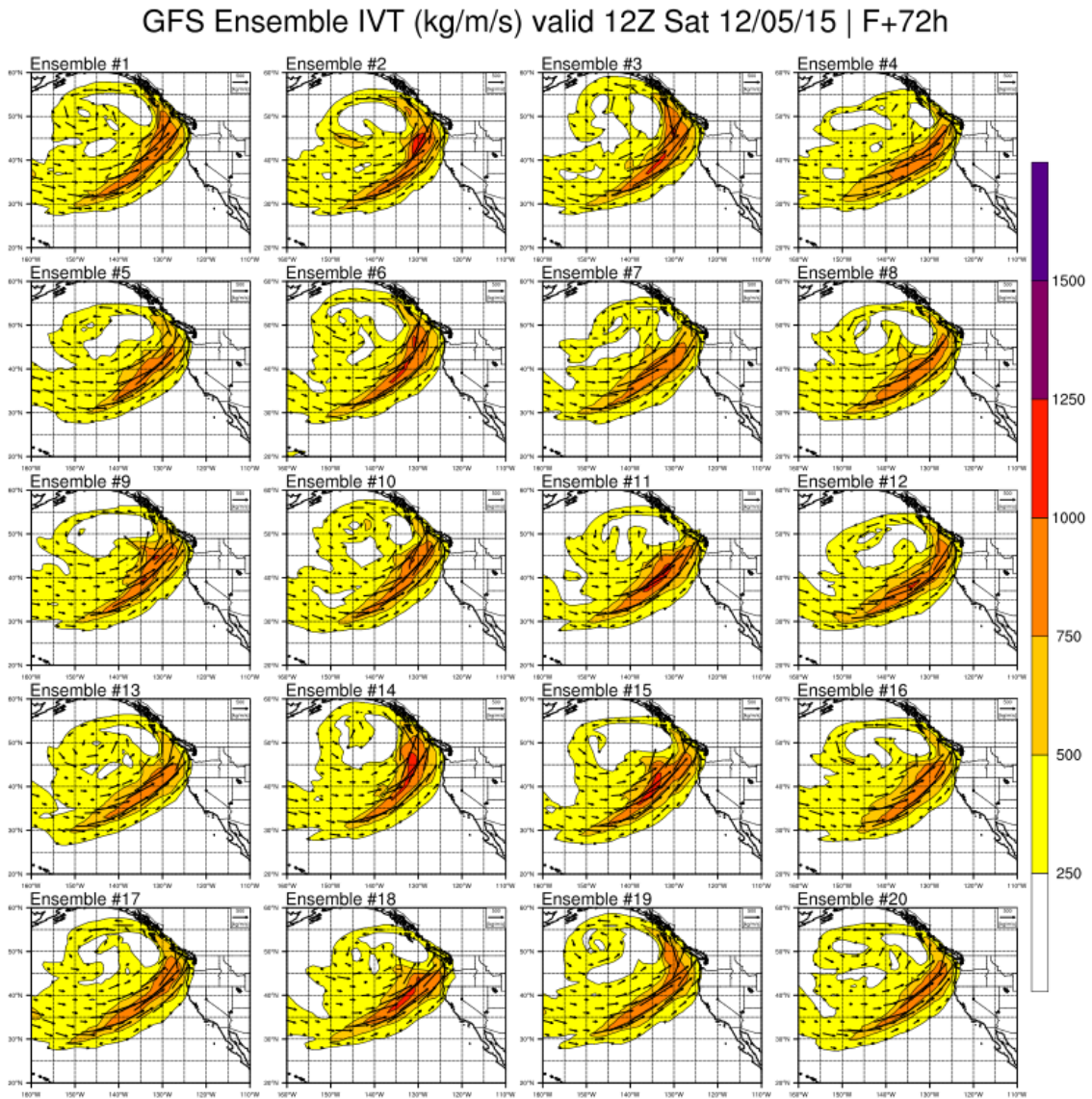
Center for Western Weather and Water Extremes



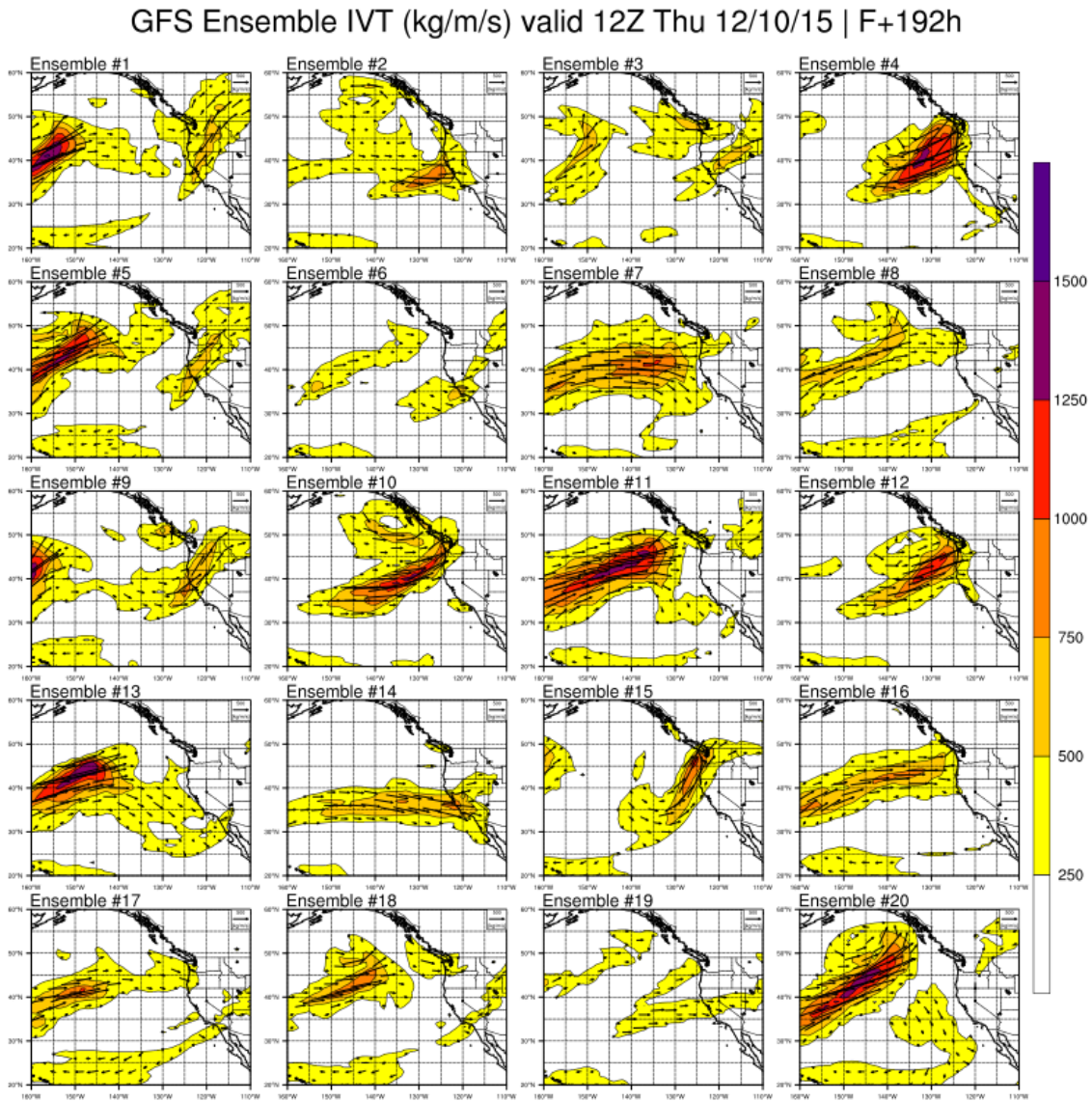
NWRFC flood forecast map as of 1500 UTC 15 Feb showing several rivers predicted to reach flood stage on 15-16 Feb (red dots)

“Ensemble” prediction of ARs

3-days lead time

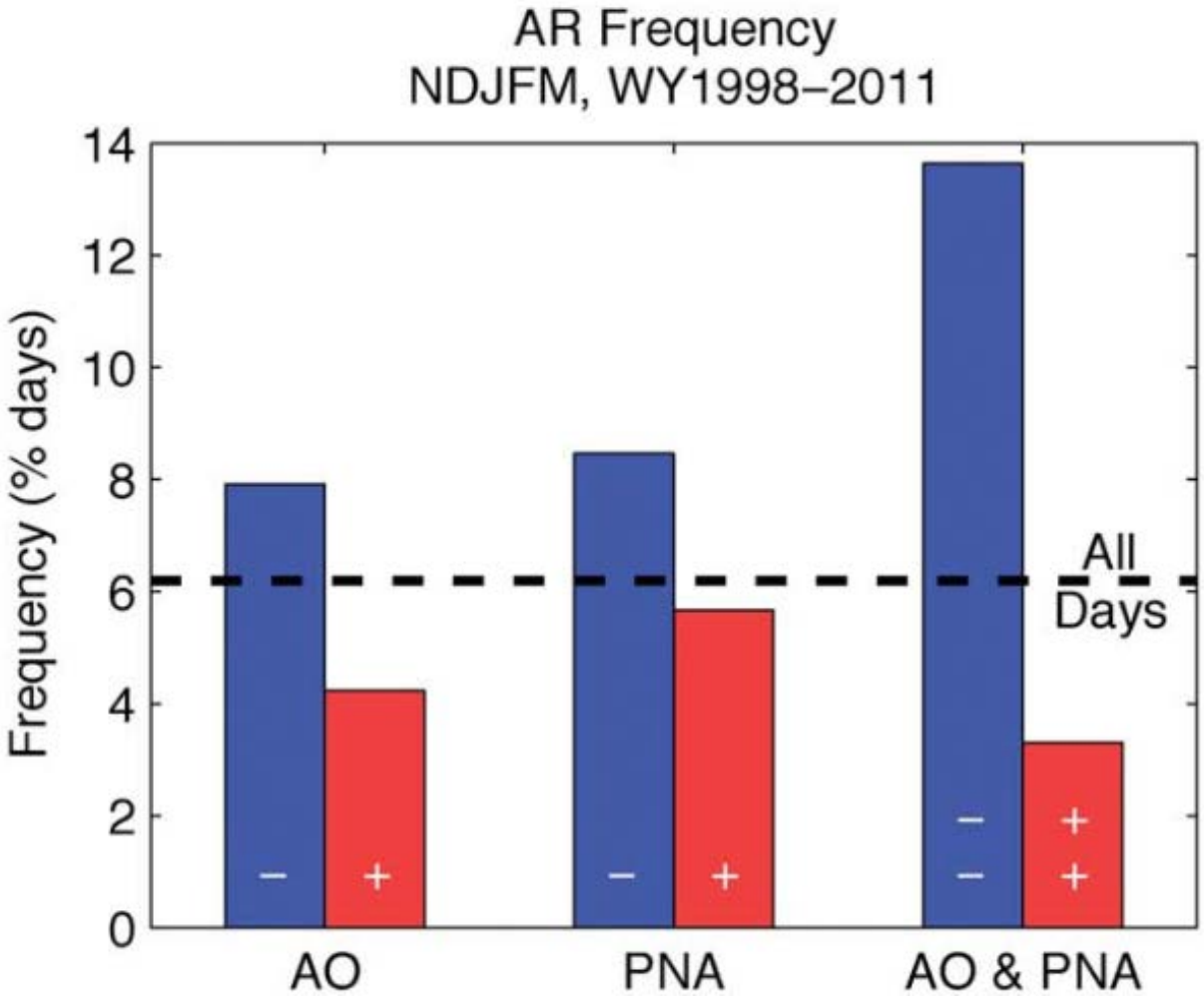


8-days lead time



The 2010/2011 snow season in California's Sierra Nevada: Role of atmospheric rivers and modes of large-scale variability

Guan, B., N.P. Molotch, D. E. Waliser, E. Fetzer and P.J. Neiman
Water Resources Research (2013)



Arctic Oscillation (negative , i.e., southward cold-air outbreaks) combined with Pacific North American "teleconnections" pattern (negative, southern storm track). Favors Atmospheric river conditions striking the Sierra and causing precipitation


Thank
you!