Supporting Western Water's Information Needs

F. Martin Ralph
Center for Western Weather and Water Extremes
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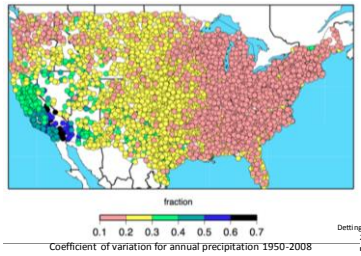
California Central valley in flood on 21 January 2017 near Sacramento Photo courtesy John Neilson-Gammon

Atmospheric and Oceanic Sciences
AMS Washington Policy Forum
24 April 2018, Washington, DC

Variability of Annual Precipitation



Coefficient of variation for annual precipitation 1950-2008

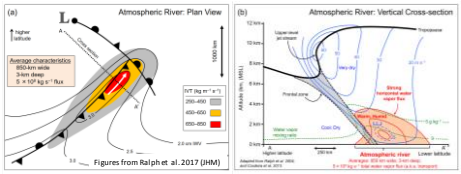
- Southwestern (SW) U.S. has the largest year to year precipitation variability in the US.
- Variability in the SW can exceed half the annual average.
- The year to year variability in CA is largely caused by the wettest days (ARs).

Dettinger, M.D., Ralph, F.M., Das, T., Neiman, P.J., and Cayan, D., 2011: **Atmospheric rivers, floods, and the water resources of California**. *Water*, **3**, 455-478.

Glossary of Meteorology
Added May 2017

ATMOSPHERIC RIVER

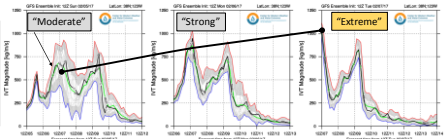
A long, narrow and transient corridor of strong horizontal water vapor transport that is typically associated with a low-level jet stream ahead of the cold front of an extratropical cyclone. The water vapor in atmospheric rivers is supplied by tropical and/or extratropical moisture sources. Atmospheric rivers frequently lead to heavy precipitation where they are forced upward, e.g., by mountains or by ascent in the warm-conveyor-belt. Horizontal water vapor transport in the mid-latitudes occurs primarily in atmospheric rivers and is focused in the lower troposphere.



Figures from Ralph et al. 2017 (JHM)

NCEP GEFS dProg/dt Example from February 2017 – "Oroville Case" (dam spillway issue)

Oroville Dam Spillway



Init: 12Z/5 Feb | Init: 12Z/6 Feb | Init: 12Z/7 Feb

Image Description: 7-day forecasts of the NCEP GEFS IVT [kg m^{-1} s^{-1}] at 38N, 123W. The following is indicated at each forecast time: ensemble member maximum (red), ensemble member minimum (blue), ensemble mean (green), ensemble control (black), ensemble standard deviation (white shading), and each individual member (thin gray). Time advances from left to right.

Key: Variability in north-south shift of ARs result in increases or decreases in IVT magnitude at the coast. In this case the ARs ultimately ended up **stronger**.

Center for Western Weather and Water Extremes
SCRIPPS INSTITUTION OF OCEANOGRAPHY AT UC SAN DIEGO

F. M. Ralph (mralph@ucsd.ucsd.edu) and J. Cordeira

Russian River Reservoirs are Dual Purpose

Flood protection in a flood-prone watershed
(US Army Corp of Engineers)

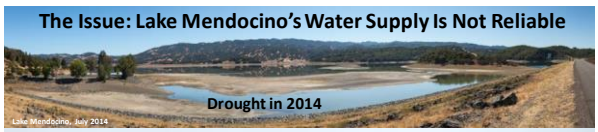
Water supply for 600,000 people and agriculture
(Sonoma County Water Agency)

Operations Dictated by
Storage Levels Relative to "Rule Curve"

Lake Mendocino (Coyote Valley Dam)
Flood Control Pool (empty space): 48,100 AF
Water Supply Pool: 68,400 A

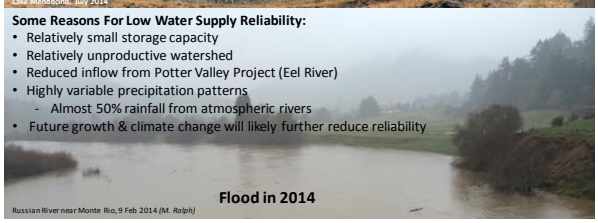
Lake Sonoma (Warm Springs Dam)
Flood Control Pool:136,000 AF
Water Supply Pool: 245,000 AFF (Nov. 1 – March 1)

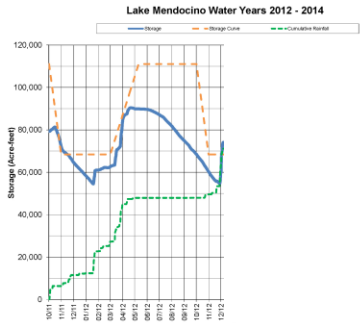
The Issue: Lake Mendocino's Water Supply Is Not Reliable



Some Reasons For Low Water Supply Reliability:

- Relatively small storage capacity
- Relatively unproductive watershed
- Reduced inflow from Potter Valley Project (Eel River)
- Highly variable precipitation patterns
  - Almost 50% rainfall from atmospheric rivers
- Future growth & climate change will likely further reduce reliability





Lake Mendocino FIRO Steering Committee

- **Co-Chairs**
  - Jay Jasperse – Sonoma County Water Agency
  - F. Martin Ralph – UCSD / SIO / CW3E
- **Members**
  - Michael Anderson – California DWR
  - Levi Brekke – USBR
  - Mike Dillabough – USACE / SPN
  - Michael Dettinger – USGS
  - Joe Forbis – USACE / SPK
  - Alan Haynes – NOAA / NWS
  - Patrick Rutten – NOAA / NMFS
  - Cary Talbot – USACE / ERDC
  - Robert Webb – NOAA / OAR

Project Partners

A Comprehensive **Work Plan** to Evaluate FIRO for Lake Mendocino

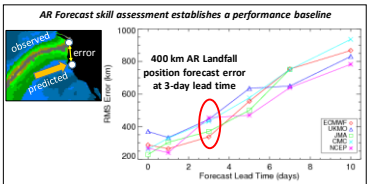
- Viability Assessment Process
- Evaluation Framework
- Benefits Assessment
- Implementation Strategies
- Technical and Scientific Support

Atmospheric River Reconnaissance

FM Ralph (Scripps/CW3E), V Tallapragada (NWS/NCEP), J Doyle (NRL)

Water managers, transportation sector, agriculture, etc… require improved atmospheric river (AR) predictions

AR Forecast skill assessment establishes a performance baseline



Wick, G.A., P.J. Neiman, F.M. Ralph, and T.M. Hamill, 2013: Evaluation of forecasts of the water vapor signature of atmospheric rivers in operational numerical weather prediction models. *Wea. Forecasting*, **28**, 1337-1352.

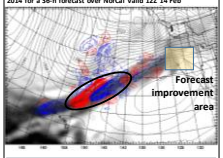
New Adjoint includes moisture – and finds AR is prime target

36-h Sensitivity (Analysis) 00Z 13 February (Final Time 12Z 14 February 2014)

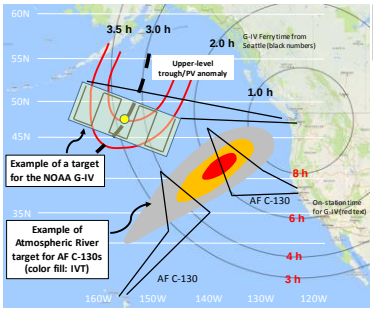
J. Doyle, C. Reynolds, C. Amerault, F.M. Ralph

(International Atmospheric Rivers Conference 2016)

Color contours show the forecast sensitivity to 850 mb water vapor (grey shading) uncertainty at analysis time 00Z 13 Feb 2014 for a 36-h forecast over NorCal valid 12Z 14 Feb



- Moisture sensitivity is strongest along AR axis; located > 2000 km upstream
- **Moisture sensitivity substantially larger than temp. or wind sensitivity.**



2018 Atmospheric River Reconnaissance Flight Strategies

Center time: 0000 UTC
Dropsonde deployment window: 2100 – 0300 UTC

Each aircraft has a range of about 3500 nm

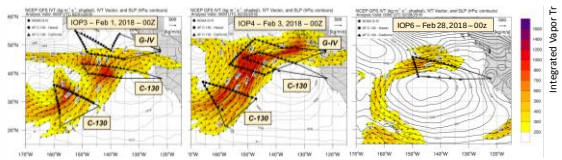
F.M. Ralph (AR Recon PI) and AR Recon Team

AR Recon Modeling and Data Assimilation Steering Committee

Formation of an "AR DA Steering Committee" and "AR DA Technical Work Plan"

Steering Committee

- F. Martin Ralph – (UCSD/Scripps/CW3E) - AR Recon PI and AR DA SC Co-Chair
- Vijay Tallapragada (NOAA/NWS/NCEP) – AR Recon Co-PI and AR DA SC Co-Chair
- Jim Doyle (NRL)
- Aneesh Subramanian (UCSD/Scripps/CW3E)
- Chris Davis (NCAR/MMM)
- Florian Pappenberger (ECMWF)

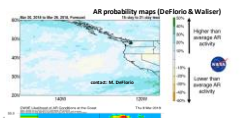


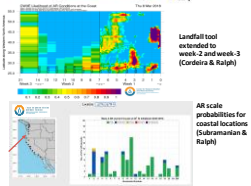
S2S Outlooks Supporting Water

Goal: Develop week-2 and week-3 outlooks for AR activity on the US West Coast. Evaluate and improve understanding of outlooks on these timescales.

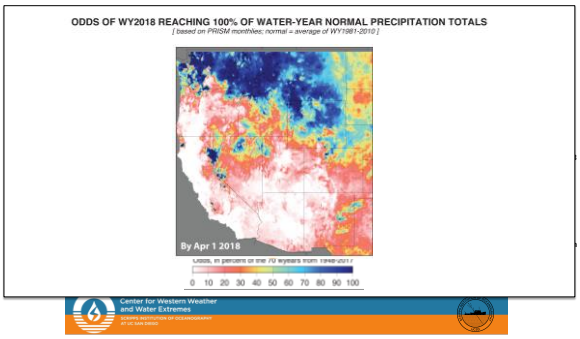
Scripps Institution of Oceanography: F.M. Ralph (PI), A. Subramanian
JPL : Duane Waliser, Mike DeFlorio, Bin Guan, Alex Goodman
PSU : Jay Cordeira
CSU : Elizabeth Barnes
Data : WCRP / WWRP S2S Project

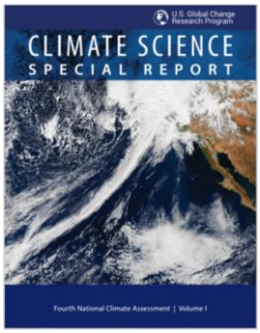
Supported by CA Dept. of Water Resources
Proposed working with NWS/NCEP/CPC





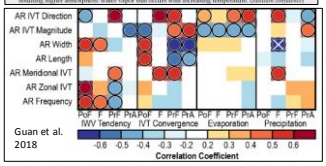
Center for Western Weather and Water Extremes
Jet Propulsion Laboratory California Institute of Technology
Plymouth State University
Colorado State University





Atmospheric Rivers Highlighted in the U.S. Fourth National Climate Assessment, released on 3 November 2017

5. The frequency and severity of landfalling "atmospheric rivers" on the U.S. West Coast (narrow streams of moisture that account for 30%–40% of the typical snowpack and annual precipitation in the region and are associated with severe flooding events) will increase as a result of increasing evaporation and resulting higher atmospheric water vapor that occurs with increasing temperature. (*Medium confidence*)

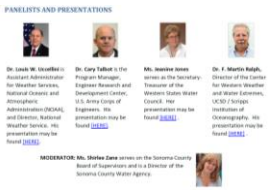


Guan et al. 2018

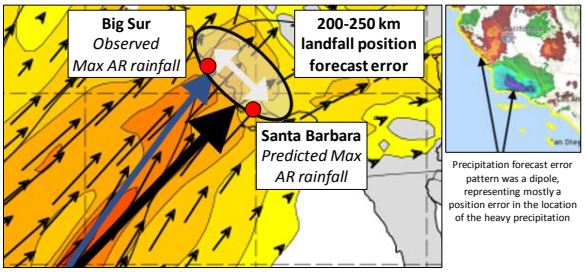
Congressional Staff Briefing on July 13, 2016

"A New Frontier in Water Operations: Atmospheric Rivers, Subseasonal-to-Seasonal Predictions and Weather Forecasting Technology"

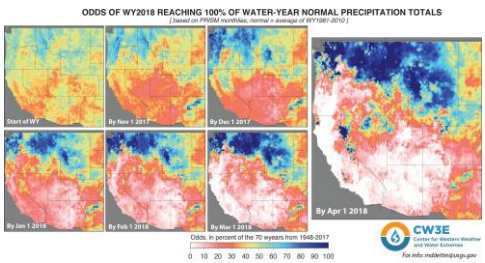
An interagency, cross-disciplinary team of experts convened in Washington to provide Congressional staff with a briefing on atmospheric rivers, subseasonal-to-seasonal precipitation prediction needs, and the benefits of enhanced predictive forecasting technology to the future of water management.



AR Forecast Evaluation: 22 March 2018



Precipitation forecast error pattern was a dipole, representing mostly a position error in the location of the heavy precipitation



- How the developing drought has evolved in terms of the odds of reaching 100% of normal precipitation by end of WY2018.
- Notice how drought conditions have developed across the Southwest, as odds of reaching normal have progressively dwindled month by month. Also notice that, although March was pretty wet in California/Nevada, it was—arguably—too little too late to set us up for reaching 100% of normal this year, in all but a few locales.