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and Water Extremes

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FIRO National Expansion Pathfinder: Science Background and Next Steps

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FIRO Phase III Atmospheric Science and Program Support Effort*

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Texas FIRO Workshop
Arlington, TX, 21 September 2023



U.S. ARMY

FIRO Phase III:

National Expansion Pathfinder

FY23-FY27



1. National forecast skill assessment and improvement campaign
 - Continued investment in Atmospheric River (AR) and other storm type forecast improvements that have yielded significant benefits
4. Conduct full viability assessment of system of 8+ dams in another region nationally
 - Explore a region where different storm types (in addition to ARs) are key to heavy rain and flooding (e.g., tropical storms/hurricanes, long-lived thunderstorm clusters, Nor'Easters)
5. Conduct full viability assessments on two single dams in other regions nationally



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“Proof is in the Pudding”

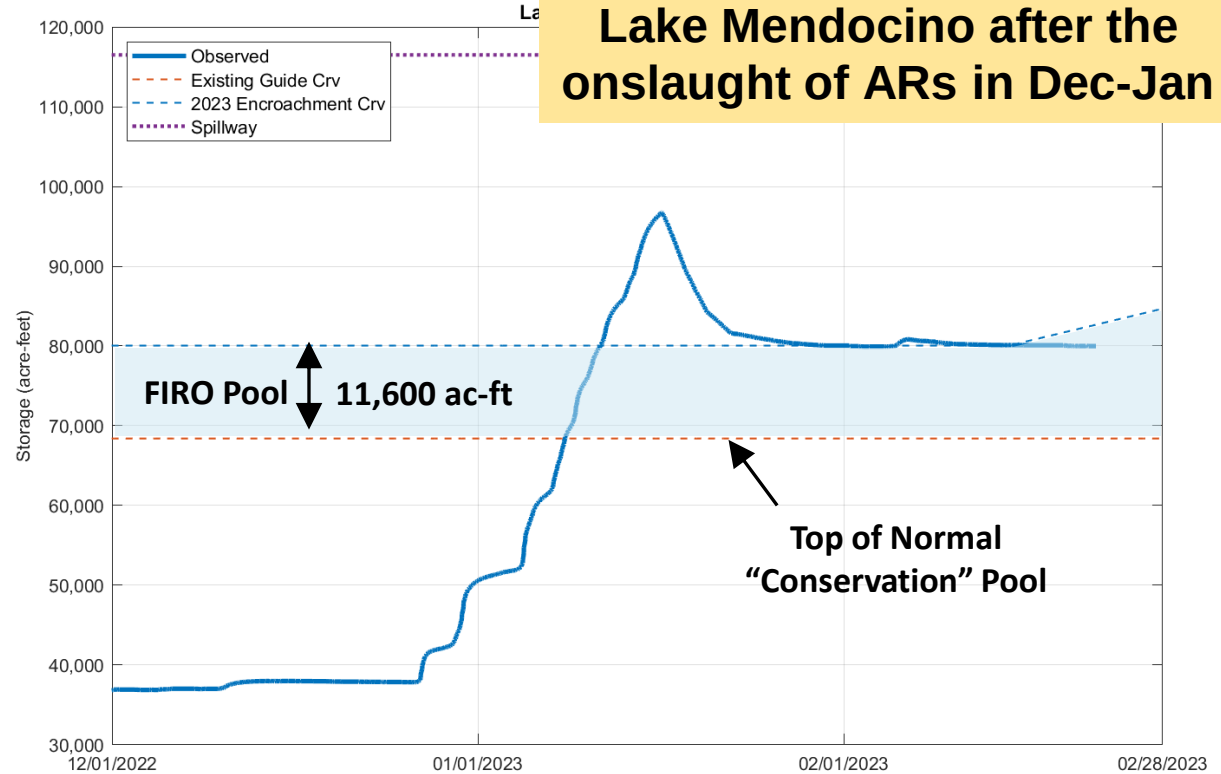
(or... in the water behind the dam)



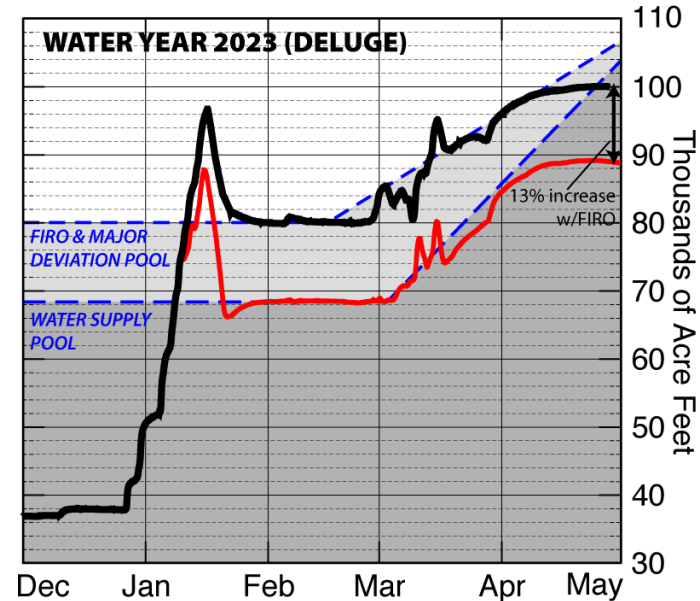
Water Year 2023 Lake Mendocino Storage



Water Year 2023
FIRO allowed retention of an
extra 11,600 acre feet at
Lake Mendocino after the
onslaught of ARs in Dec-Jan



Actual (with FIRO; thick black line) and modeled (without; red line) storage histories at Lake Mendocino during Water years 2020 and 2023.



Key FIRO Finding

Better forecasts of extreme precipitation, streamflow and thus the storms that produce them, can enable greater flexibility in operating many reservoirs, creating greater water supply reliability and reducing flood risk



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“QPF is the tall pole in the tent”

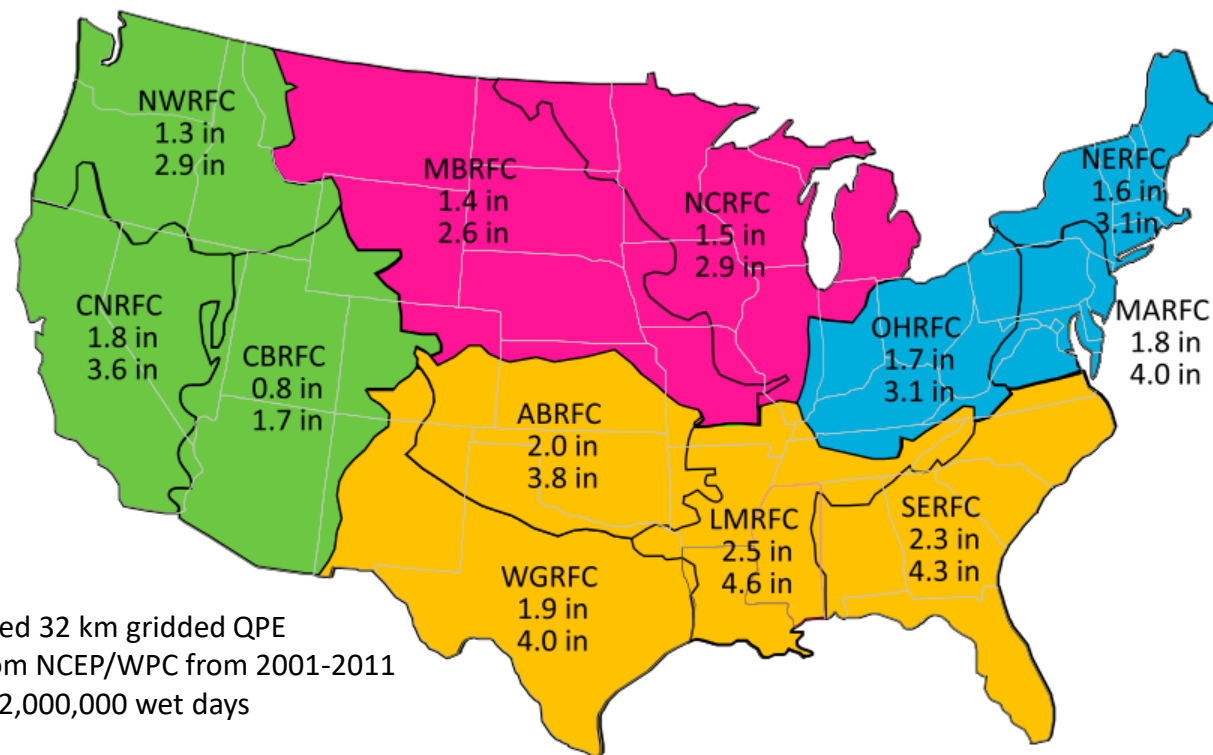
*(for streamflow prediction... Rob Hartman,
former Hydrologist in Charge of NWS/CNRFC)*



Extreme quantitative precipitation forecast performance at the Weather Prediction Center from 2001 to 2011

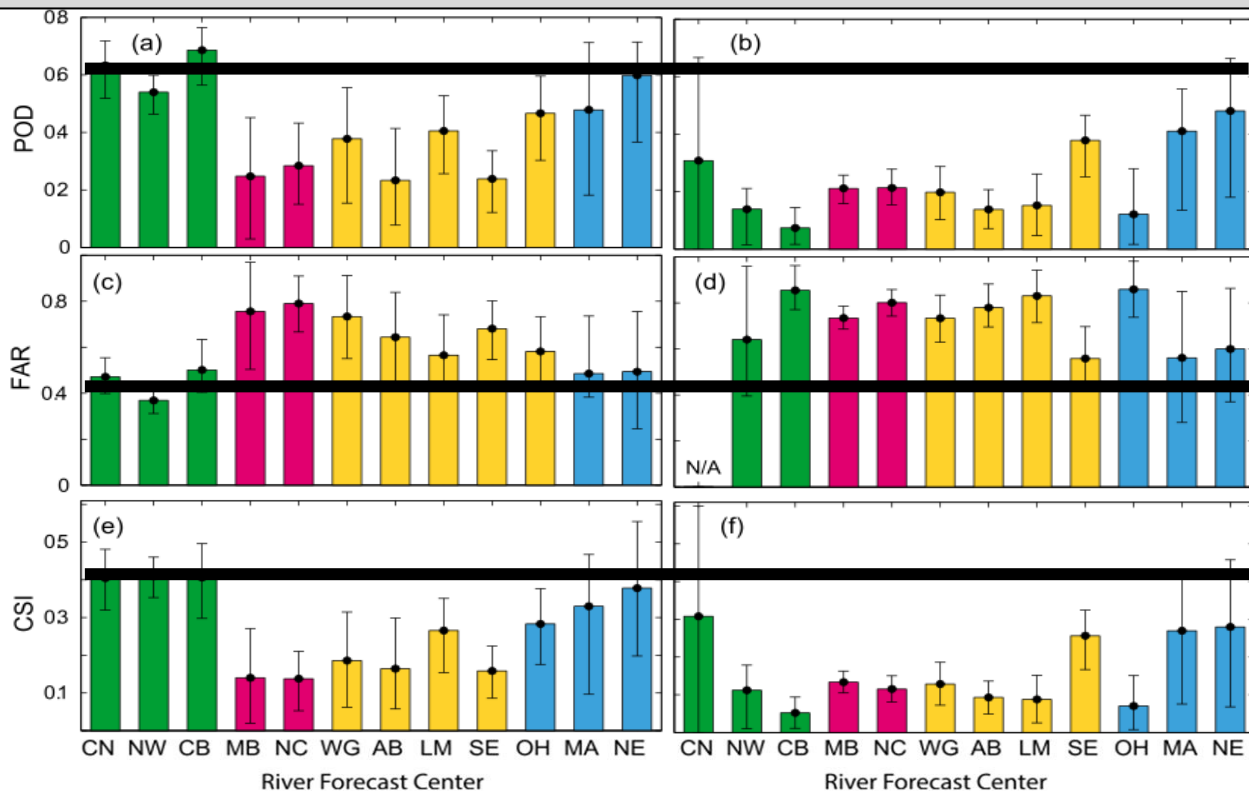
Sukovich, E. M., F. M. Ralph, F. E. Barthold, D. W. Reynolds and D. R. Novak *Wea. Forecast.*
(2014)

**Regional thresholds for
Top 1% and 0.1%
heaviest daily
precipitation**



Extreme quantitative precipitation forecast performance at the Weather Prediction Center from 2001 to 2011

Sukovich, E. M., F. M. Ralph, F. E. Barthold, D. W. Reynolds and D. R. Novak *Wea. Forecast.*
(2014)

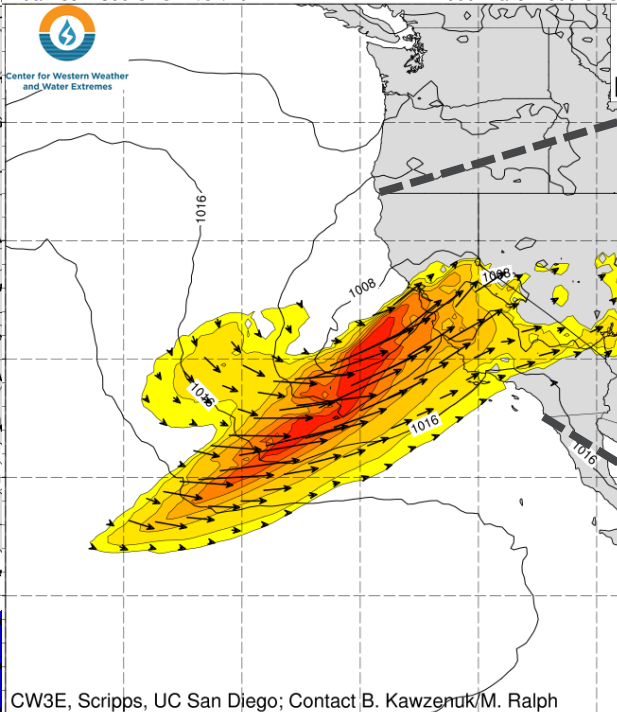
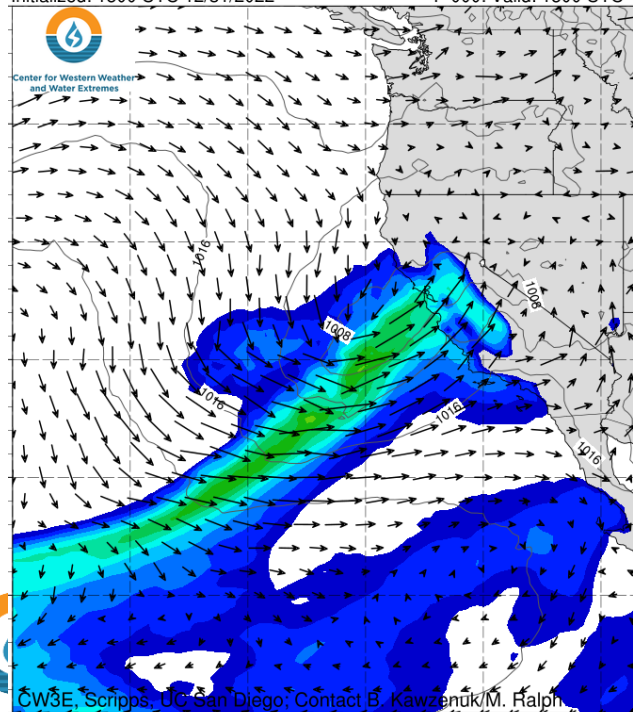


Used 32 km gridded QPE
and QPF from
NCEP/WPC from 2007-
2011.

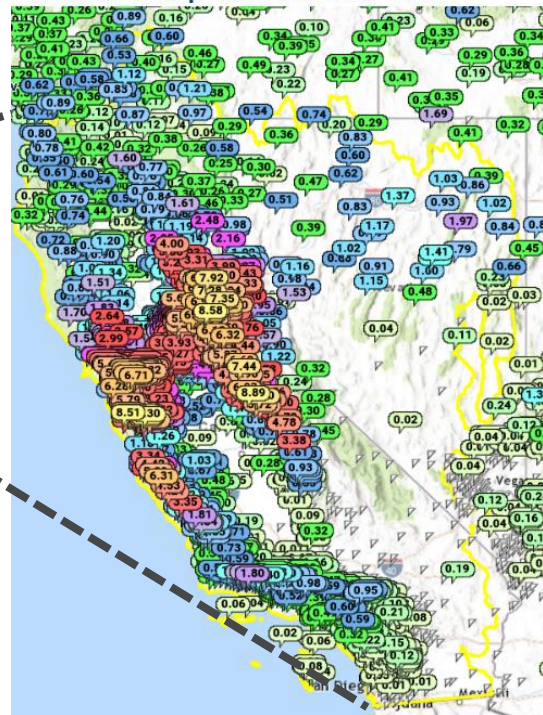
For 1-day lead time.

New Years Day 2023 AR

NCEP GFS IWV (mm; shaded), 850-hPa Wind (vectors), and NCEP GFS IVT ($\text{kg m}^{-1} \text{s}^{-1}$; shaded), IVT Vector, and SLP
 Initialized: 1800 UTC 12/31/2022 F-000: Valid: 1800 UTC 12/31/2022 F-000: Valid: 1800 UTC 12/31/2022



Observed Precip - Last 24 Hours - Raw



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

Lake Mendocino Release *Approximate* Travel Time

Lake
Mendocino

Takes 1-3 days to
flow 74 miles*

Guerneville

Ocean

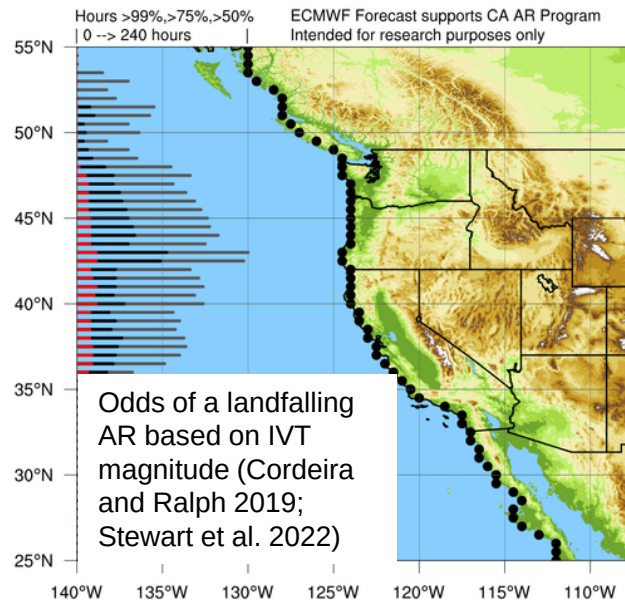
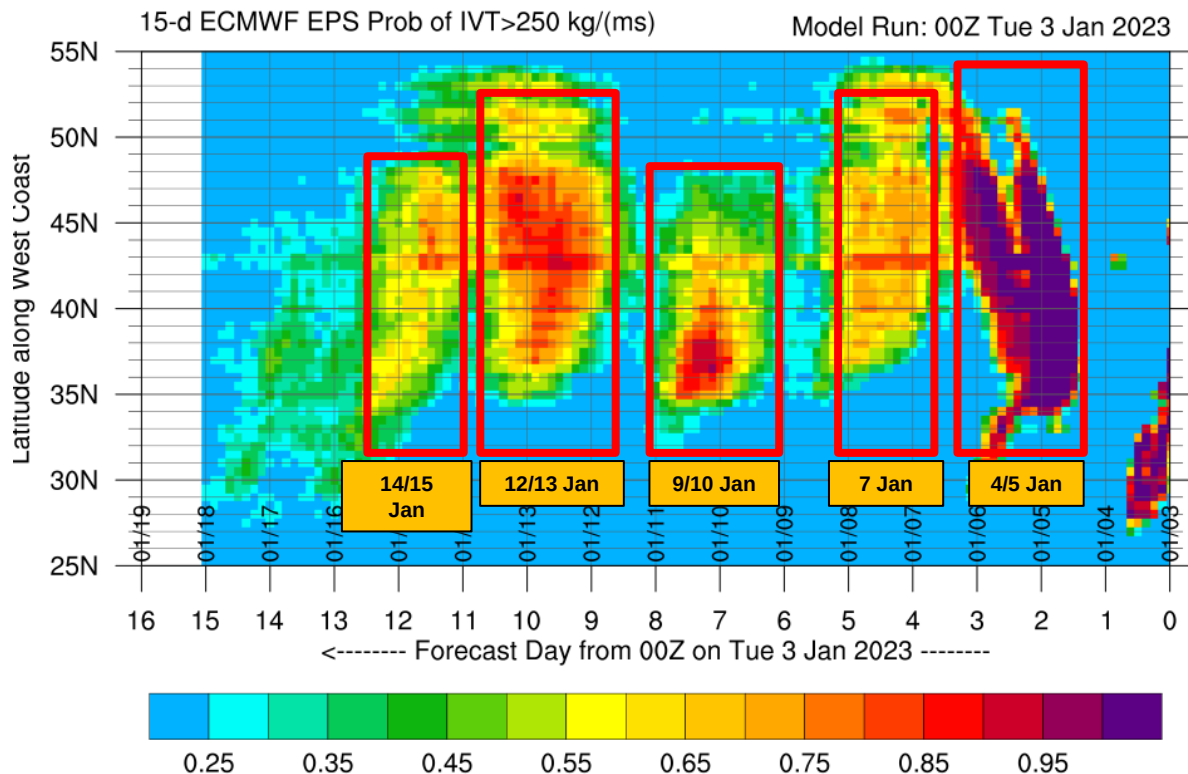
Bottom Line

- Two days to release the extra water, plus
 - 1-3 days to flow past flood-prone area downstream
- ➔ Predictive skill is needed at 3-5 days lead-time for the storms that produce heavy rain and possible flooding



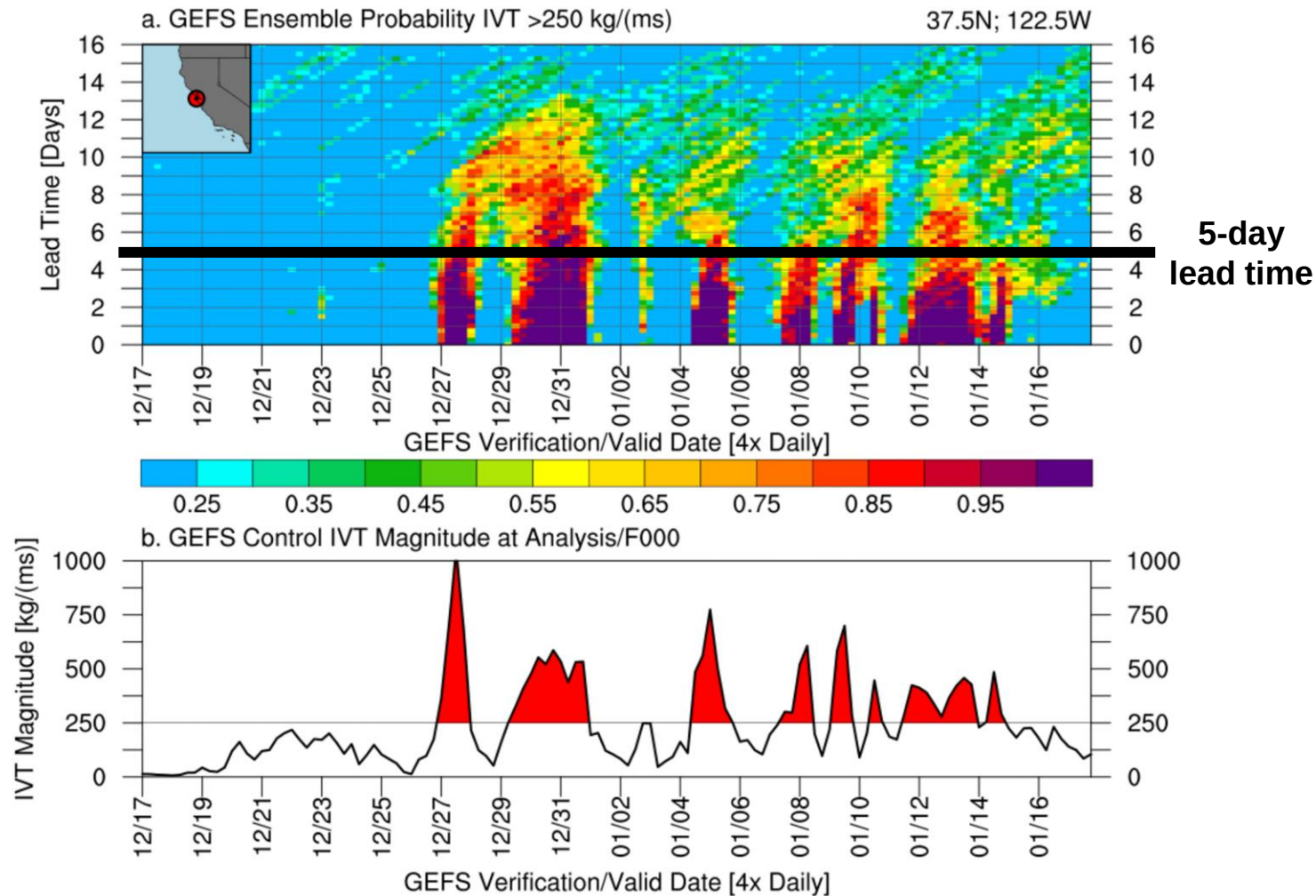
*Uses information from Coyote Valley Dam and Lake Mendocino Water Control Manual (1986)

How far in advance can we predict landfalling ARs?





J. Cordeira

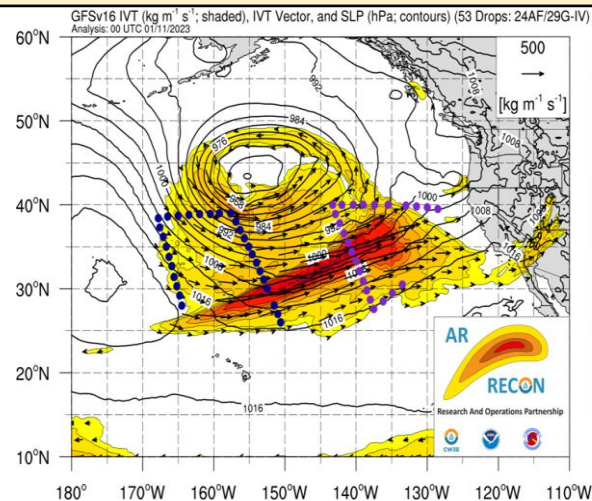


AR RECON 2023

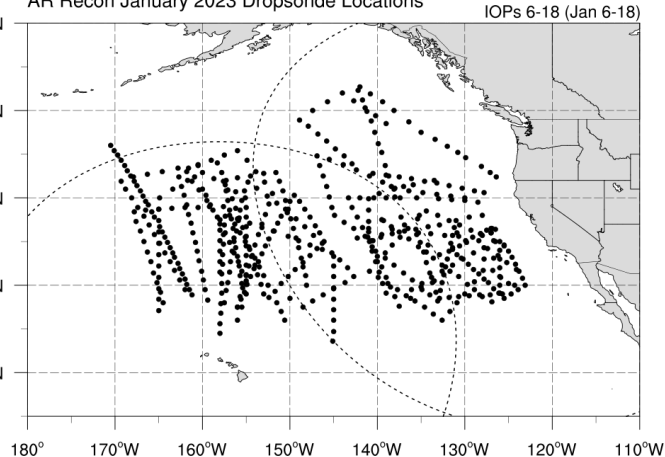
Status 25 January 2023

4 USAF C-130 aircraft based at Mather Field in Sacramento, California
1 NOAA G-IV Jet based in Honolulu, Hawaii (through January 2023)

Jan 2023 Longest Flight Sequence on Record
included IOPs for 13 consecutive days*



AR Recon January 2023 Dropsonde Locations



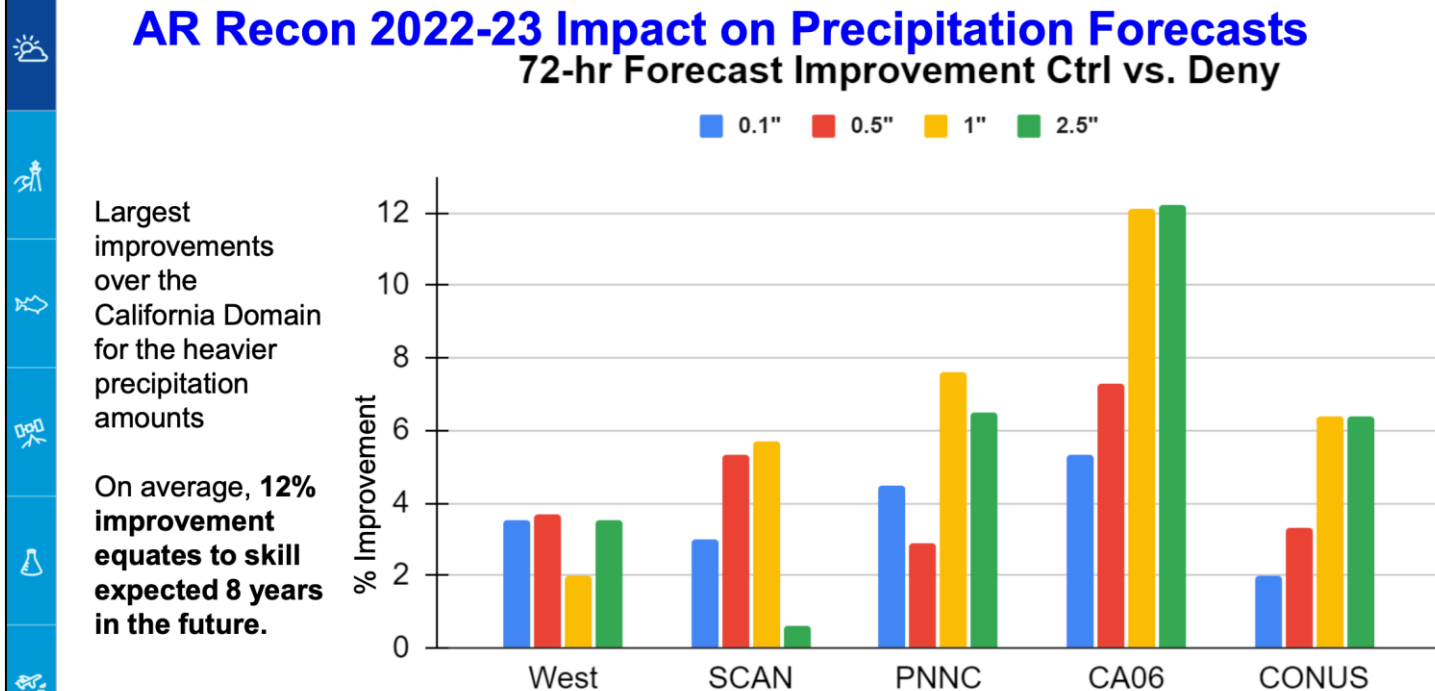
*IOP = Intensive Observing Period, indicate days when AR Recon flights are flown

Key support from California Department of Water Resources/AR Program and US Army Corps of Engineers/FIRO Program

AR Recon: Better observations → Improved Forecast Skill (WY23)

Presentation
by V. Tallapragada

AR Recon Workshop
June 2023
@ECMWF

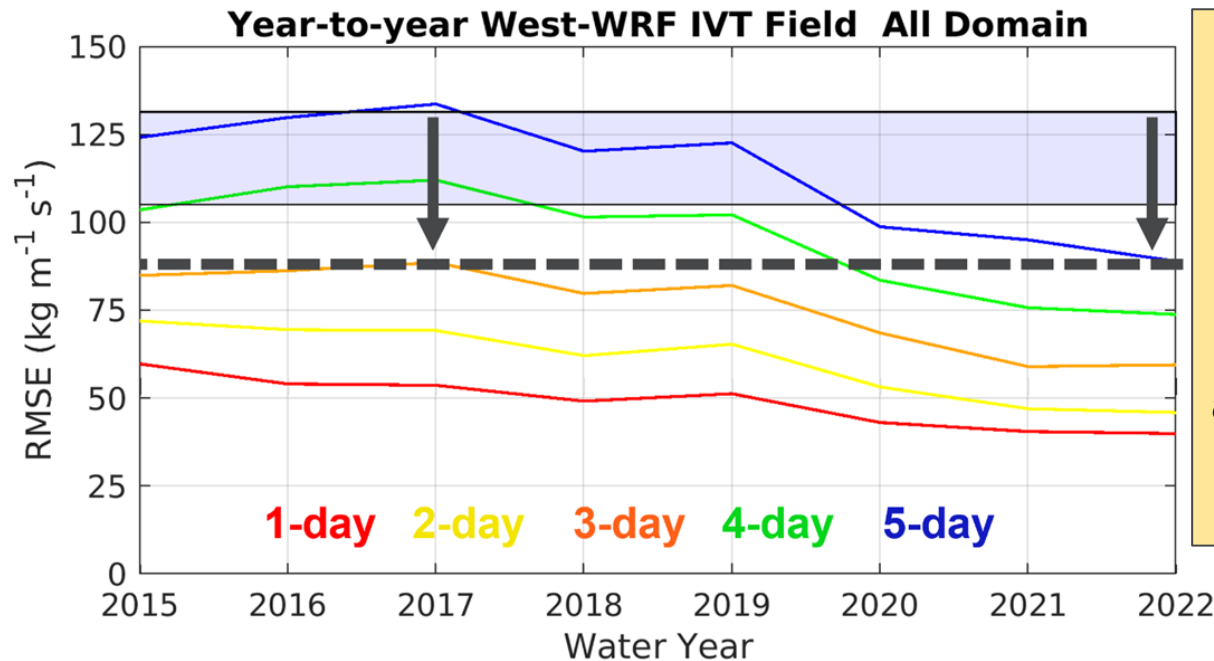


NATIONAL WEATHER SERVICE

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WEATHER RESEARCH AND FORECASTING FOR THE WEST (WEST-WRF) MODEL IMPROVEMENTS OVER THE YEARS



Shaded area represents min/max RMSE from 30-year West-WRF 5-day reforecasts

West-WRF has motivated development in NOAA of the “Atmospheric River Analysis and Forecast System” (AR-AFS) jointly between NCEP and CW3E, including use of CW3E’s “COMET” Supercomputer

Research is improving the skill of predicting ARs

Highlights the importance of improving resolution and physics packages in West-WRF, as well initial conditions in parent global models via AR Recon

Lead (on verification)
Rachel Weihs (CW3E)



Forecast Informed Reservoir Operations

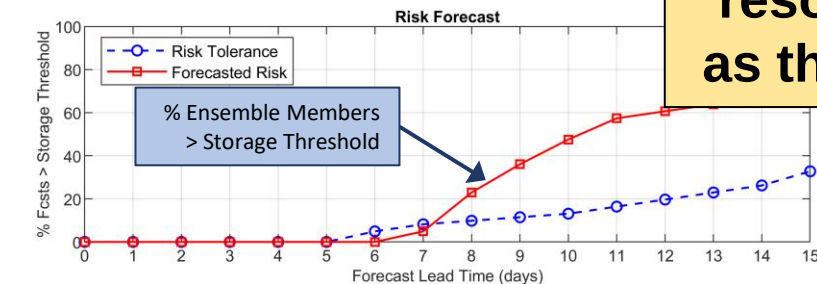
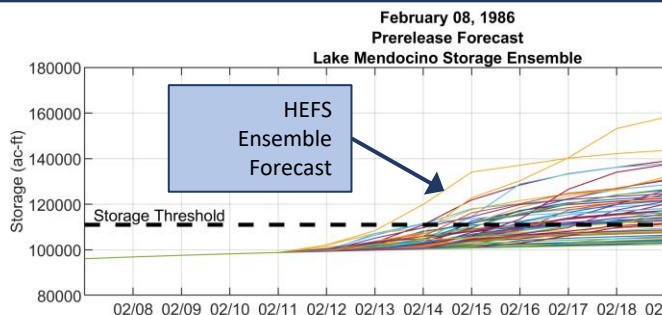
Using Ensemble Streamflow Predictions for a Multi-Purpose Reservoir in Northern California

10.1029/2019WR026604

Chris J. Delaney¹, Robert K. Hartman², John Mendoza¹, Michael Dettinger³, Luca Delle Monache³, Jay Jasperse¹, F. Martin Ralph³, Cary Talbot⁴, James Brown⁵, David Reynolds⁶, Simone Evett⁷

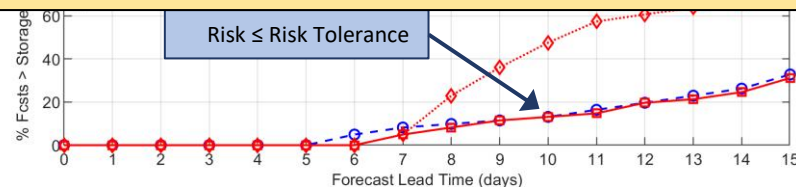
¹ Sonoma Water
² RKH Consulting Services
³ University of California San Diego
⁴ U.S. Army Corps of Engineers
⁵ Hydrologic Solutions Ltd.
⁶ University of Colorado
⁷ Independent Researcher

- Ensemble Forecast Operations is probabilistic decision support system for reservoir flood control operations.
- Utilizes ensemble streamflow predictions (ESPs), which account for forecast variability, to manage to forecasted risk of exceeding critical storage levels.
- Demonstrates improved reservoir storage reliability for water supply and ecosystems.



NWS' Hydrologic Ensemble Forecast System (HEFS) is vital to FIRO success

Including enabling innovative water resources engineering developments such as the EFO model (Delaney et al. 2020 WRR)





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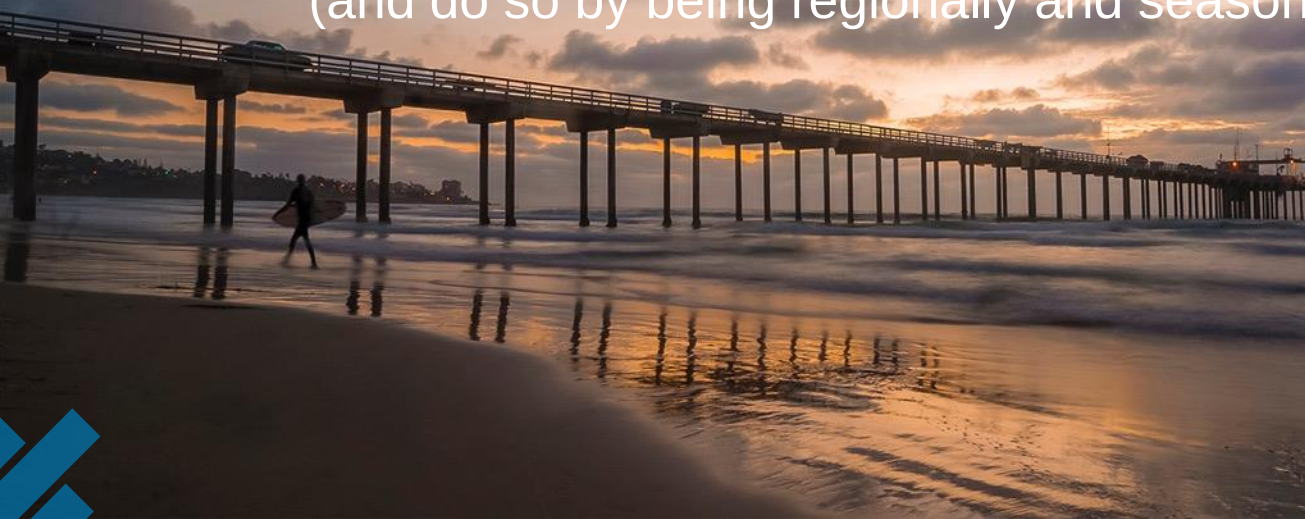
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CW3E FIRO strategy to improve QPF skill: Get the “storm” right (in all 4 dimensions)

(and do so by being regionally and seasonally specific)

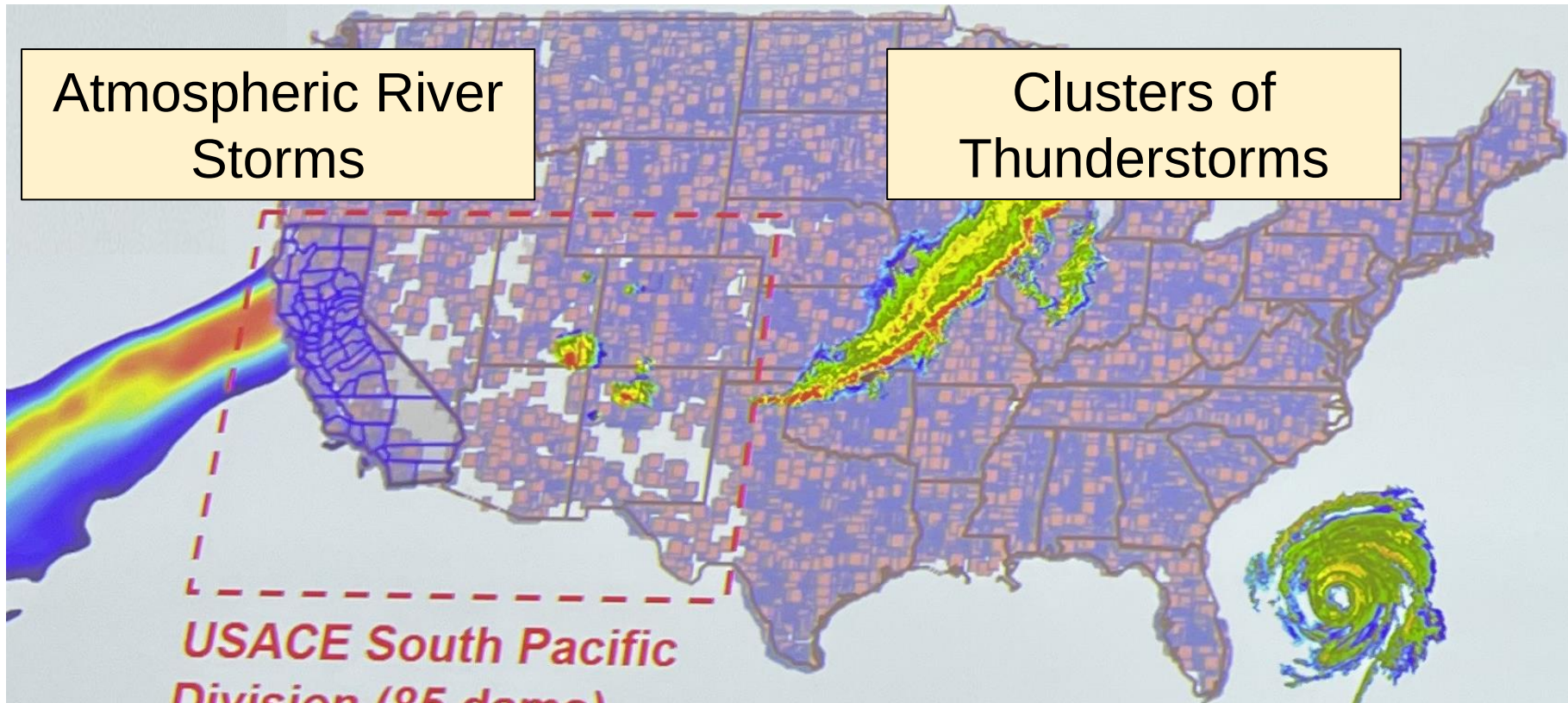


Atmospheric River
Storms

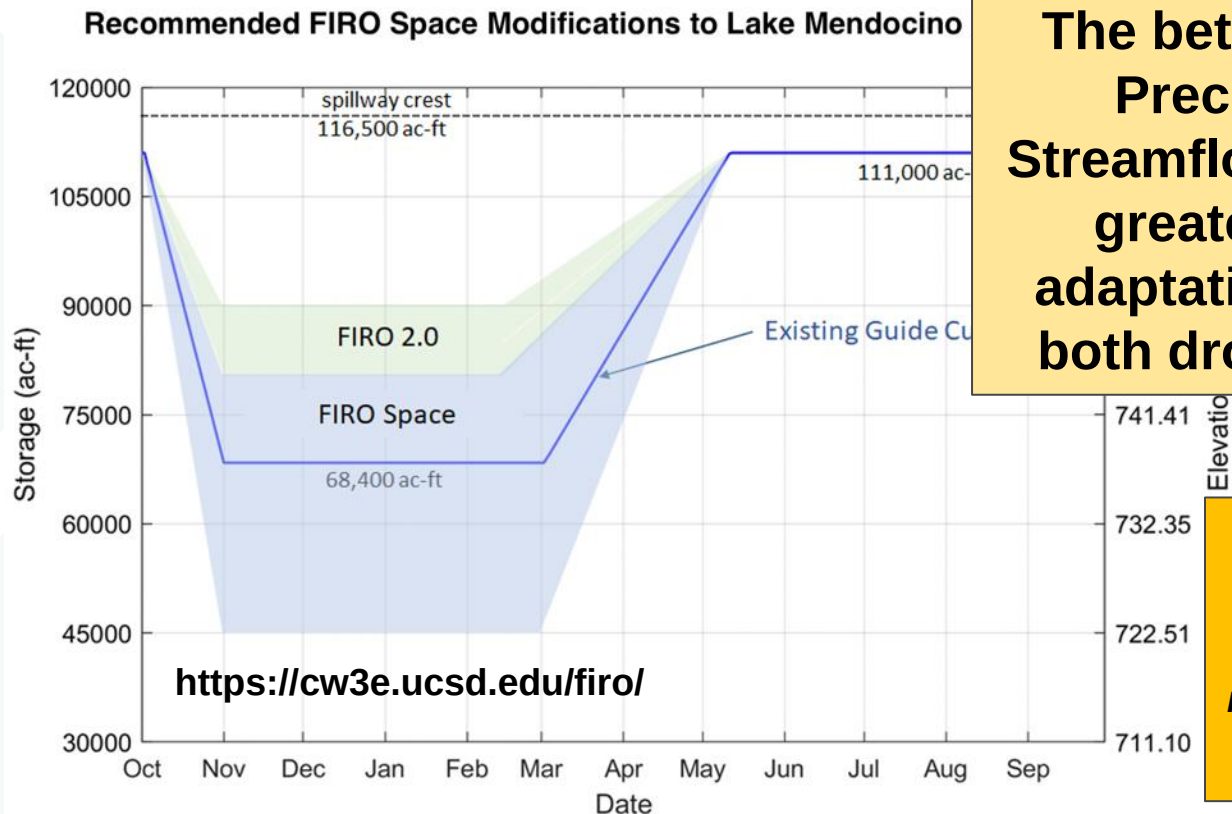
Clusters of
Thunderstorms

*USACE South Pacific
Division (85 dams)*

Tropical Storms
and Hurricanes



Future Improvements in Forecast Skill Can Add Flexibility



The better the Extreme Precipitation and Streamflow forecasts, the greater the climate adaptation potential for both drought and flood

FIRO CONTACTS

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THANK YOU



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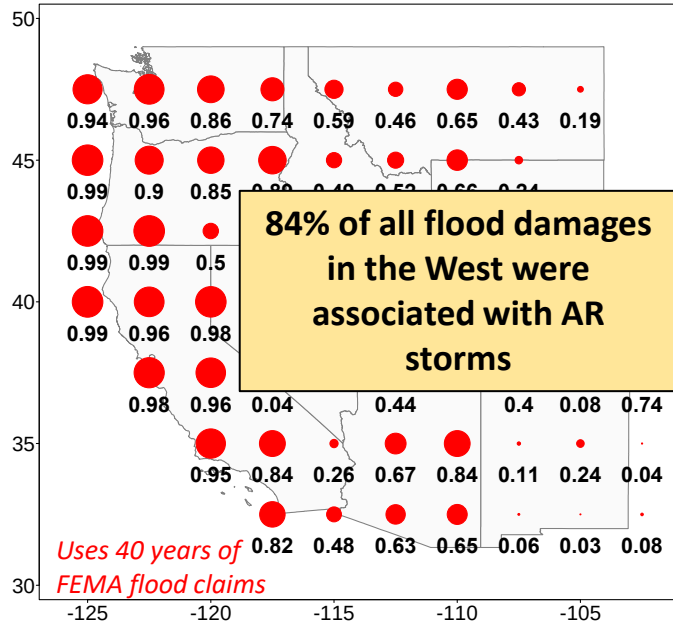


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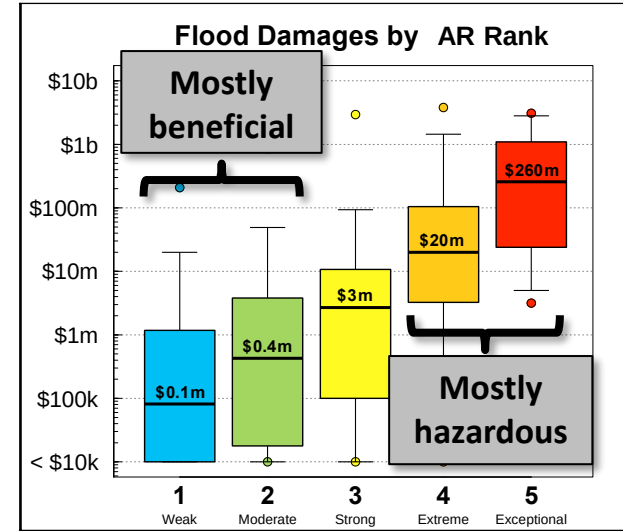
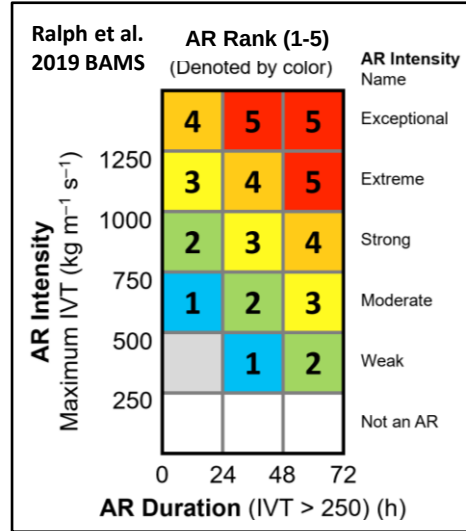
F. Martin Ralph, mralph@ucsd.edu, CW3E.UCSD.edu

ARs drive flood damages in the western U.S.

Proportion of Insured Losses Due to ARs



Corringham, Ralph, Gershunov, Cayan and Talbot, Sci. Advances (2019)



Corringham et al. 2019, Science Advances

Flood damages increase exponentially with AR Ranking



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