Forecast-Informed Reservoir Operations

“Managing water before the first drop hits the ground”

Cary Talbot, PhD, PE
FIRO Program National Lead
USACE-ERDC

NWC Annual Meeting
Sacramento, CA - October 3, 2023

U.S. ARMY

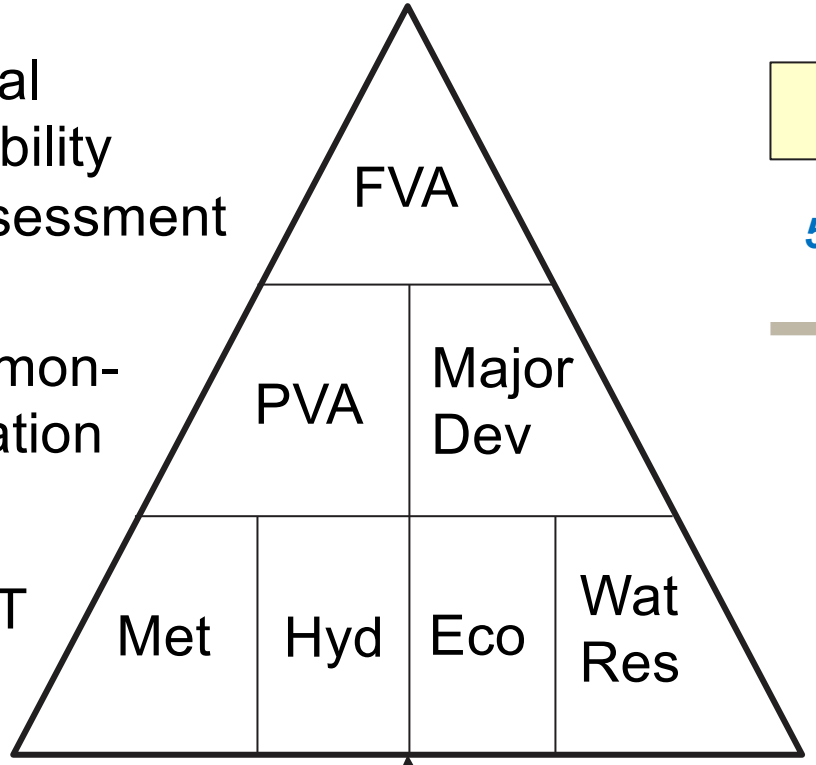
US Army Corps of Engineers®

FIRO Background

- **2012-2015** – Driest 3-year period in California history*
- **May 2016** update to Water Control Management Policy *allows* use of forecasts in water management operations but does not define *how*
- FIRO is R&D effort to define *how* forecast information can be safely, effectively and officially implemented in water control manual (WCM) updates and practice
- FIRO viability assessed at candidate reservoirs through a careful, deliberate and collaborative process at pilot sites across the West with a variety of conditions

**at the time, 2020-2022 is now the driest 3-year period on record*

FIRO Viability Assessment Process



Meteorological Research	Hydrologic Research
Ecosystem Factors	Water Resources Ops

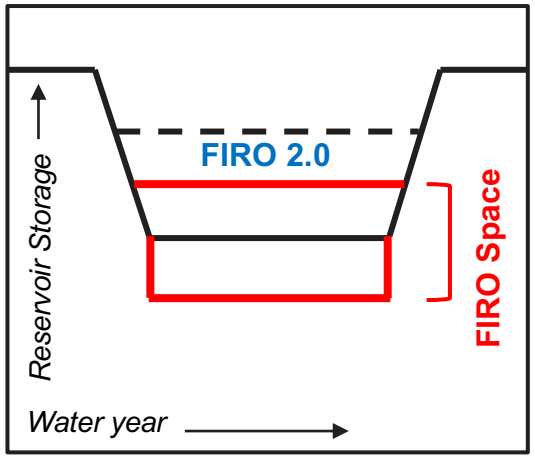
Interim

5-year Major Deviation

WCM Studies

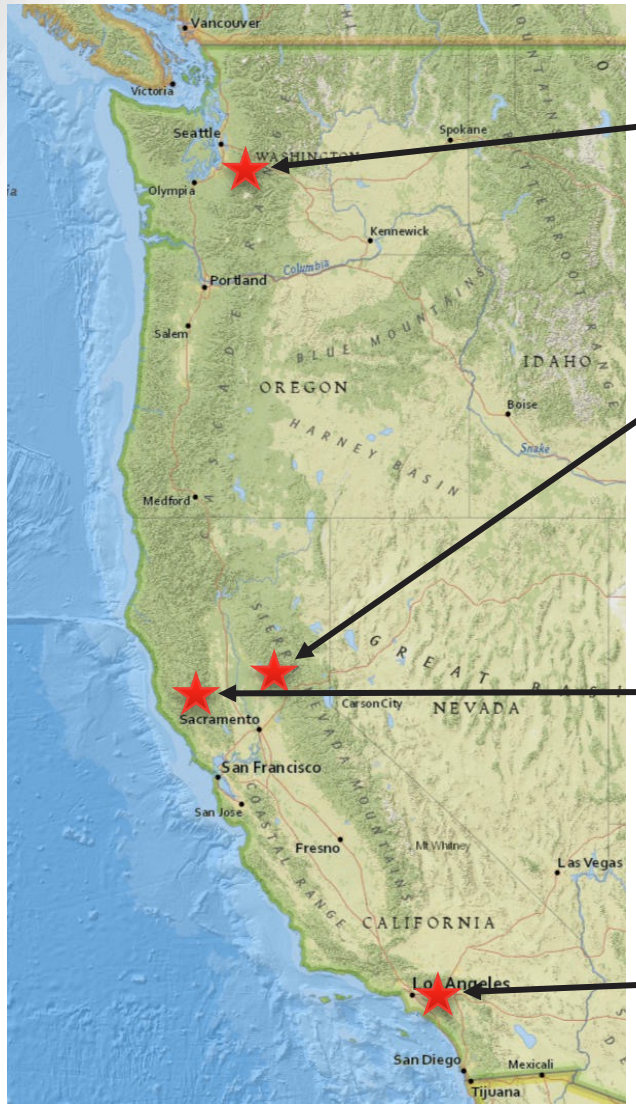
Additional Technical Studies for WCM Update Process
Study 1
Study 2
etc…

WCM Update



Key takeaway: FIRO is a Research And Operations Partnership

Current FIRO Pilot Project Locations



Howard Hanson Dam
Green River, Seattle District USACE

New Bullards Bar Dam
Yuba River, Yuba Water Agency
Oroville Dam
Feather River, CA Dept. of Water Resources
Sacramento District, USACE

Lake Mendocino
Lake Sonoma (added in FY22)
Russian River, San Francisco District USACE

Prado Dam
Seven Oaks Dam (added in FY22)
Santa Ana River, Los Angeles District USACE,
San Bernardino County Flood Control District

FIRO Viability Assessments – Current Status

Lake Mendocino

Work Plan Completed Sep 2015

PVA Published Nov 2017

FVA Published Feb 2021

Prado Dam

Work Plan Completed Jul 2019

PVA Published Jul 2021

New Bullards Bar & Oroville Dams

Work Plan Completed Mar 2021

PVA Published Dec 2022

Howard Hanson Dam

Lake Sonoma

Work Plan Completed Apr 2022

Seven Oaks Dam

Develop Work Plan

Conduct Preliminary Viability Assessment

Conduct Final Viability Assessment

Select Site and Form Steering Committee

Publish Work Plan

Publish PVA

Publish FVA

FIRO Viability Assessment Timeline

Collaboration is Key to FIRO Success

- FIRO pilots are led by interagency Steering Committees carefully formed with senior representatives from stakeholder agencies and academic partners
  - Blend of engineers and scientists from research, operations and regulatory perspectives
  - Each agency responsible for supporting their engagement

Phases of FIRO Research & Development

Phase I – Lake Mendocino

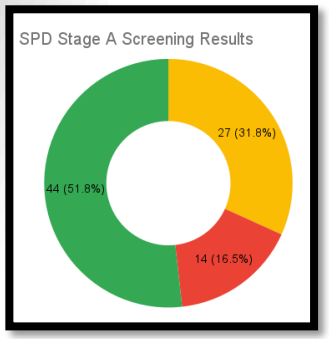
- Oct 2014 – Dec 2020
- Initial FIRO pilot, defined viability assessment process and use of steering committees
- Preliminary Viability Assessment: Jul 2017
- Final Viability Assessment: Feb 2021

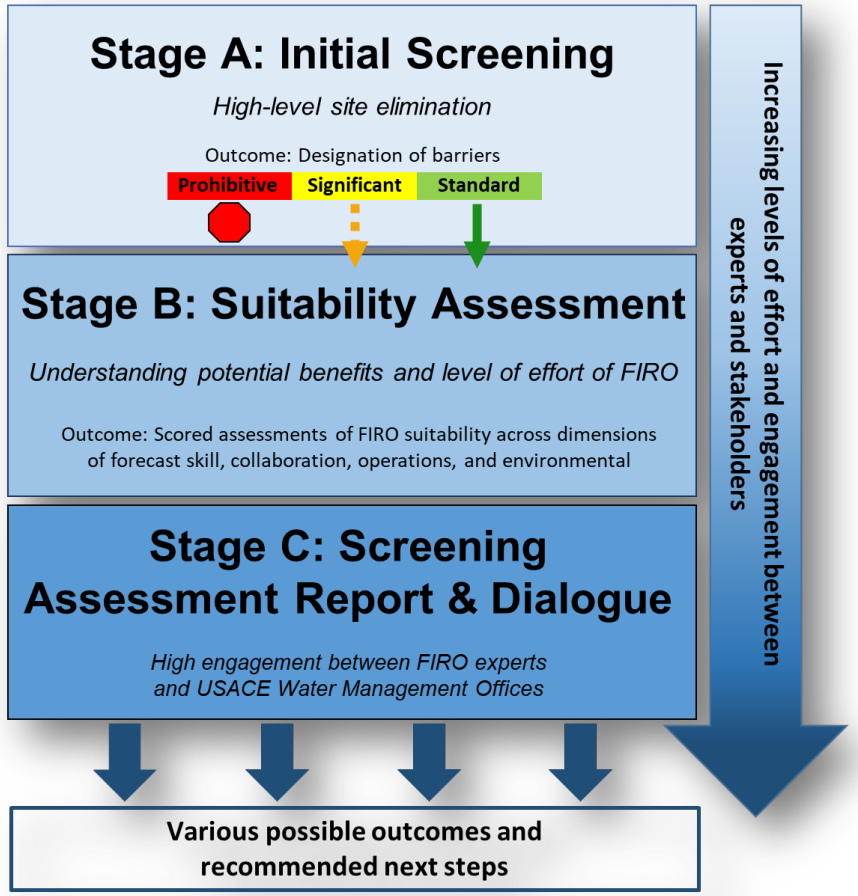
Phase II – Expanded Effort

- Oct 2019 – Dec 2023
- Added three more pilots:
  - Prado Dam
  - New Bullards Bar/Oroville Dams
  - Howard Hanson Dam
- Screening Process Development
  - USACE South Pacific Division dams as testbed

FIRO Phase II – Developing the Screening Process *SPD Beta test*

U.S. ARMY





- 85 SPD reservoirs screened in Stage A
- 14 reservoirs eliminated from FIRO consideration
- 13 reservoirs nominated for Stage B beta

- Stage B analysis in progress now
- 13 site reports will be produced in 2023
- Outcomes include recommended steps

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
2. Completion of Phase II viability assessments to support planned WCM updates
   - Prado, Yuba-Feather, Howard Hanson, Lake Sonoma, Seven Oaks
3. Conduct full FIRO viability assessment on Willamette Valley, Oregon system of dams (14 dams in total)
   - Willamette Valley dam operations are managed in coordinated fashion from a single water management office

FIRO Phase III:
National Expansion Pathfinder

FY23-FY27

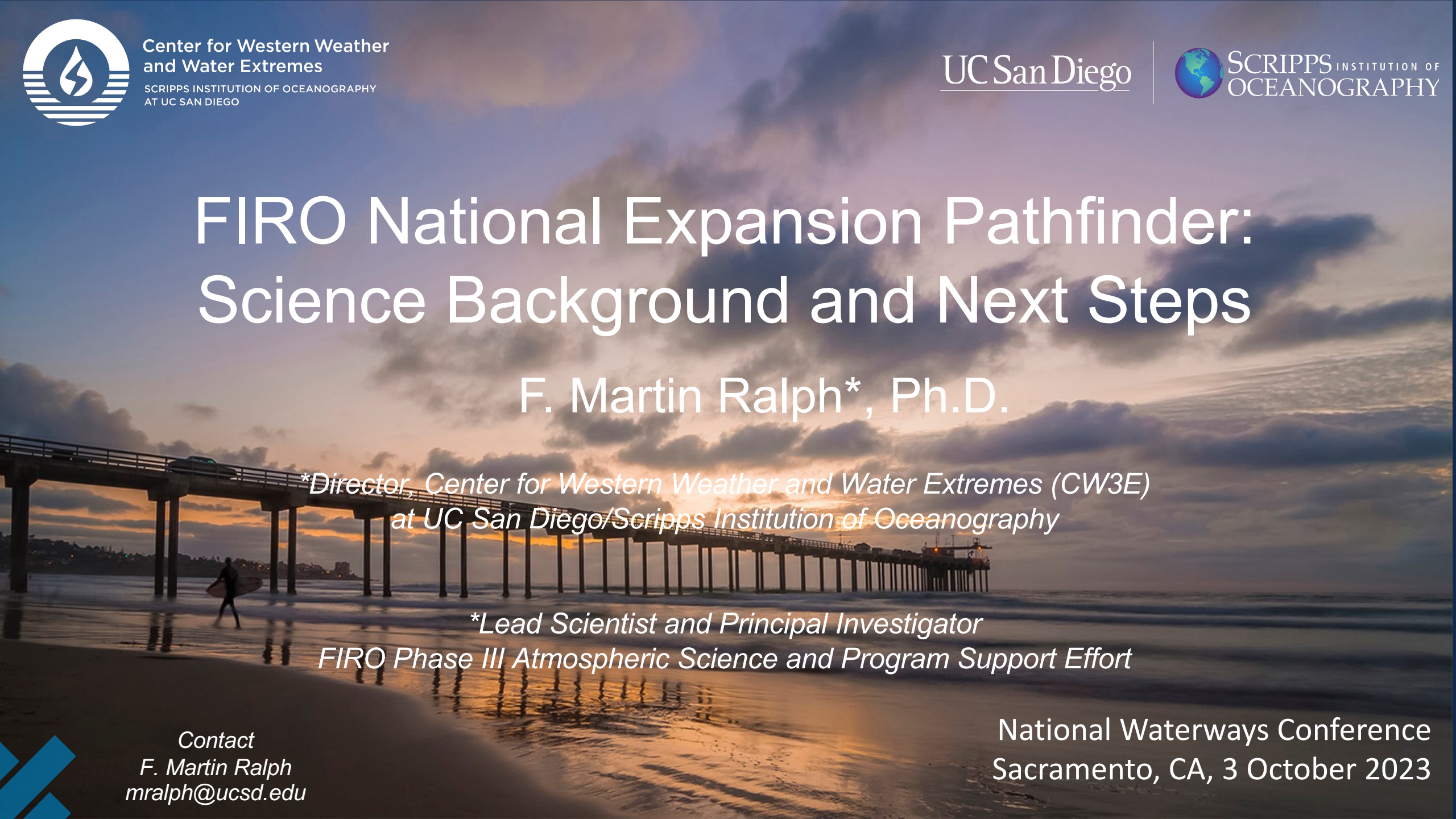
4. Conduct full viability assessment of system of 8+ dams in another region nationally
   - Explore a region where different storm types (in addition to ARs) are key to heavy rain and flooding (e.g., tropical storms/hurricanes, long-lived thunderstorm clusters, Nor'Easters)
5. Conduct full viability assessments on two single dams in other regions nationally
6. Apply FIRO screening process nationally across USACE portfolio of dams
   - Result will be identification of FIRO-suitable sites to help prioritize future FIRO viability assessment efforts

New USACE FIRO-Specific Positions

- Two national FIRO-specific positions created to support FIRO R&D and implementation going forward
  - National FIRO Program Lead: Cary Talbot
  - Water Management Integration Lead: Joe Forbis

Thank you!

Cary Talbot
USACE FIRO Program National Lead
Cary.A.Talbot@usace.army.mil



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

UC San Diego | SCRIPPS INSTITUTION OF OCEANOGRAPHY

FIRO National Expansion Pathfinder: Science Background and Next Steps

F. Martin Ralph*, Ph.D.

*Director, Center for Western Weather and Water Extremes (CW3E)
at UC San Diego/Scripps Institution of Oceanography

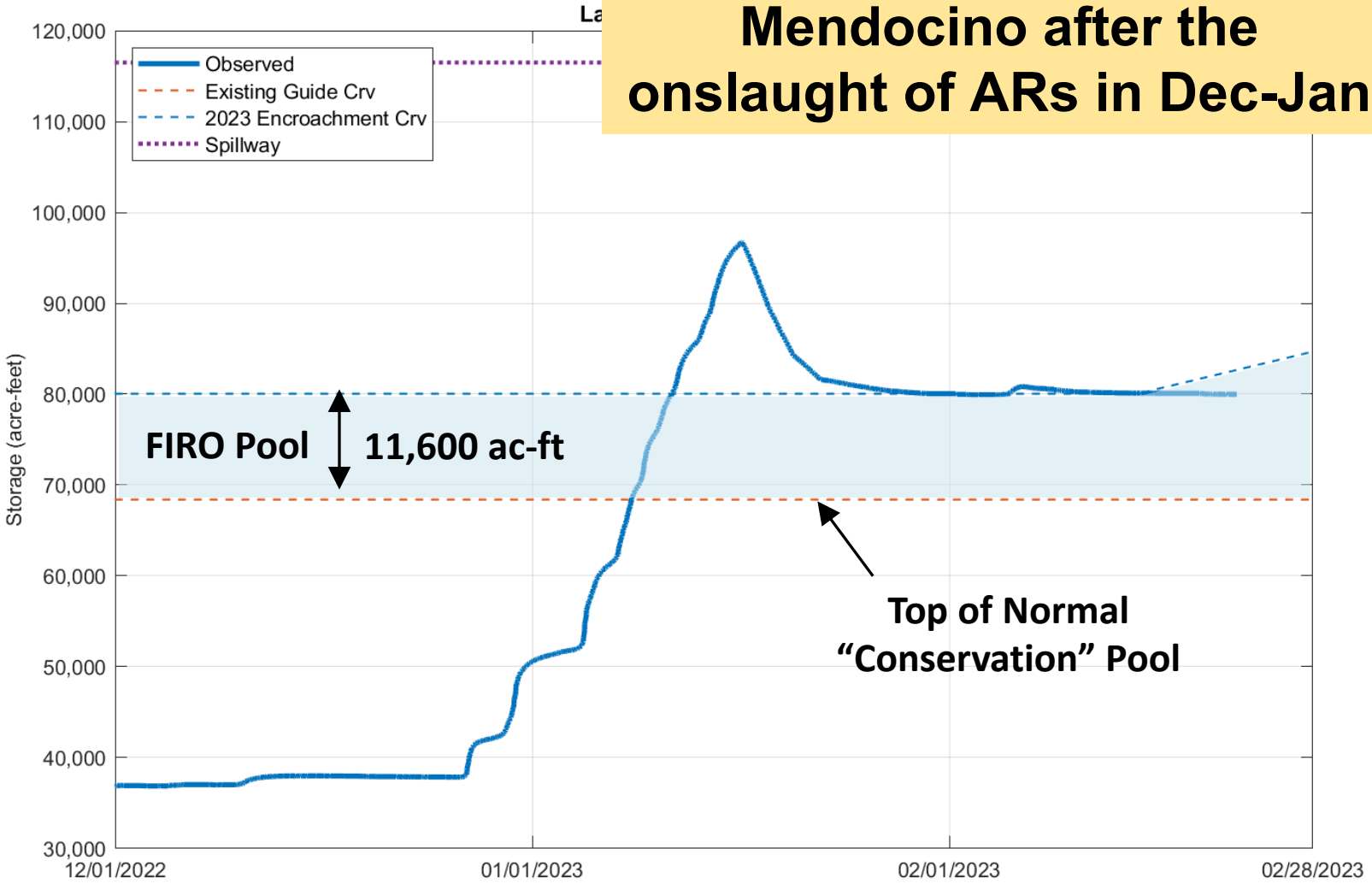
*Lead Scientist and Principal Investigator
FIRO Phase III Atmospheric Science and Program Support Effort

Contact
F. Martin Ralph
mralph@ucsd.edu

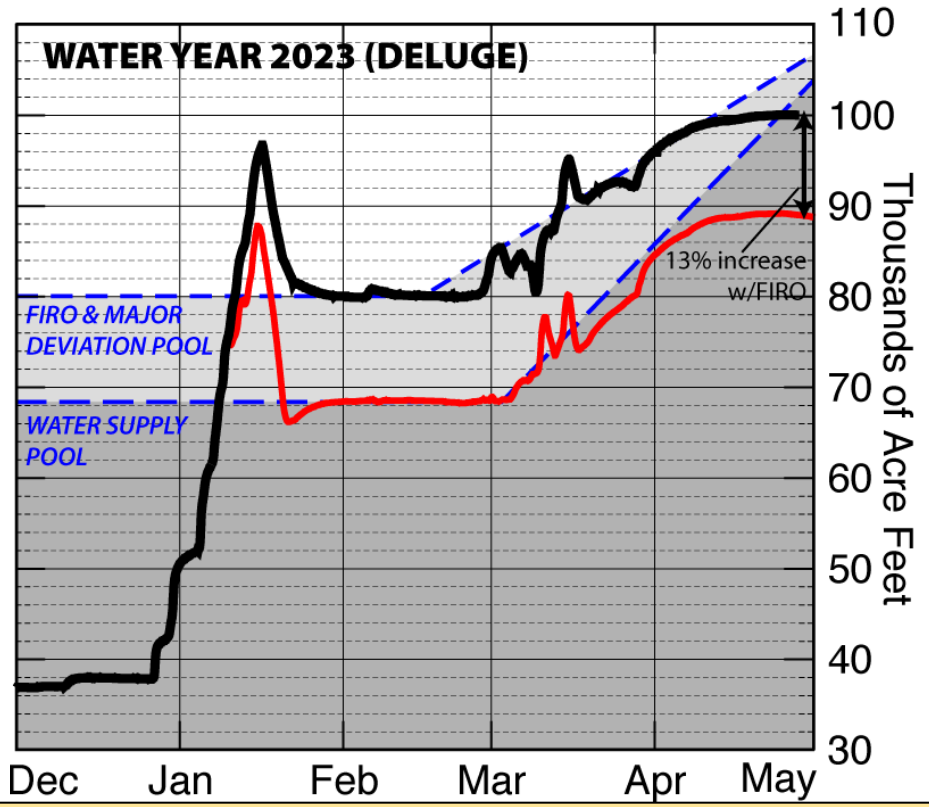
National Waterways Conference
Sacramento, CA, 3 October 2023

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.



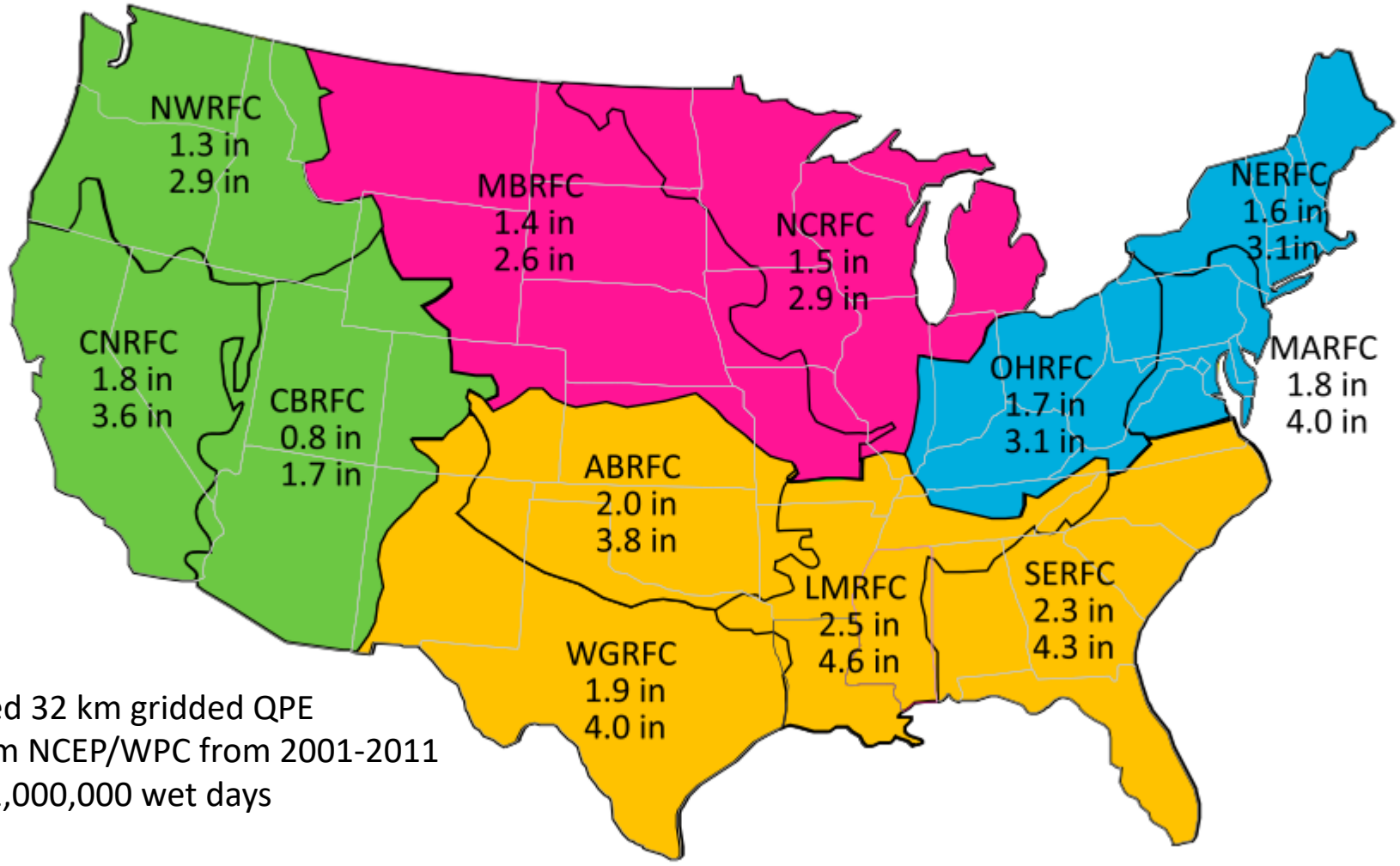
Key FIRO Finding

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

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)

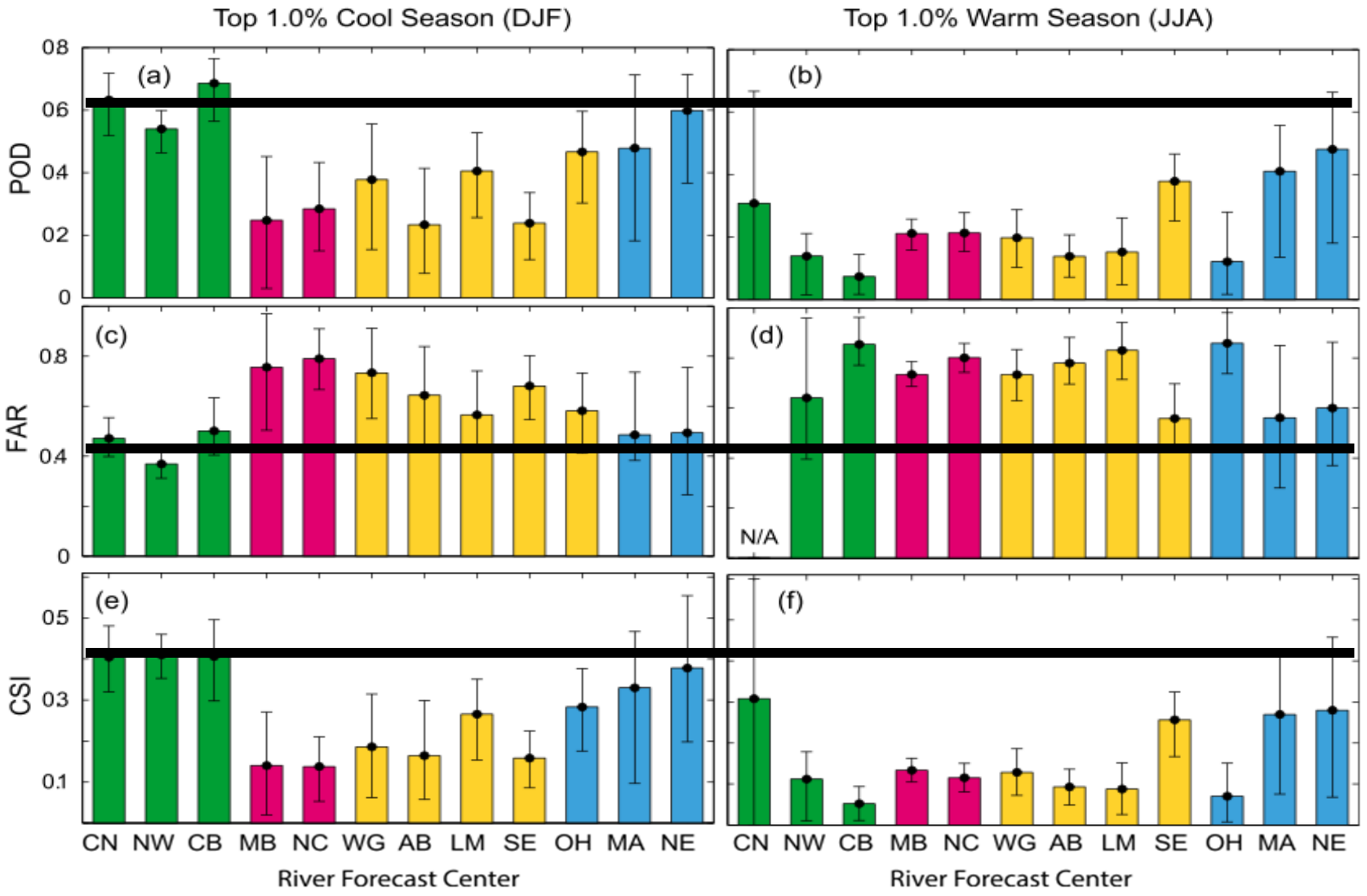
Regional thresholds for Top 1% and 0.1% heaviest daily precipitation



Used 32 km gridded QPE
from NCEP/WPC from 2001-2011
>12,000,000 wet days

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.

Center for Western Weather and Water Extremes

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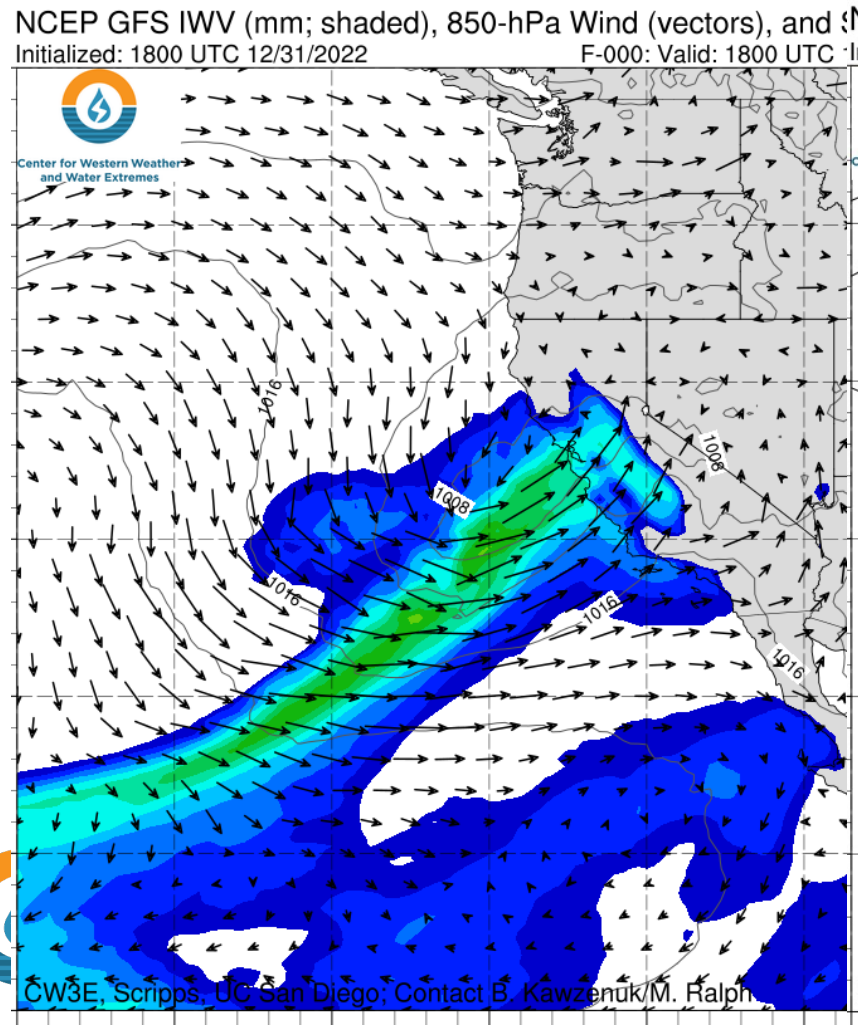
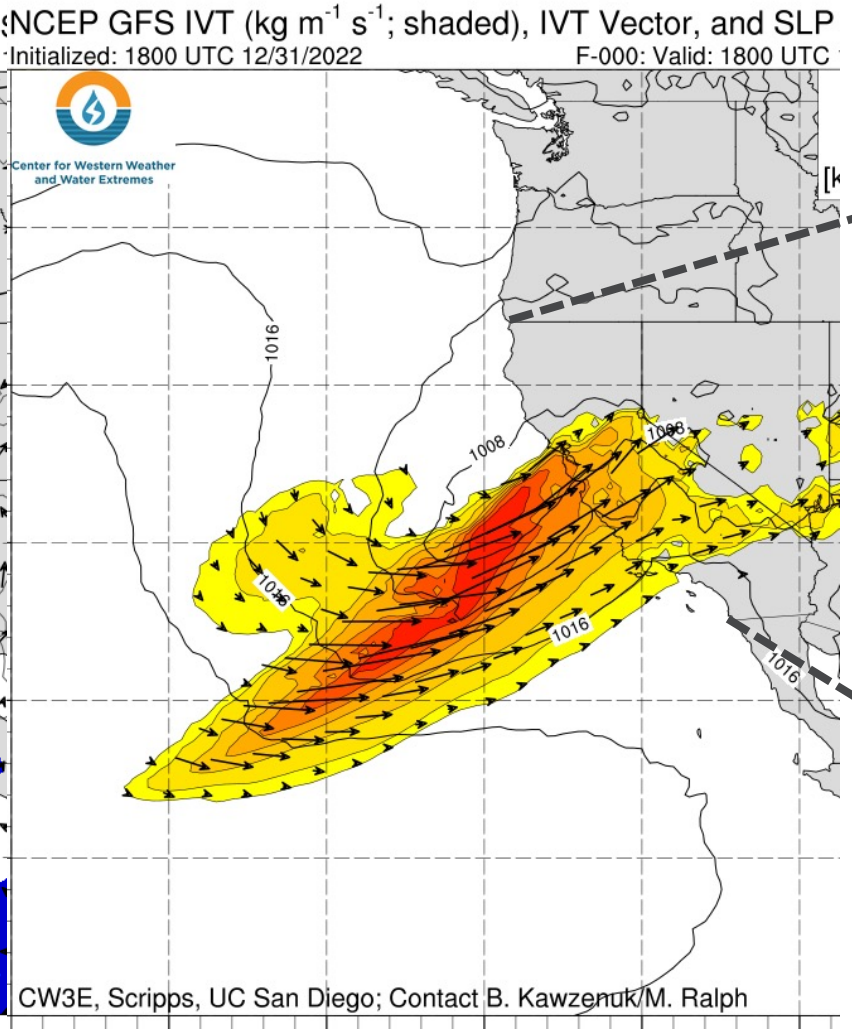
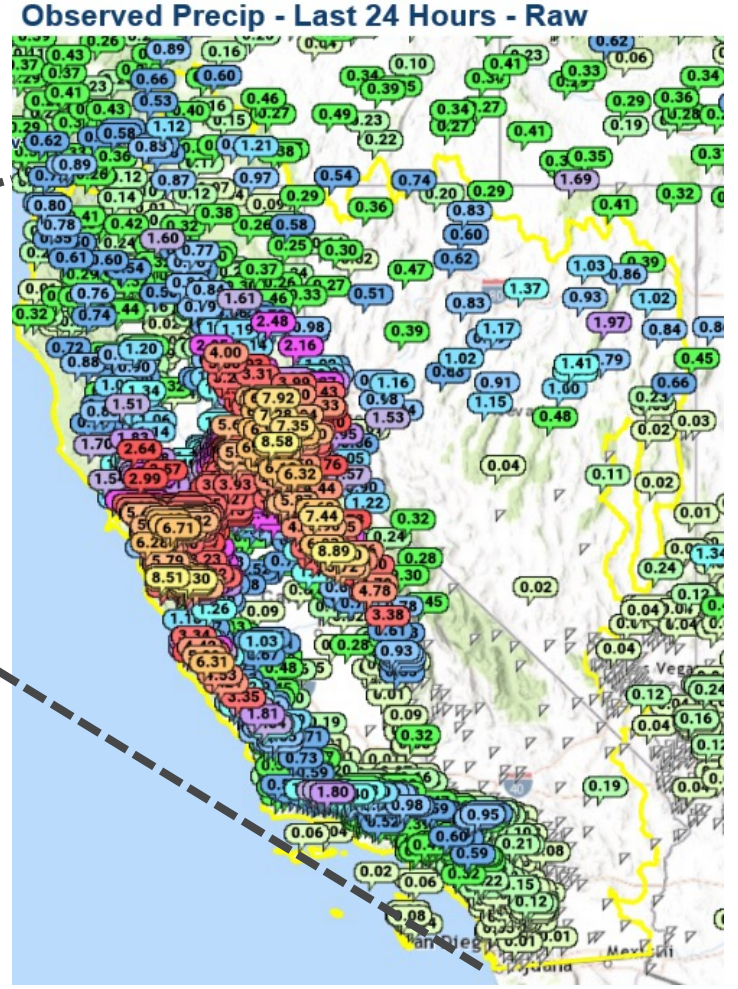
New Years Day 2023 AR



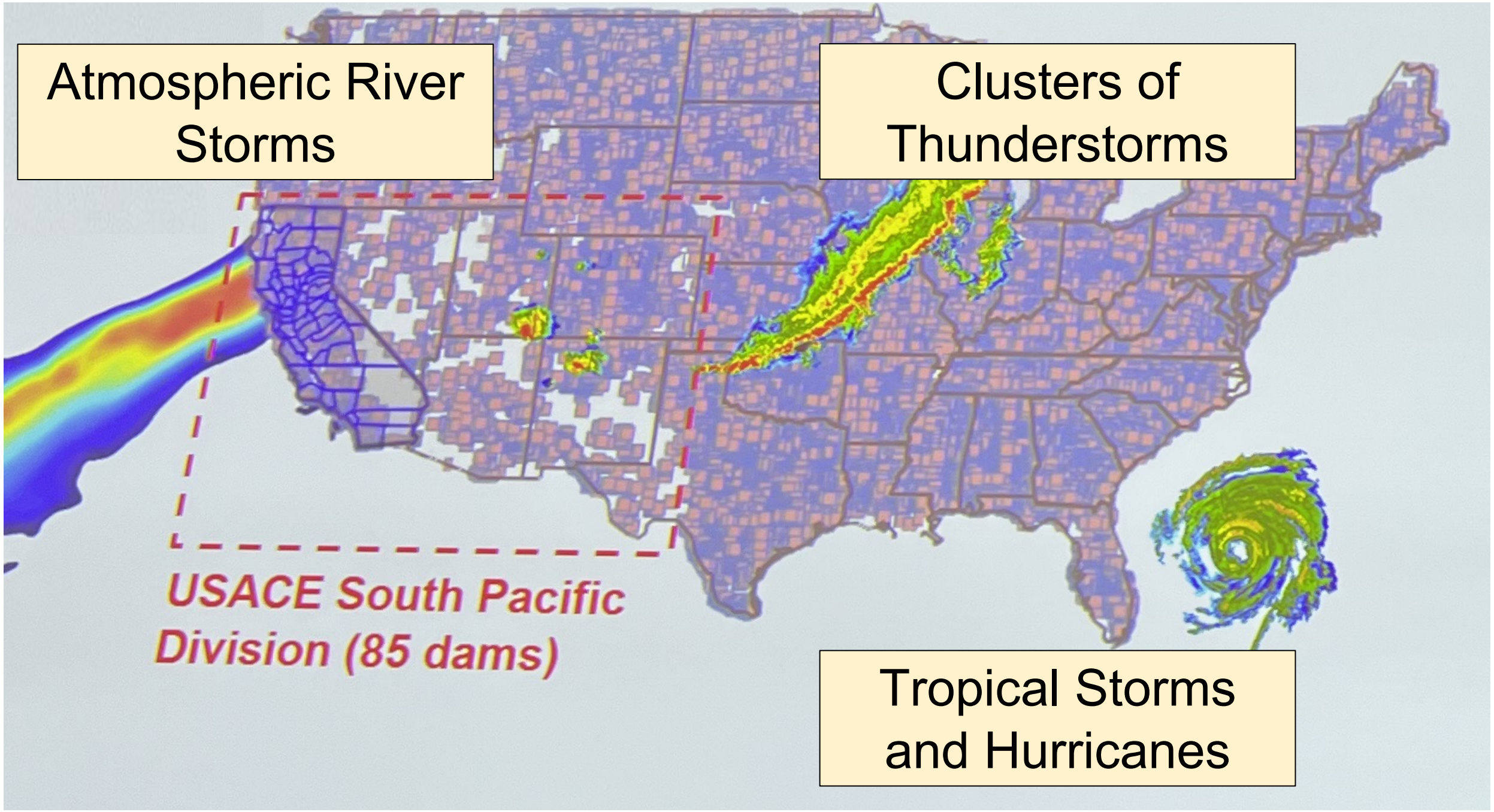




WY 2023: DEC 27, 2022 – JAN 19: A FAMILY OF 9ARs

C. Hecht

More AR3 or stronger storms hit CA in 3 weeks as would normally hit in an entire winter


Atmospheric River Storms
Clusters of Thunderstorms
USACE South Pacific Division (85 dams)
Tropical Storms and Hurricanes

THANK YOU

Contact: F. Martin (Marty) Ralph, Ph.D.
mralph@ucsd.edu

Website: CW3E.ucsd.edu

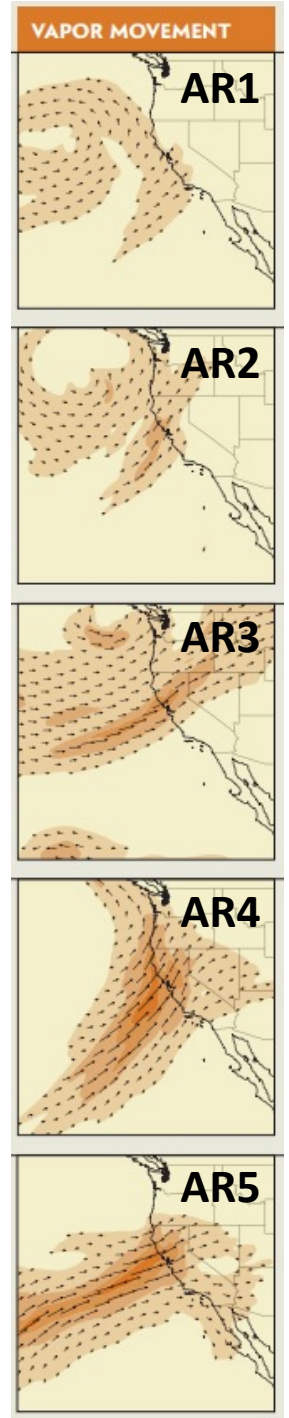
METEOROLOGY

FORECASTING ATMOSPHERIC RIVERS

Knowing when torrents of rain will strike can save property and lives

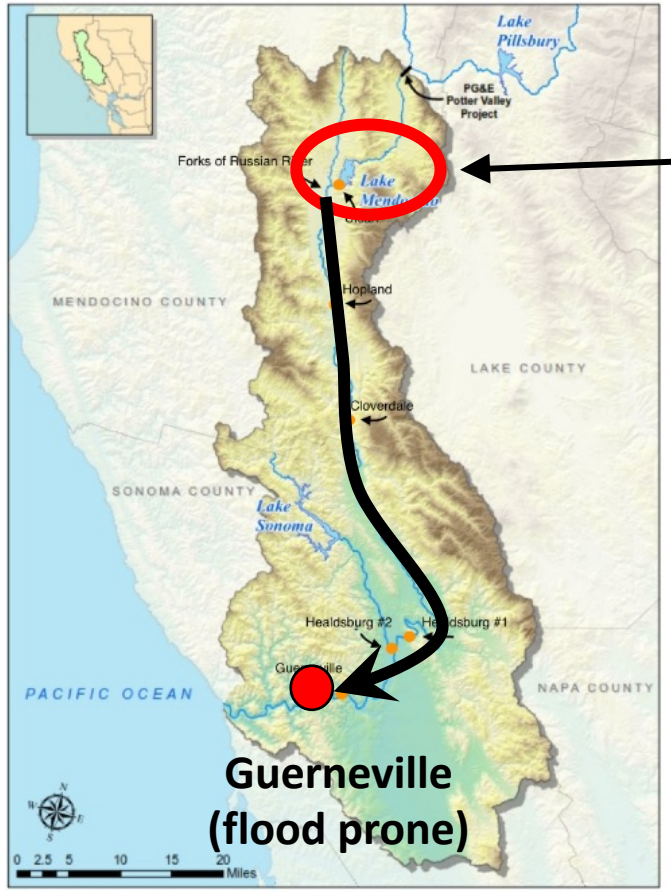
By F. Martin Ralph

Illustration by Mark Ross



AR Scale(examples)

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**

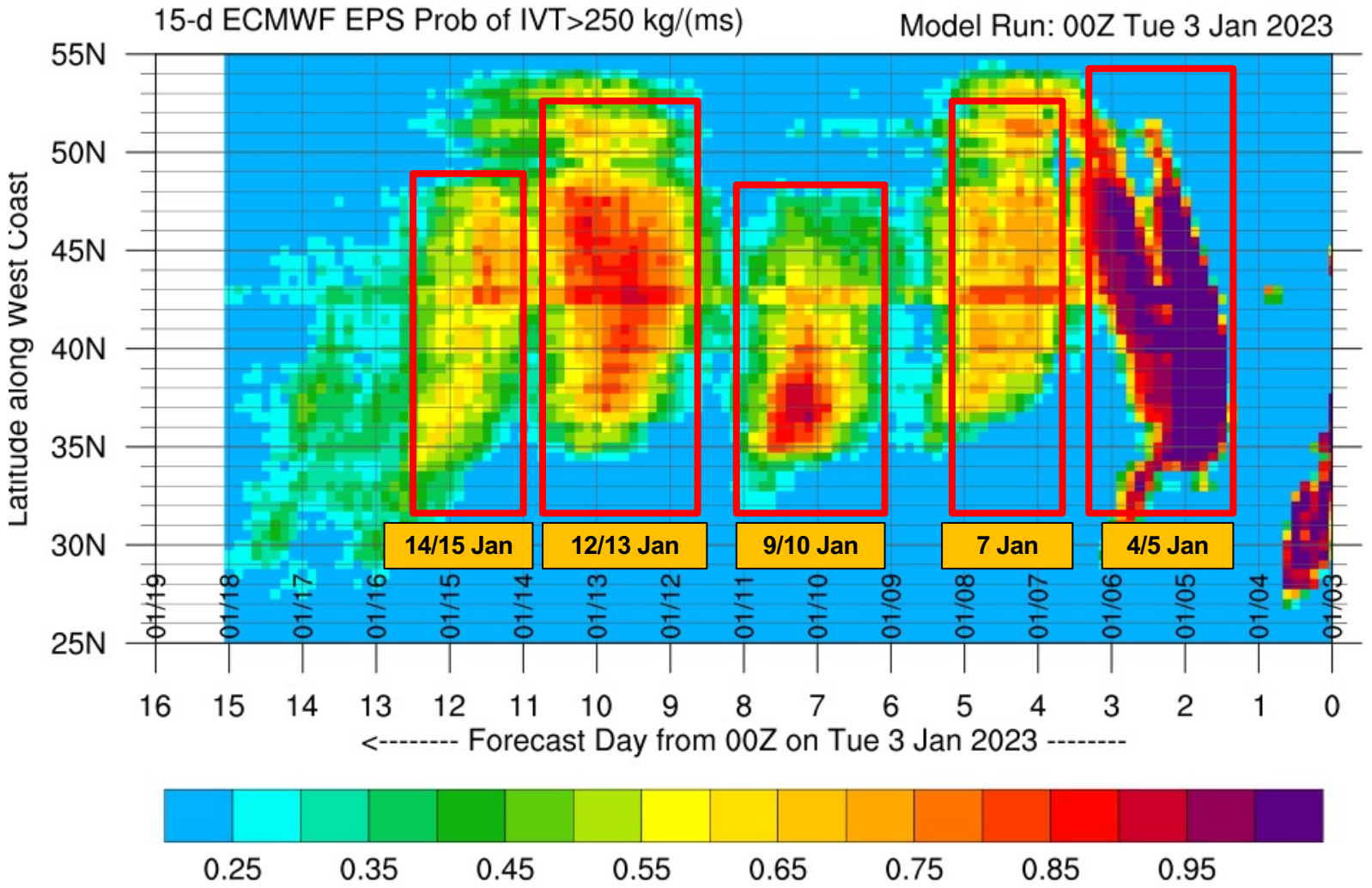
Bottom Line

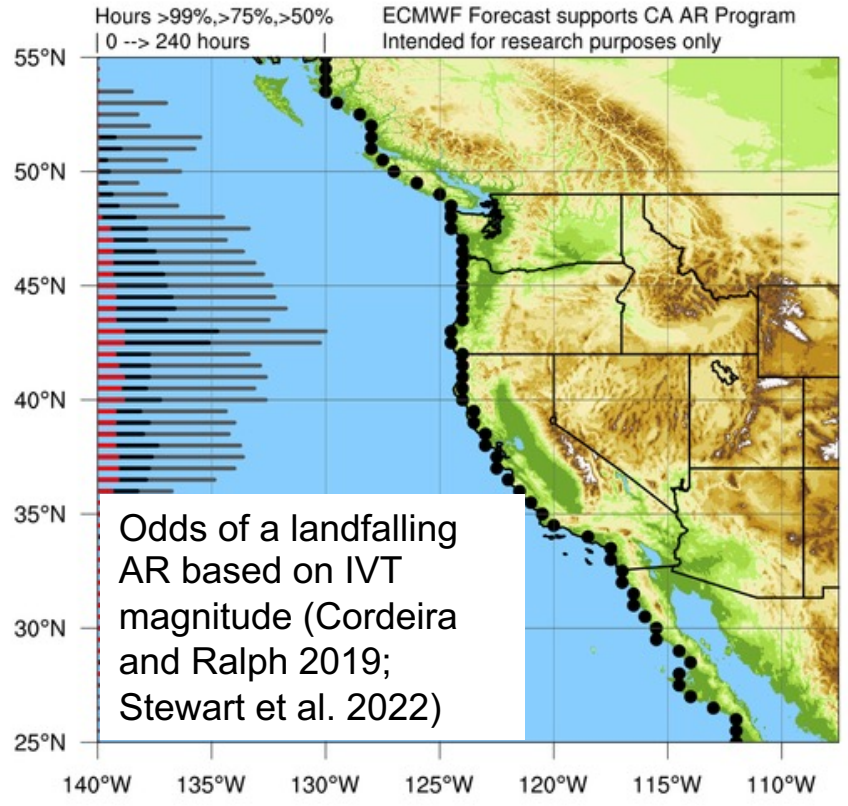
- **Two days to release the extra water, plus**
- **1-3 days to flow past flood-prone area downstream**

➔ **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?





Odds of a landfalling AR based on IVT magnitude (Cordeira and Ralph 2019; Stewart et al. 2022)

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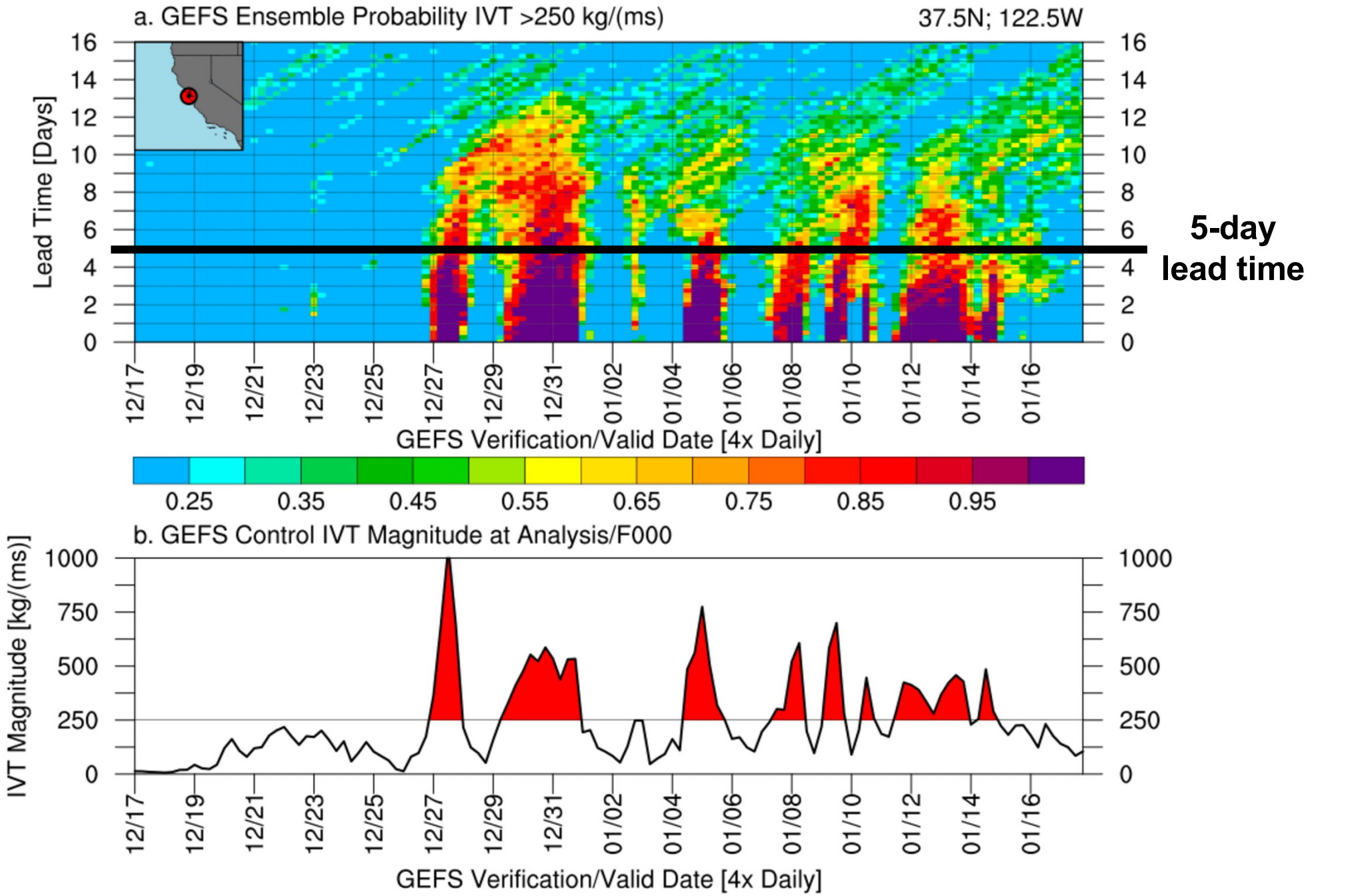
CW3E

J. Cordeira



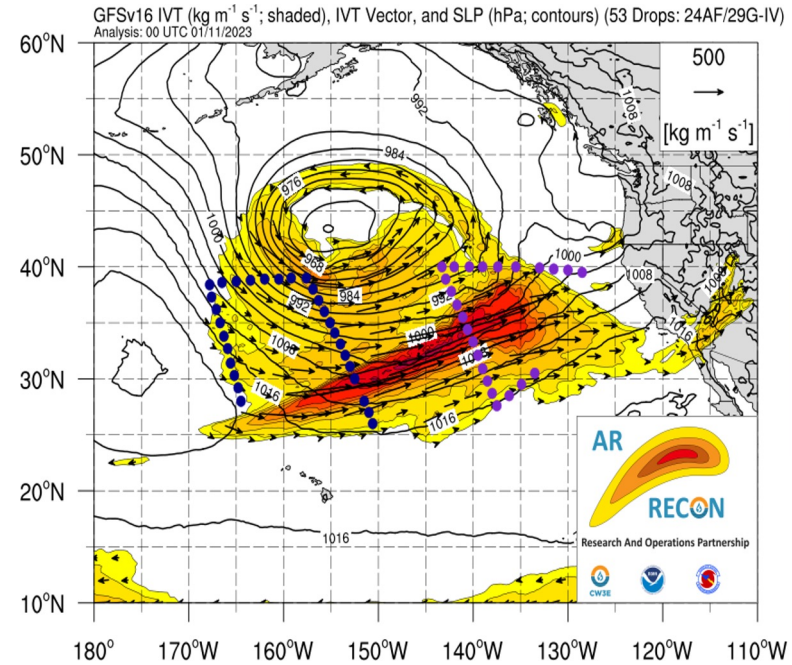
5-day lead time

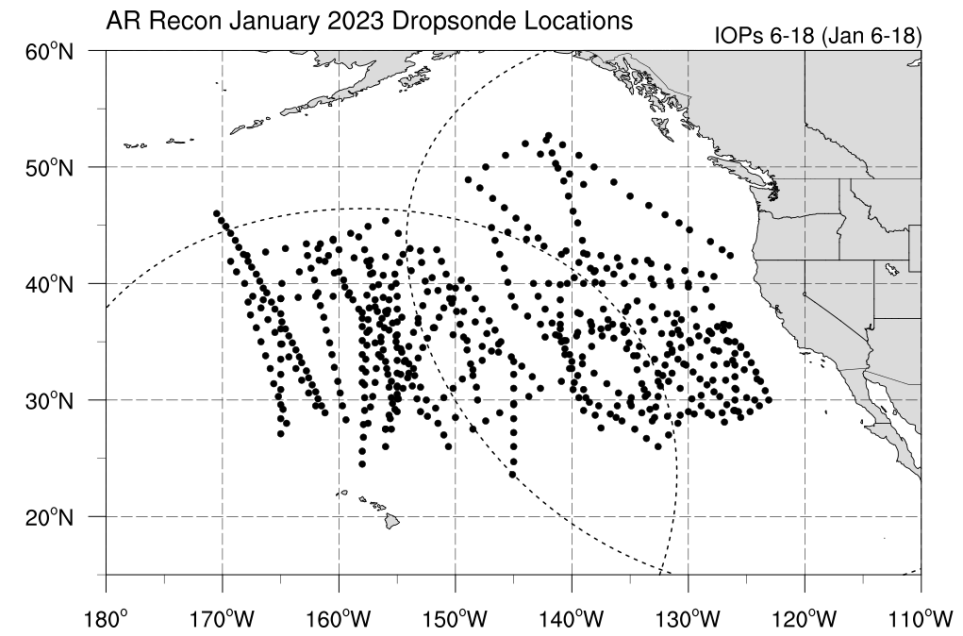
AR RECON 2023

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





**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

CW3E Center for Western Weather and Water Extremes
F. Martin Ralph, PI (UC San Diego/SIO/CW3E)
Vijay Tallapragada, Co-PI (NOAA/NWS/NCEP)
UC San Diego | SCRIPPS INSTITUTION OF OCEANOGRAPHY

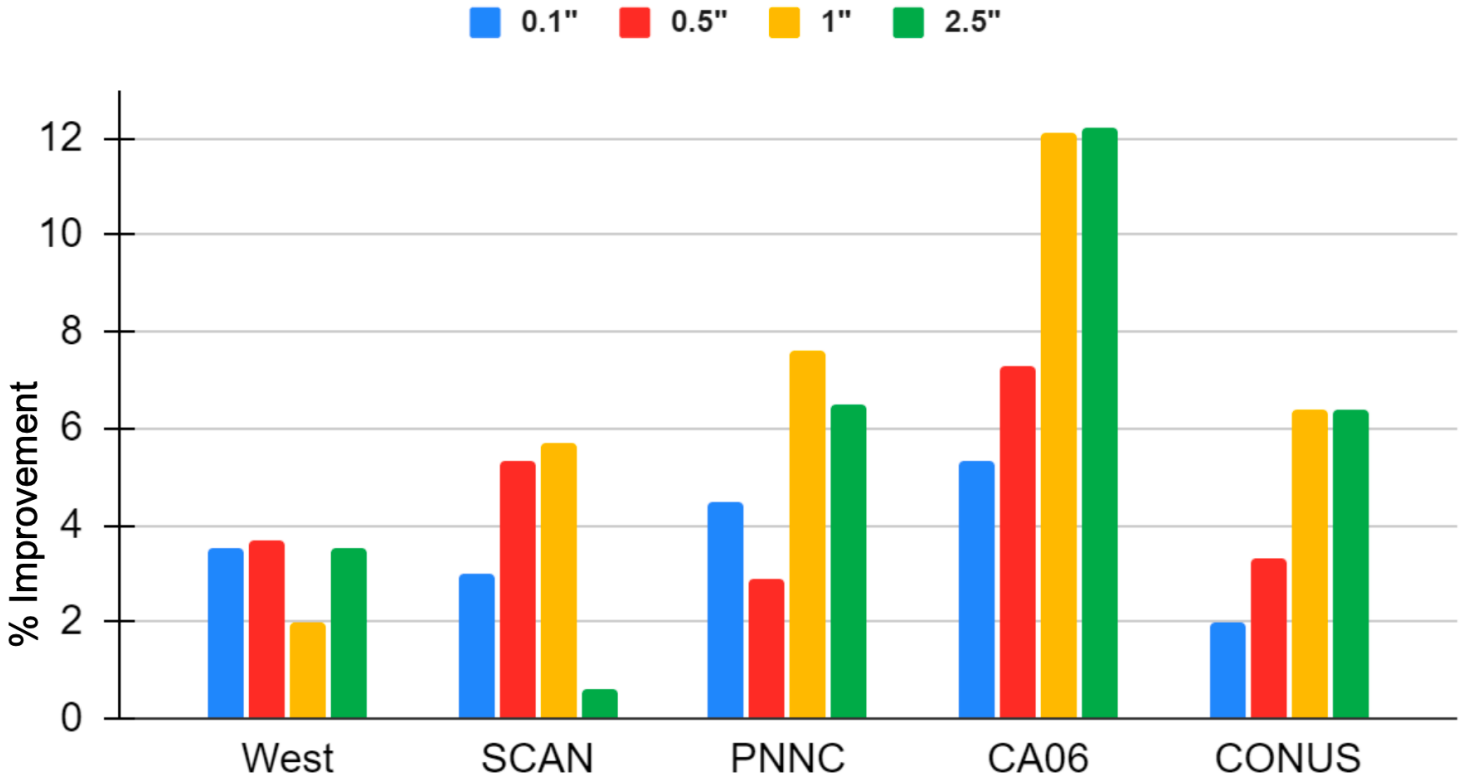
AR Recon: Better observations → Improved Forecast Skill (WY23)

Presentation
by V. Tallapragada

AR Recon Workshop
June 2023
@ECMWF

AR Recon 2022-23 Impact on Precipitation Forecasts

72-hr Forecast Improvement Ctrl vs. Deny

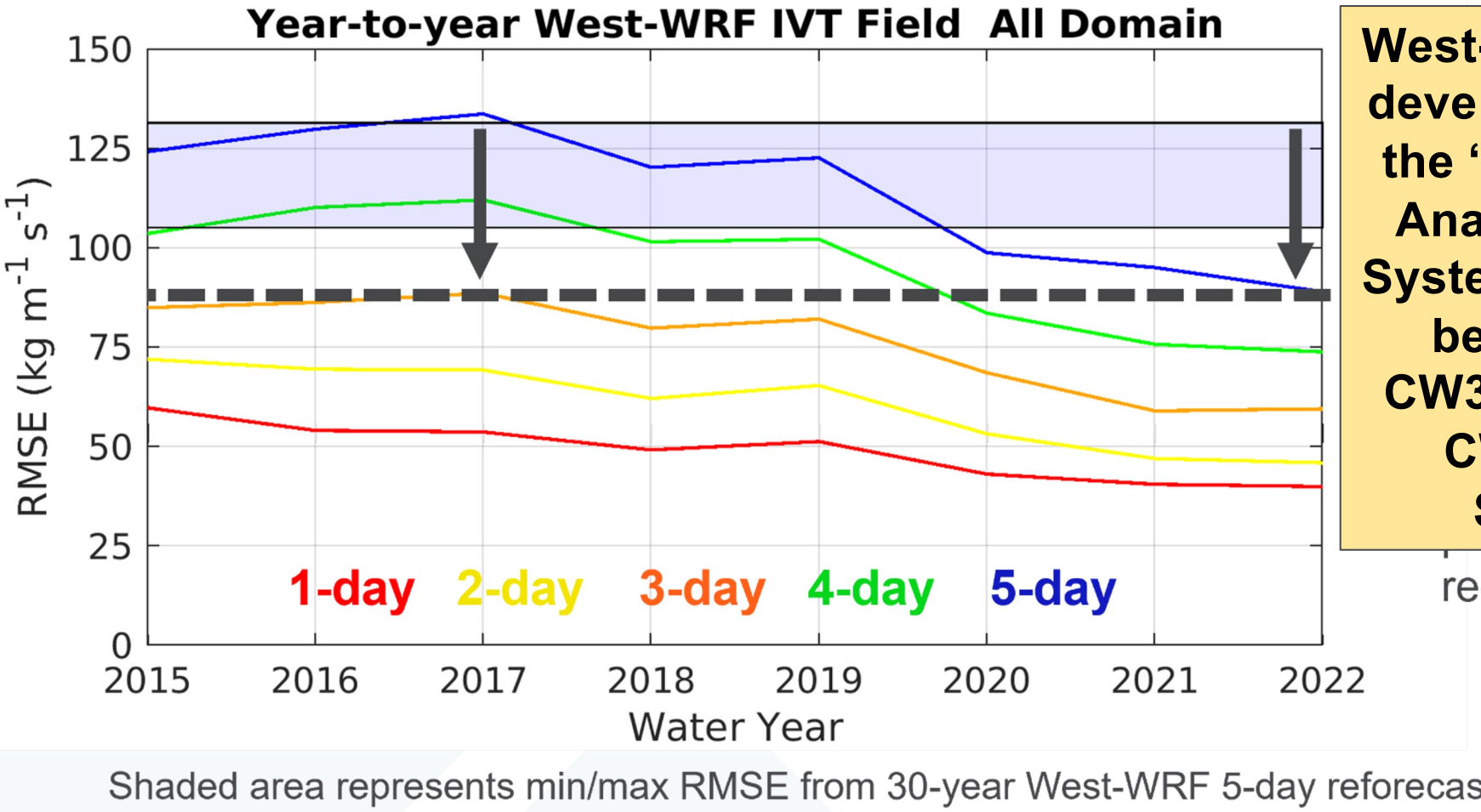


Largest improvements over the California Domain for the heavier precipitation amounts

On average, **12% improvement equates to skill expected 8 years in the future.**

AR RECON
Research And Operations Partnership

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 reforecas

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

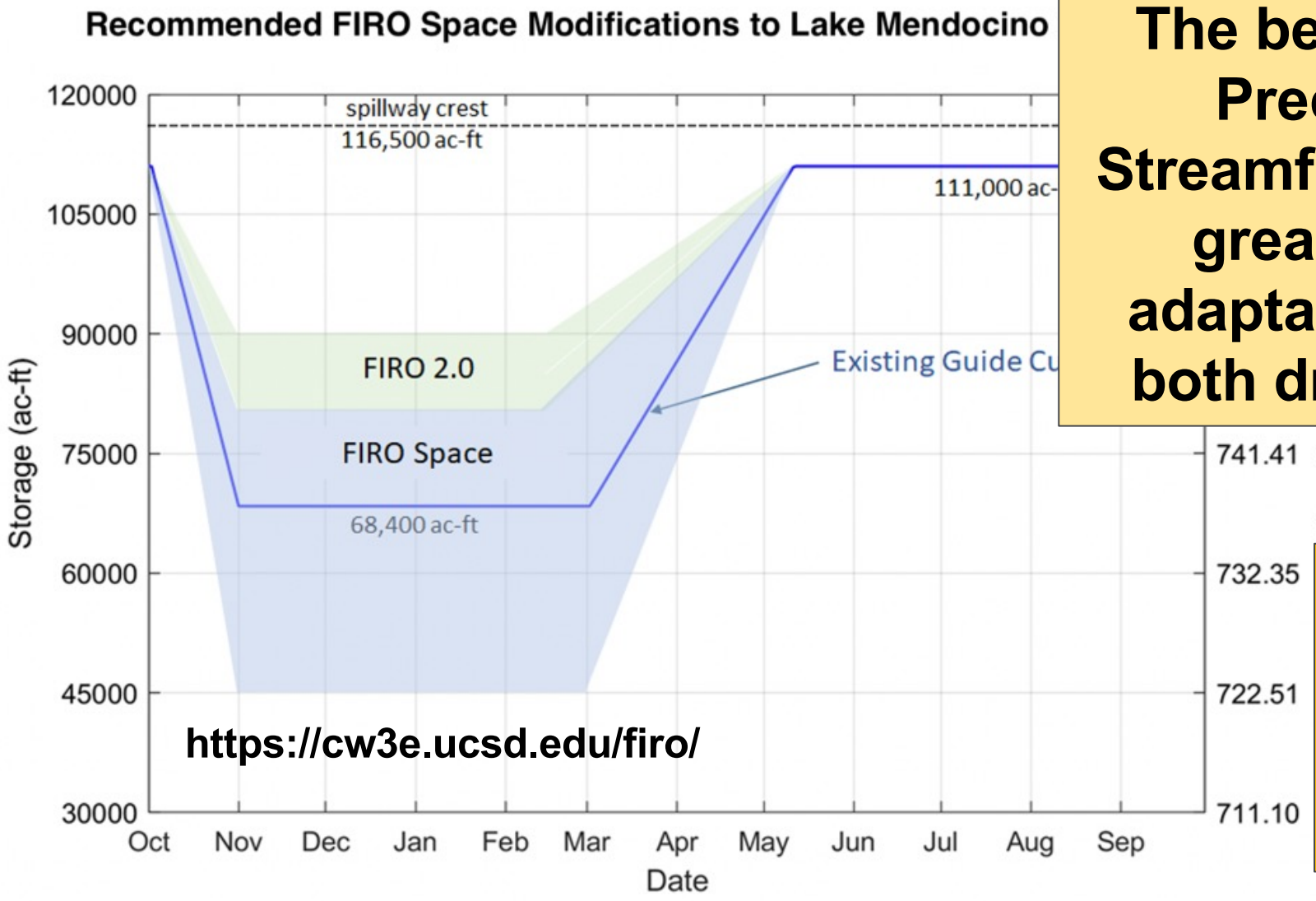
reduction)

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)

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

https://cw3e.ucsd.edu/firo/

FIRO CONTACTS

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Cary.A.Talbot@usace.army.mil

FIRO Phase III Lead Scientist/PI
F. Martin Ralph (SIO/CW3E)
mralph@ucsd.edu

FIRO Phase III: National Expansion Pathfinder

FY23-FY27

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5. Conduct full viability assessments on two single dams in other regions nationally

Lake Mendocino FIRO Benefits – WY 2020

3rd driest winter on record in Russian River watershed

10,825 ac-ft is enough water for ~22,000 homes for a year

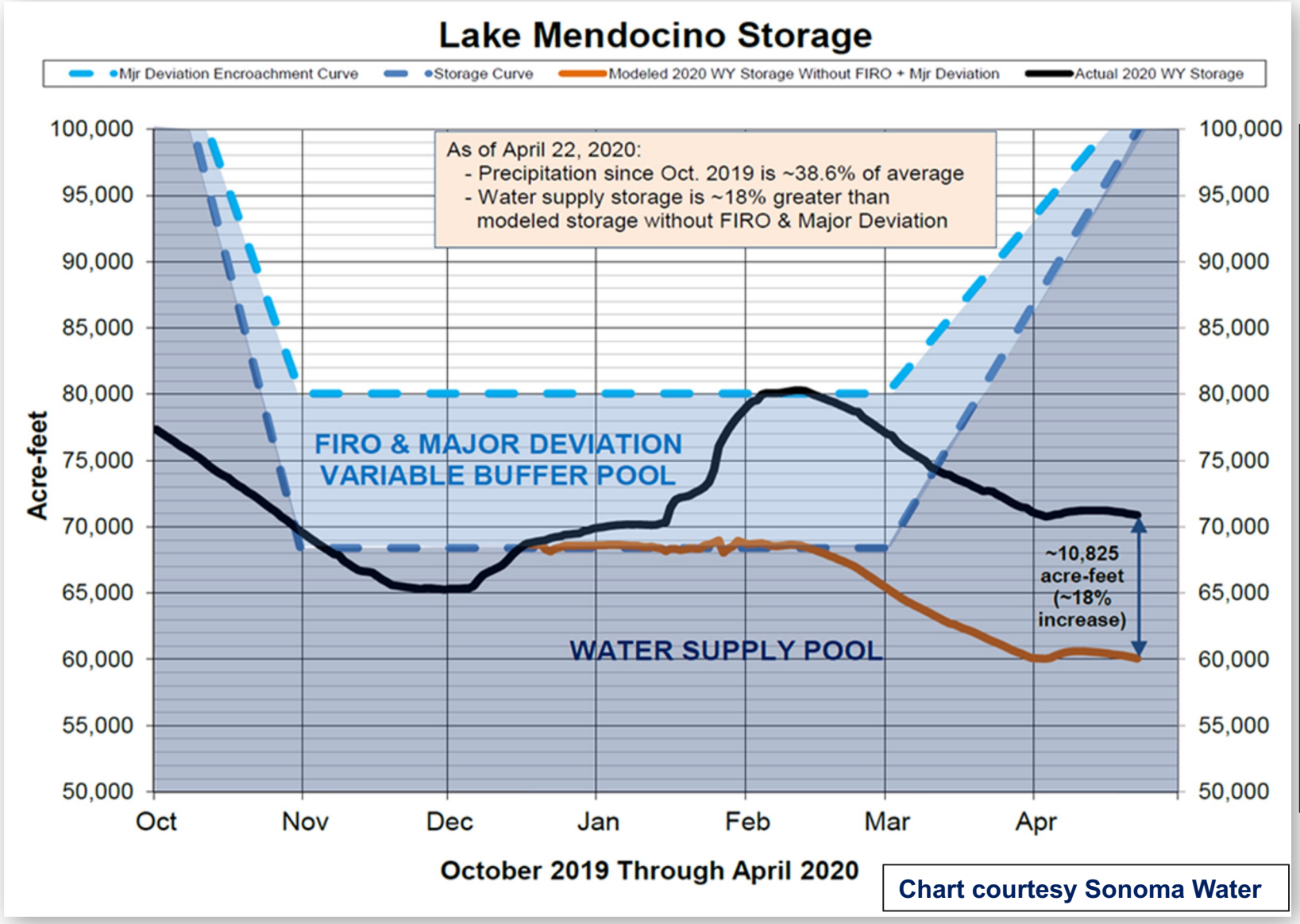


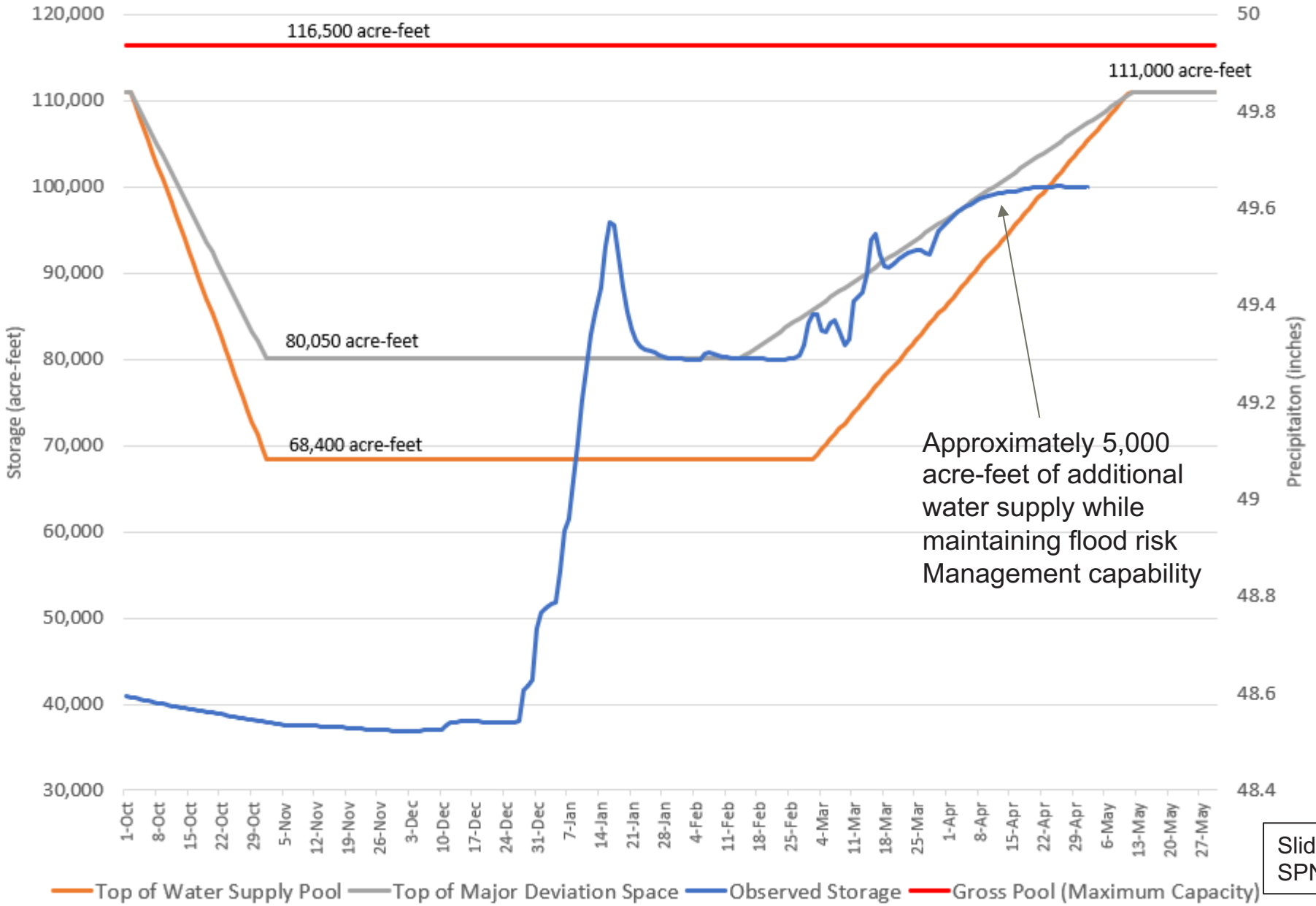
Chart courtesy Sonoma Water

Seeing the lake so full makes Kyle Farmer, a rancher in Potter Valley, happy every time he drives by it. “It’s a huge deal to become adaptive like that. I don’t think bureaucracies do that naturally,” he said. “It restored my faith in the government, obviously, a little bit.”

Drought or dangerous flooding? Research aims to tame atmospheric river risks — and save California’s rain
By Rachel Becker
www.CalMatters.org
25 February 2020

U.S. ARMY

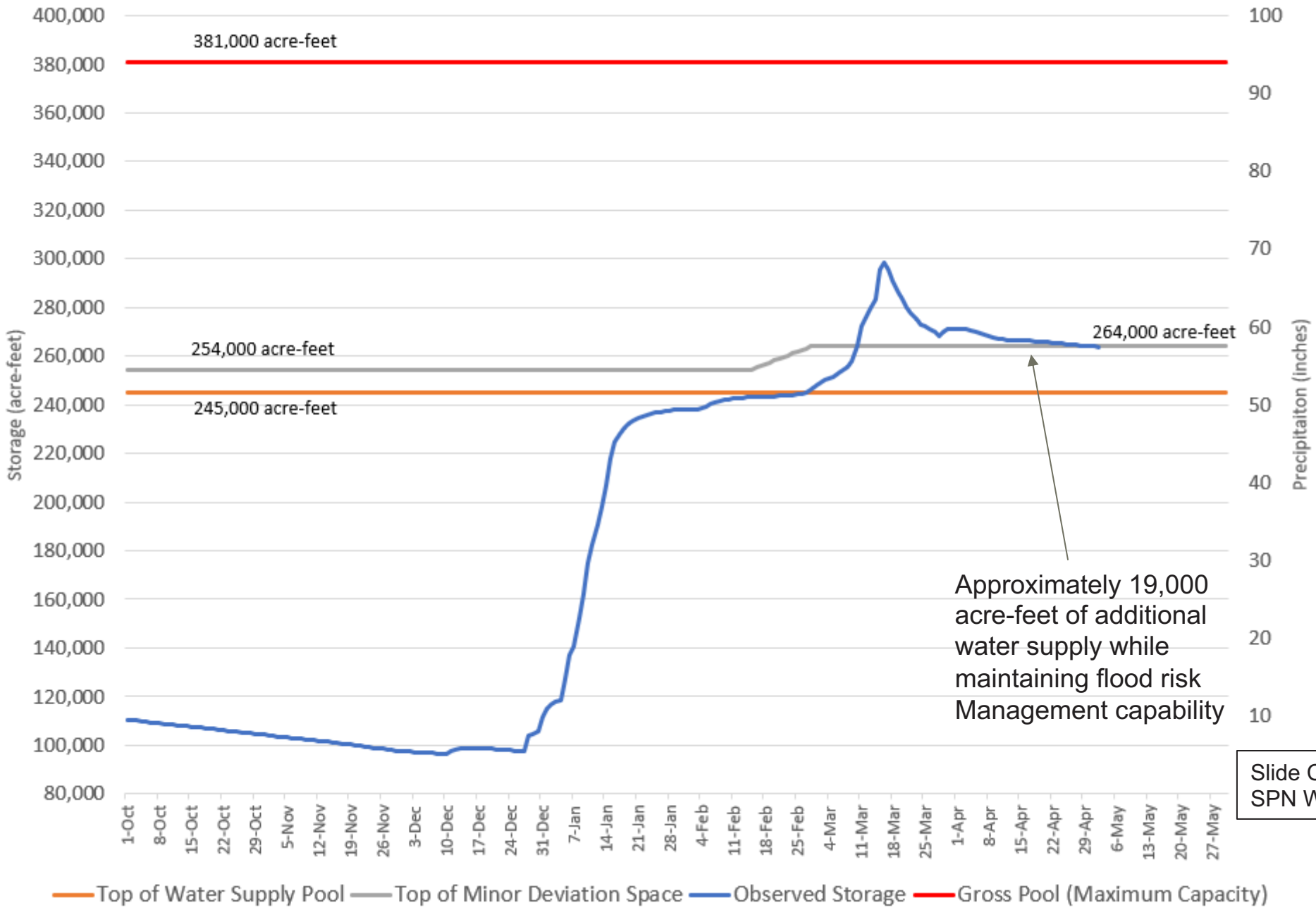
Lake Mendocino Storage for Water Year 2023



Slide Courtesy Patrick Sing
SPN Water Manager

U.S. ARMY

Lake Sonoma Storage for Water Year 2023



Approximately 19,000 acre-feet of additional water supply while maintaining flood risk Management capability

Slide Courtesy Patrick Sing
SPN Water Manager

National Waterways Conference

2023 Annual Meeting

Sacramento, California | October 2–4, 2023

New Bullards Bar Dam and Reservoir

Yuba River Development Project

New Bullards Bar Dam

Log Cabin Dam

New Colgate Powerhouse

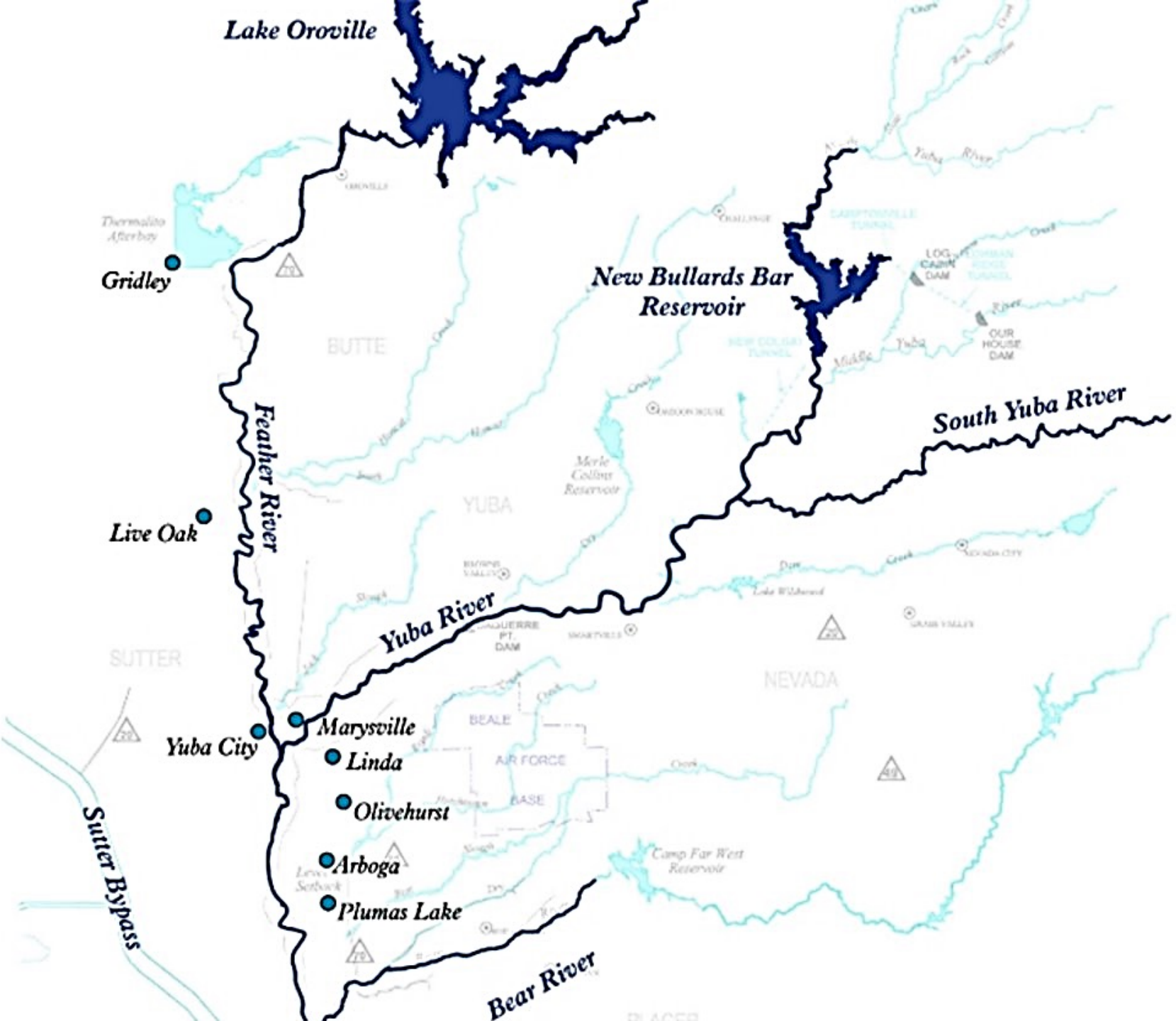
Our House Dam

New Bullards Bar is part of a larger project that reduces flood risk, ensures reliable water supplies and generates hydropower

Yuba Water's hydropower revenue is invested back into Yuba County communities

YUBA WATER AGENCY

Yuba-Feather River System



YUBA WATER AGENCY