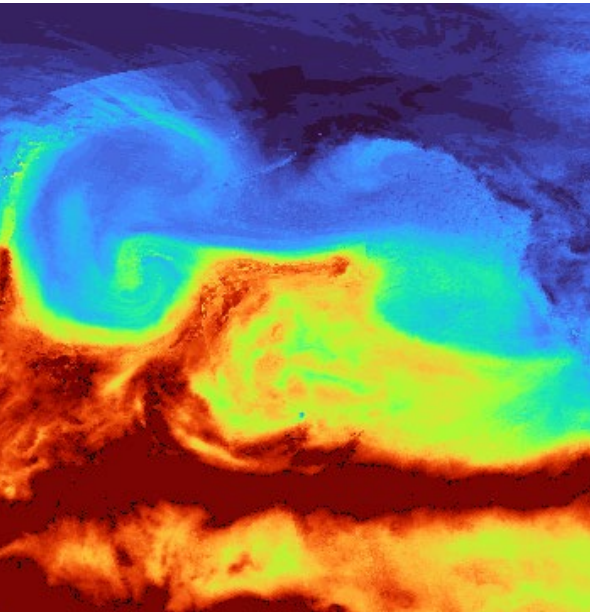
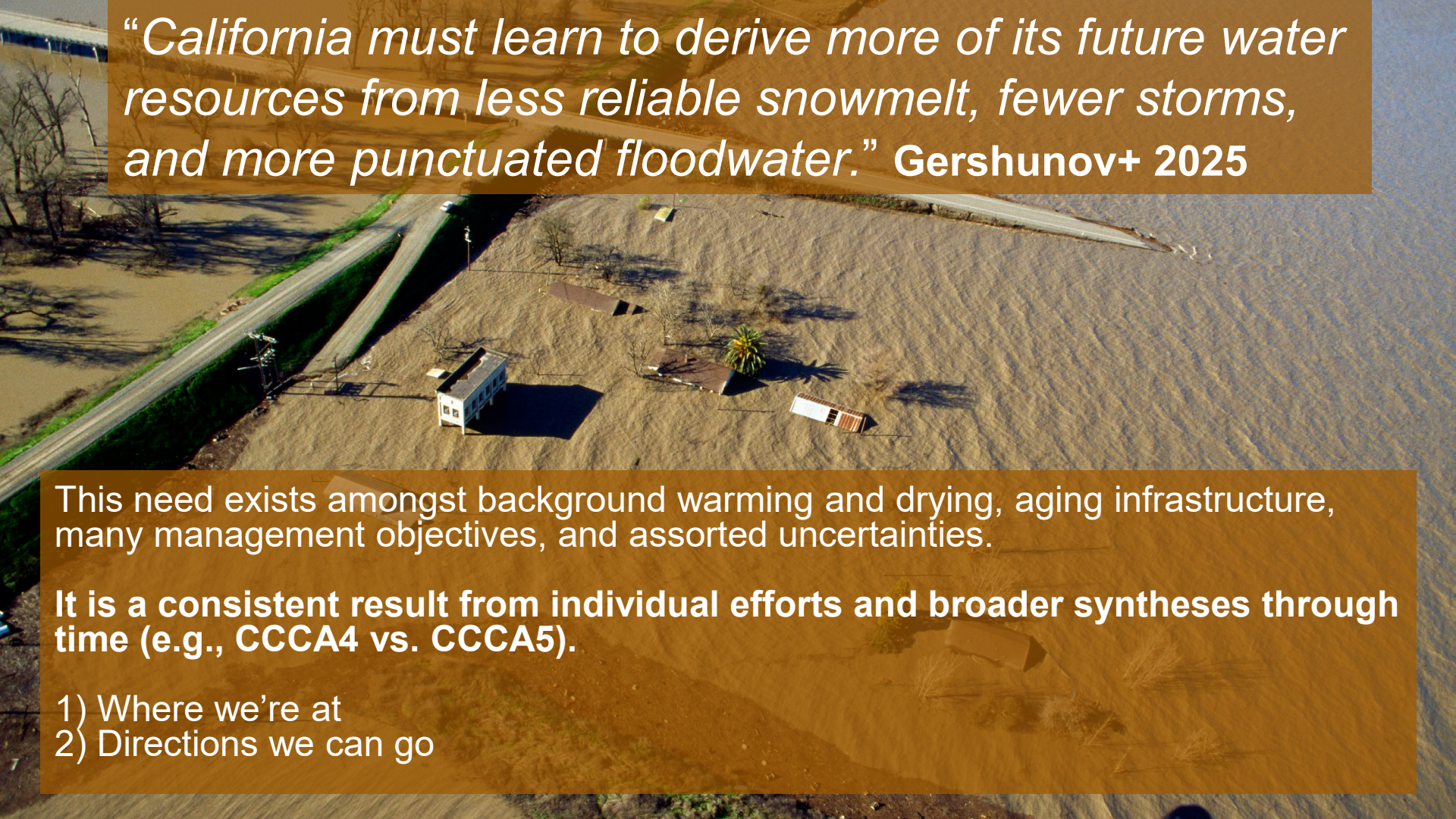


Atmospheric Rivers and Floods in California's Changing Hydroclimate

Presented by: Benjamin Hatchett, Colorado State University
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Alexander Gershunov¹, Benjamin Hatchett², Alexander Weyant¹, Michael Dettinger¹, Lu Su¹, Alan Rhoades³, Park Williams⁴, Michael Anderson⁵, Pamela Rittelmeyer⁶, Dennis Lettenmayer⁴, Daniel Cayan¹, Rosa Luna Niño¹, Kristen Guirguis¹, Tom Corringham¹, Romain Maendly⁵, F. Martin Ralph¹



An aerial photograph showing a flooded landscape. A road runs along the left side, with a green embankment. Several buildings, including a white house and a smaller structure, are partially submerged in the brown floodwater. A palm tree stands near one of the buildings. The background shows more trees and a distant road.

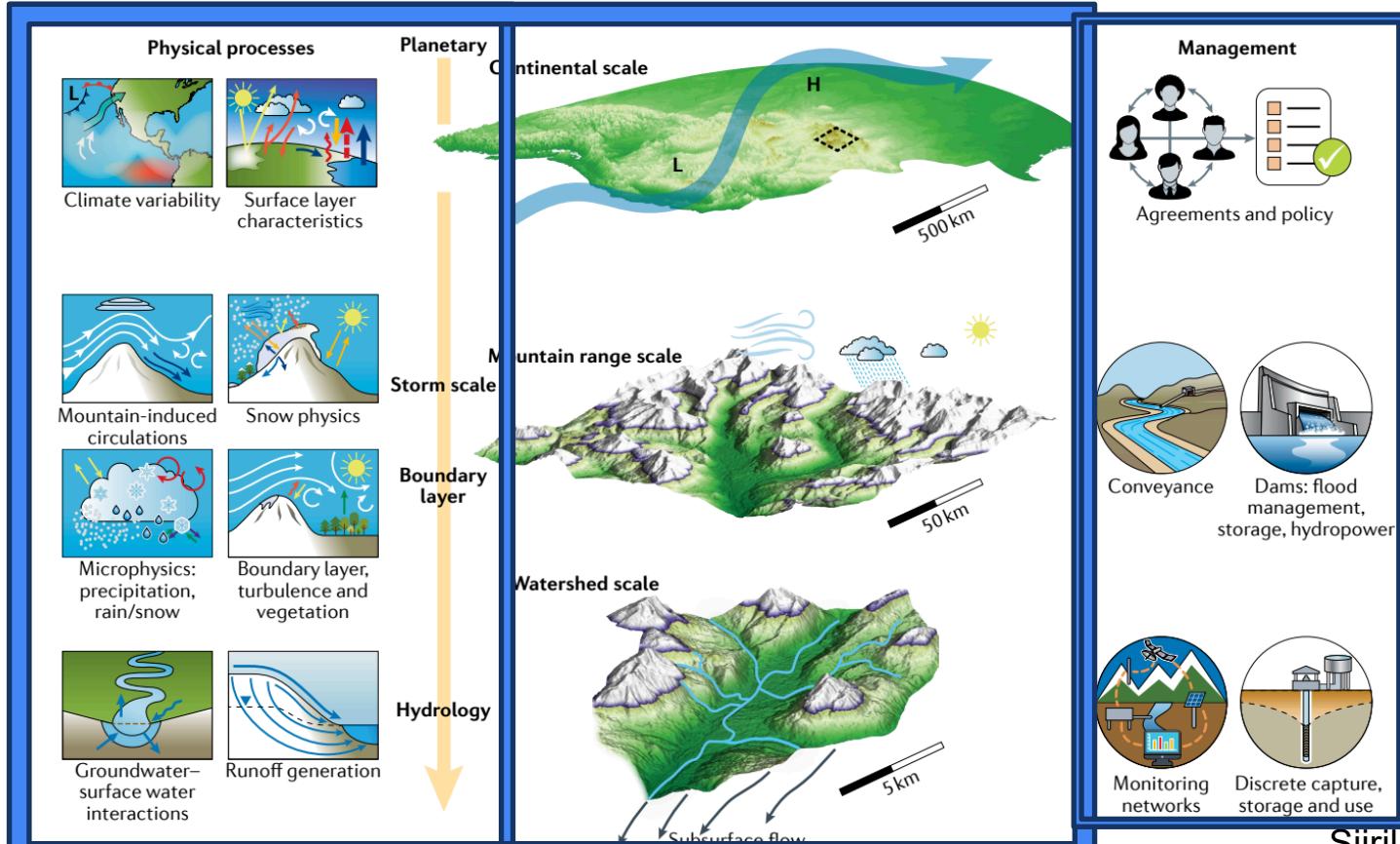
“California must learn to derive more of its future water resources from less reliable snowmelt, fewer storms, and more punctuated floodwater.” Gershunov+ 2025

This need exists amongst background warming and drying, aging infrastructure, many management objectives, and assorted uncertainties.

It is a consistent result from individual efforts and broader syntheses through time (e.g., CCCA4 vs. CCCA5).

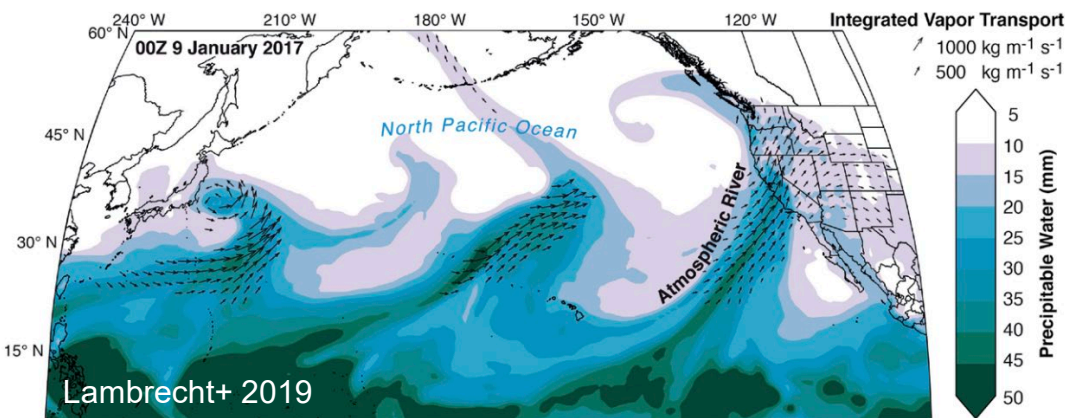
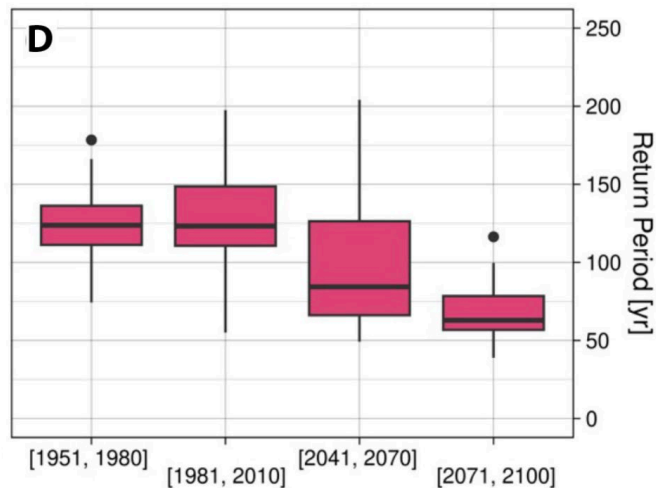
- 1) Where we're at
- 2) Directions we can go

Major Modeling Improvements: Physics, Resolution, and Tactics (Storylines)



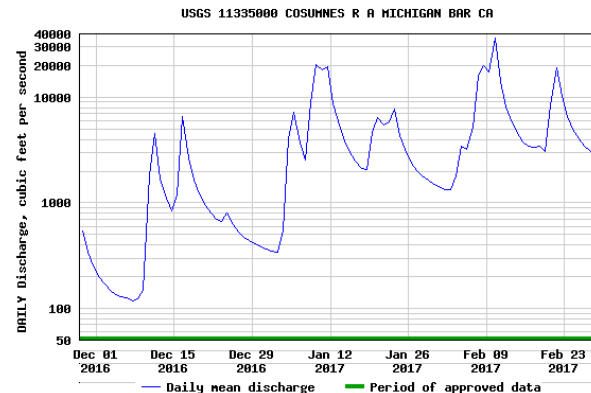
1) Expect **fewer but more intense storms**, potentially with greater **clustering** → (generally) **increased runoff**

Approximate **doubling in likelihood** of 1997 storm total precip (14 models; Gershunov+ 2025)



Sequential storm events (e.g., 1997, 2021, 2017 and 2023) most problematic (e.g., Haleakala+ 2022; Rhoades+ 2023)

Projections suggest **increases in sequential events** (Bowers+ 2023, Zhou+ 2024), but definitions and timescales vary (e.g., from 'active periods' (<14 days) to seasonal (90 days))



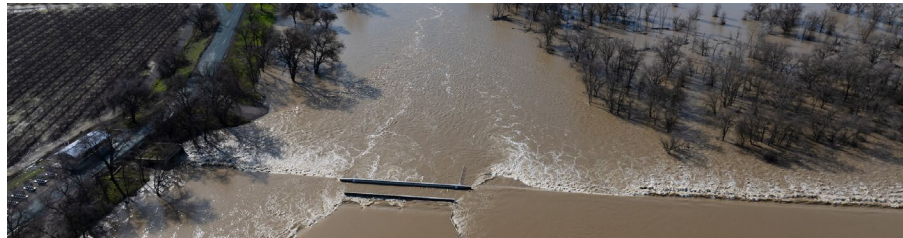
2) Storms become **increasingly warm** (more rain, less snow) and potentially more efficient at runoff generation

“...Increasingly managing storms as a hazard rather than a resource” -Mike Anderson, CA DWR

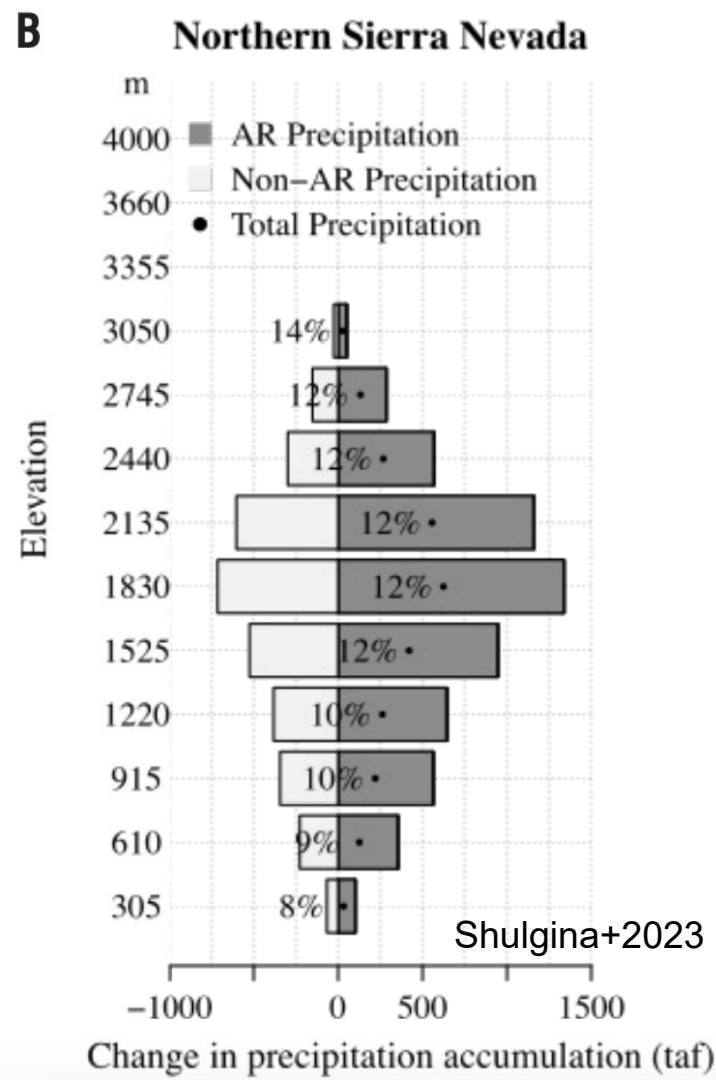
Now in “peak rain-on-snow” (Heggli+ 2023): warming storms but potential for historic snowpacks → increased ROS flood potential

Shulgina+ 2023: Projections for continued warming (snow→ rain) and increase in AR-derived precipitation (~12% during cool season).

“Beyond 2050, 1.5 million acre-feet of snow-water-equivalent (SWE) ‘lost’ in an average year” → water realized as mid-winter runoff

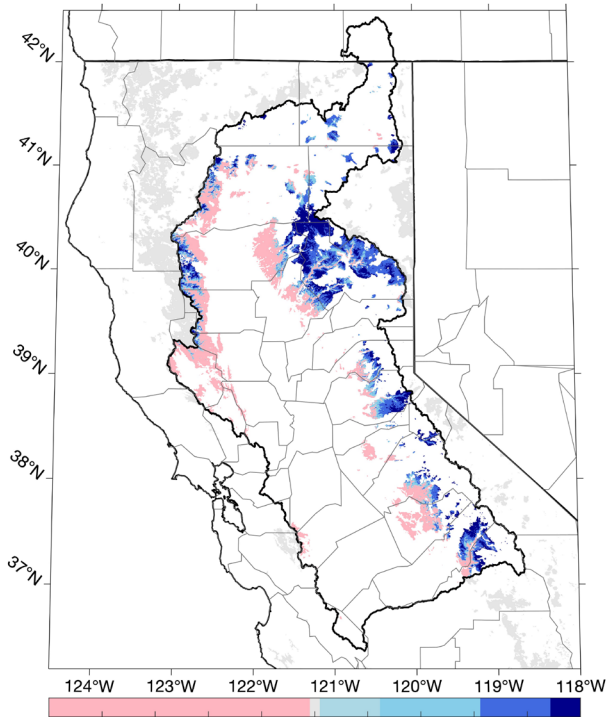


CA
DWR



3) “State of the Headwaters” abruptly changing

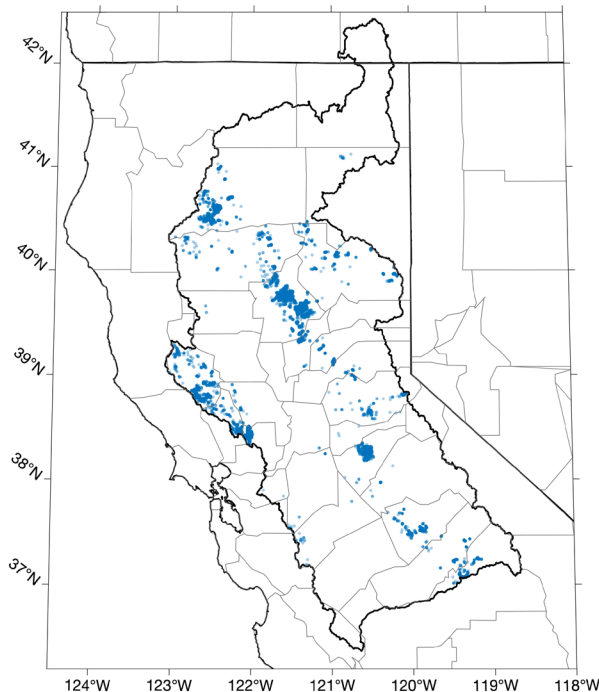
Increasing fire activity in snow-dominated watersheds (blue/pink)



Ephemeral
Snow

Seasonal
Snowpacks

Fires affect more than just
the headwaters...

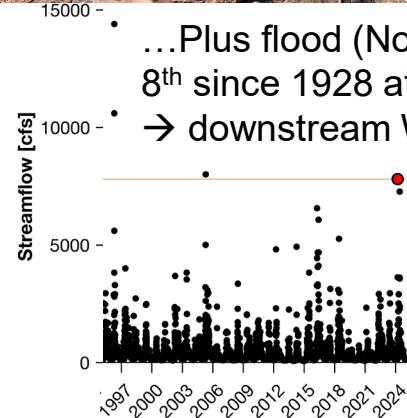


**48% of CA structures lost since
2013 upstream of freshwater Delta**

Too much high severity fire...



...Plus flood (Nov 2024
8th since 1928 at Mill Crk)
→ downstream WQ?



Planning and Operationally-Relevant Progress: Physical Science

Moving into nuance and towards system-wide understanding

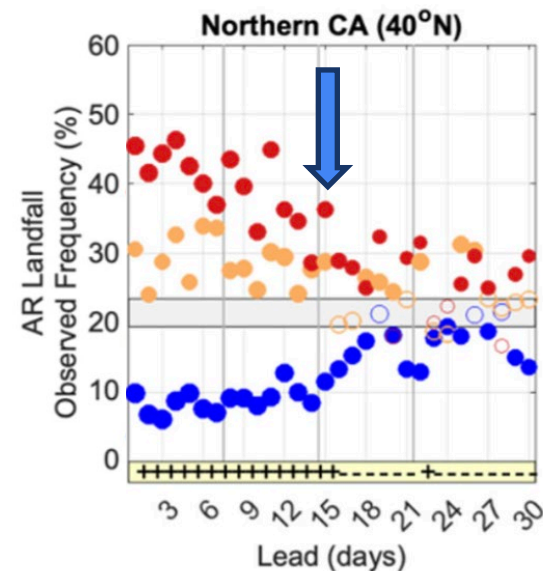
- Need for integrated (coupled GW-SW) hydrologic models and other quantitative, comprehensive ecosystem adaptive management experiments

- What are AR/Flood implications for groundwater?

(e.g., Siirilia-Woodburn+ 2024)

- Subseasonal forecasts of AR activity** (Guirguis+ 2023)

Guidance into weeks 2-3 improving...



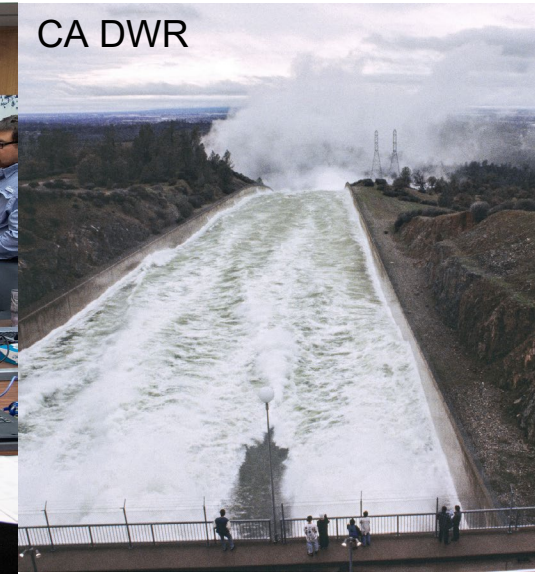
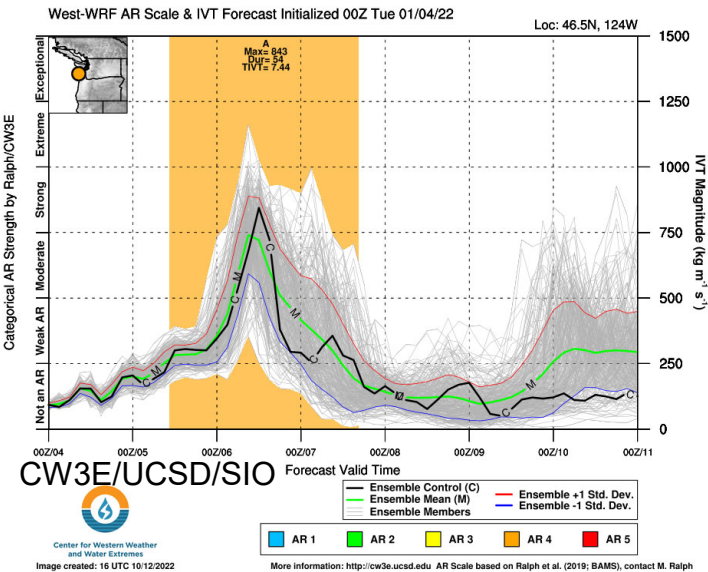
Planning and Operationally-Relevant Progress: Social Science

Techniques to assess, evaluate, and improve of knowledge sharing, decision-making, and interagency partnerships throughout the hazard management cycle

Requires: Time + Communication

Cooperation
Coordination
Collaboration
Coproduct(?)

Goal: Multi-benefit Outcomes



Remark: Maintaining and expanding observational networks is paramount for monitoring, verification, and measuring success of adaptation to changing storms/floods

→What is changing (or not)? How fast? Where?

→Are interventions/management actions meeting objectives?

→After Action Review approach: What worked well, what didn't work well, what to do better?

Continue centennial-scale records (wx+climate data, streamflow, sea level)

Continue 'contemporary' (multi-decadal) records (satellites, NOAA/DWR networks, soil moisture, snowpack; Hatchett+ 2020)

Develop new datasets (citizen/community science, remote sensing)

→ Motivates broader community engagement, builds support for science and management, shows multiple needs can be met

Report back! (Collins+ 2025, DWR 2022)

Spotlights

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