Western U.S. water prediction through the lens of hydrology: Examples and opportunities

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ACGI Workshop: When the Rain Stops: Drought on Subseasonal and Longer Timescales
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Outline

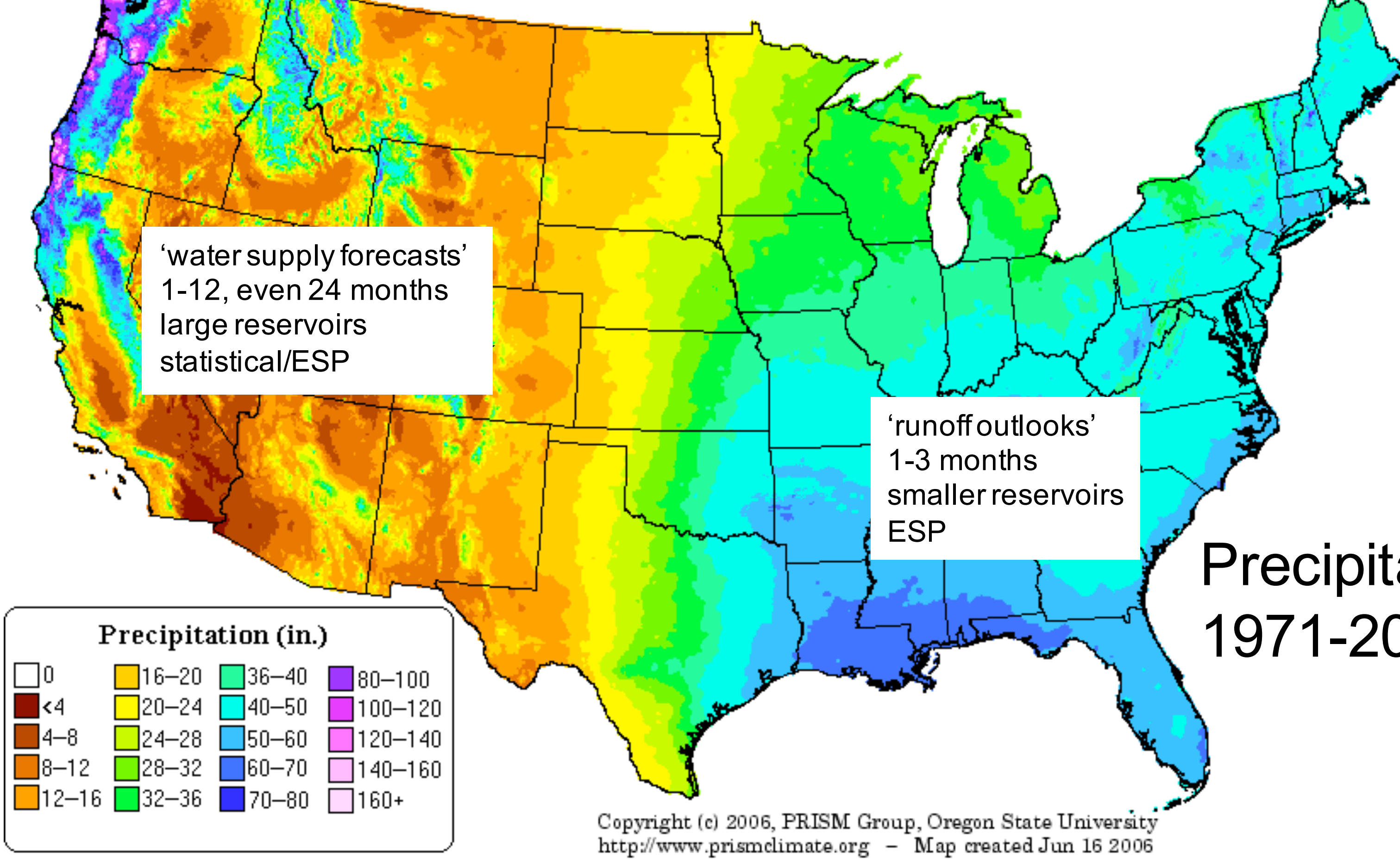
- Case Studies / Anecdotes
- Predictability
- Opportunities
- Focus on conditionality

The Arid Lands

Many droughts will occur; many seasons in a long series will be fruitless; and it may be doubted whether, on the whole, agriculture will prove remunerative.

John Wesley Powell, 1879

Report on the lands of the arid region of the United States



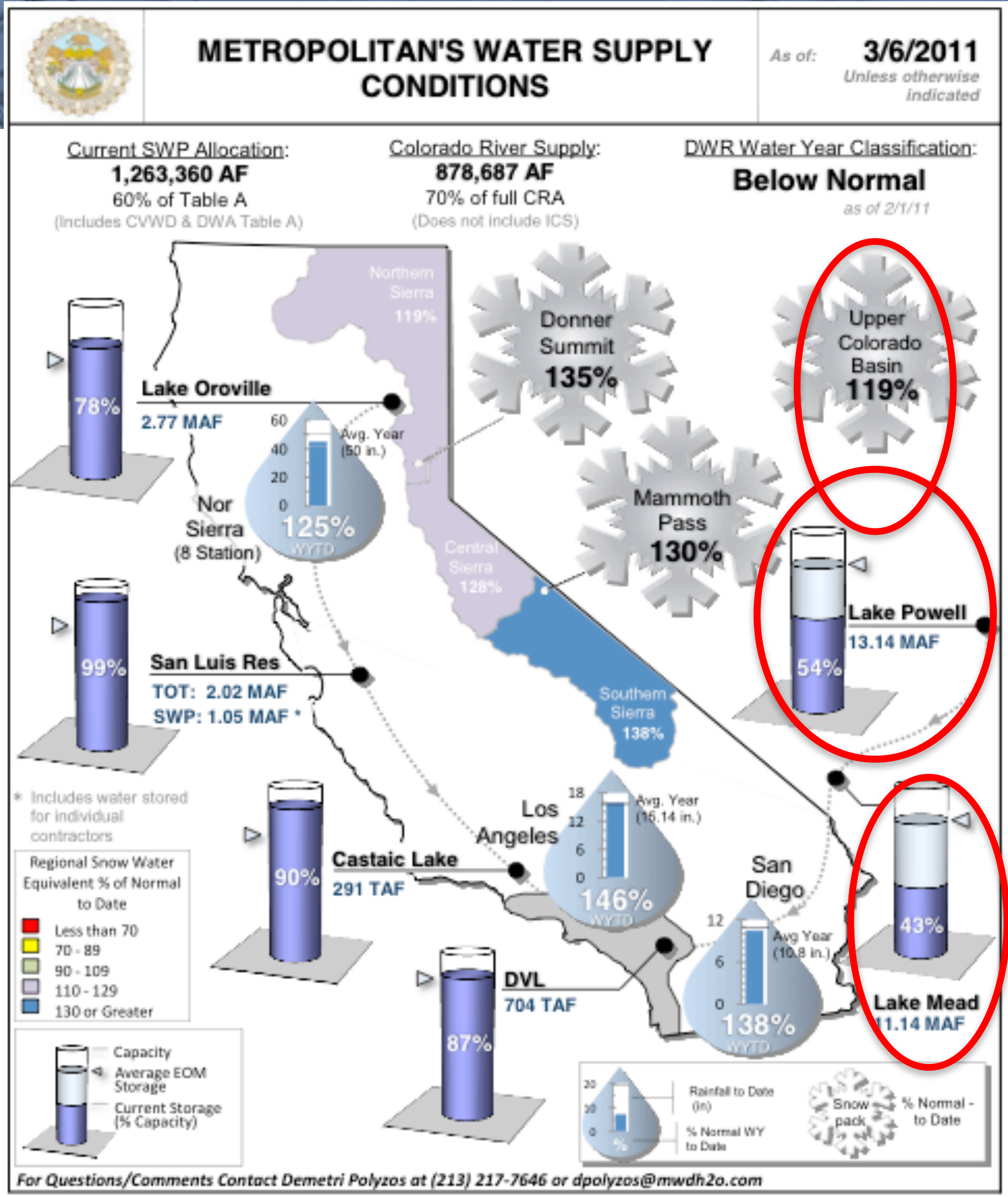
Precipitation, 1971-2000

Colorado River

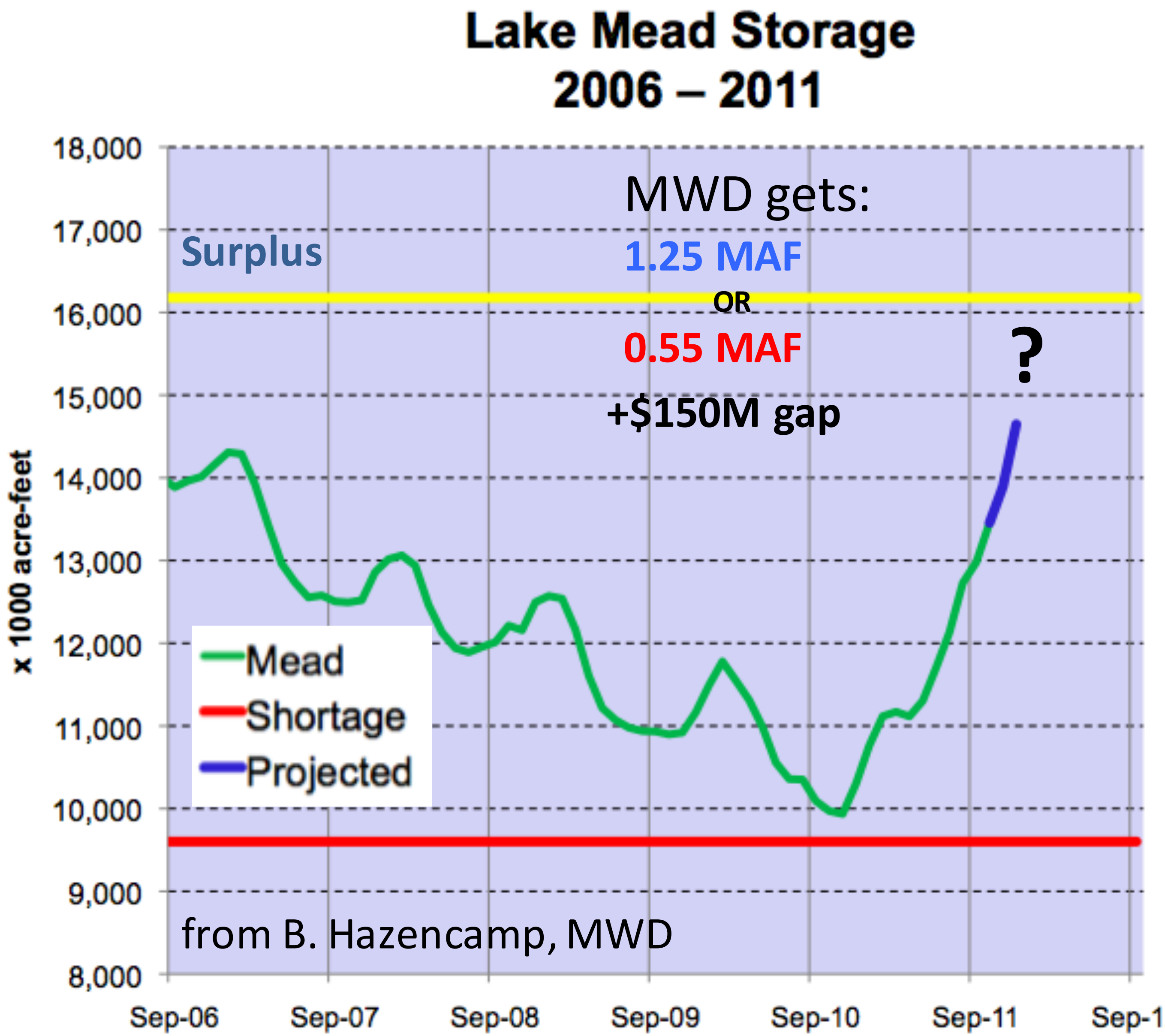
- 25 million people in 7 states rely on Colorado River water
- 3.5 million acres of irrigation
- 85% of runoff comes from above 9000 feet
- Mean annual discharge is … (?)
- Storage capacity is about 60 MAF (4-5 times mean annual flow)

Stakeholder Example

- Metropolitan Water District (California)
  - Supplies water to ~20m residents in southern California (including L.A.)
  - Issues weekly water supply conditions map (right) based on RFC, CA DWR, and NRCS forecasts and data

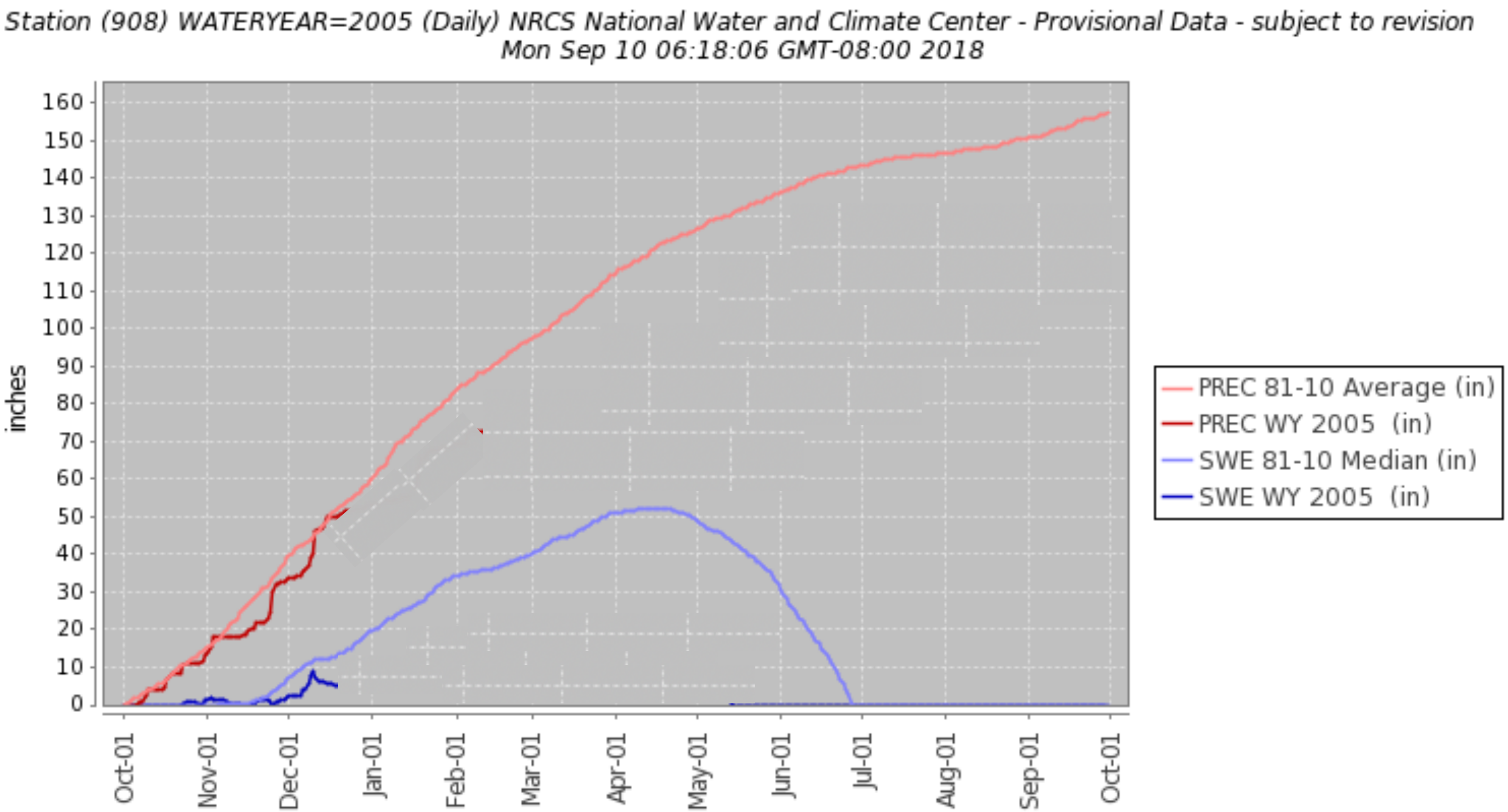


Seasonal streamflow prediction is critical

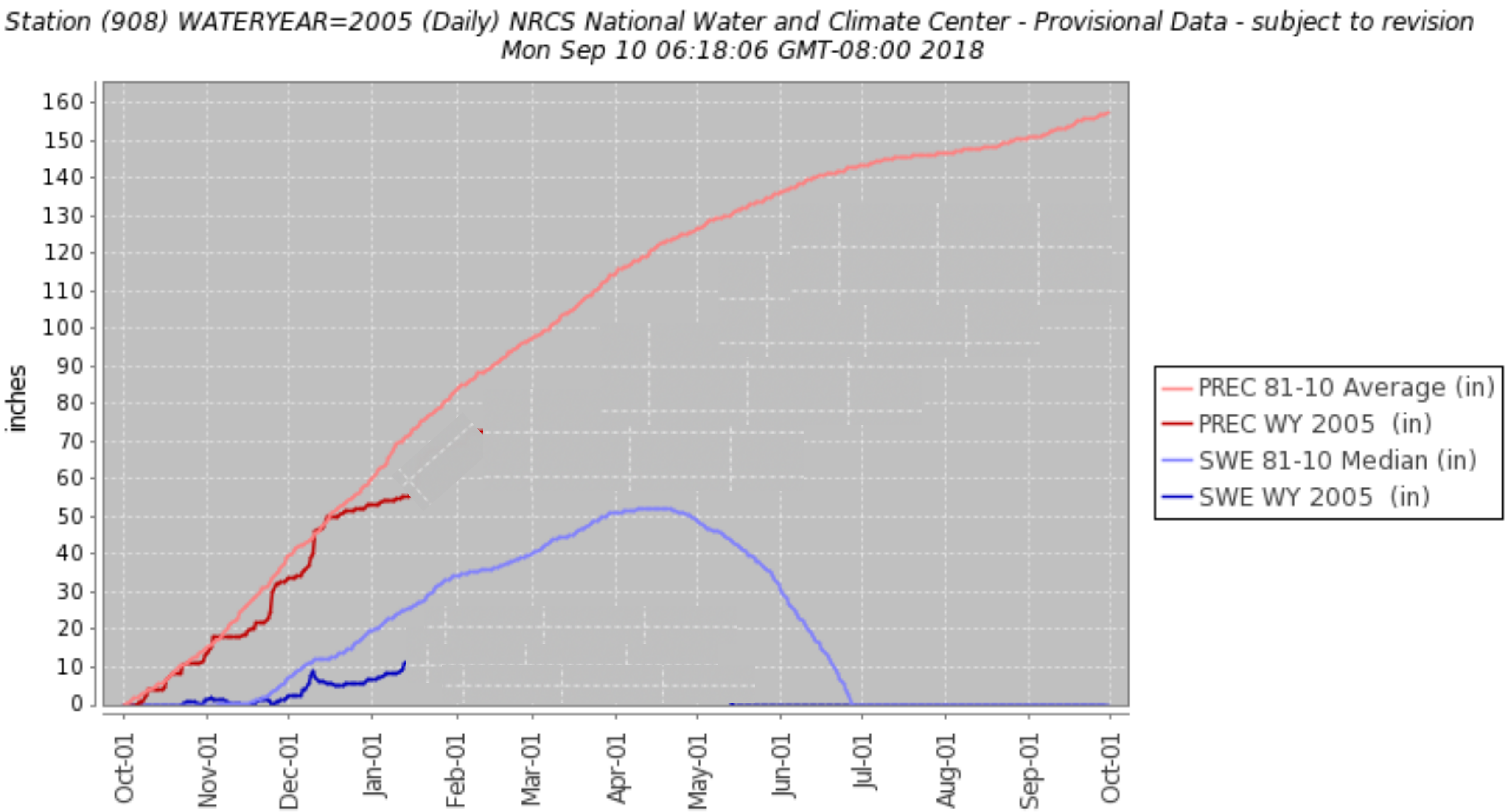


One example:
Met. Water Dist. of S. California (MWD)

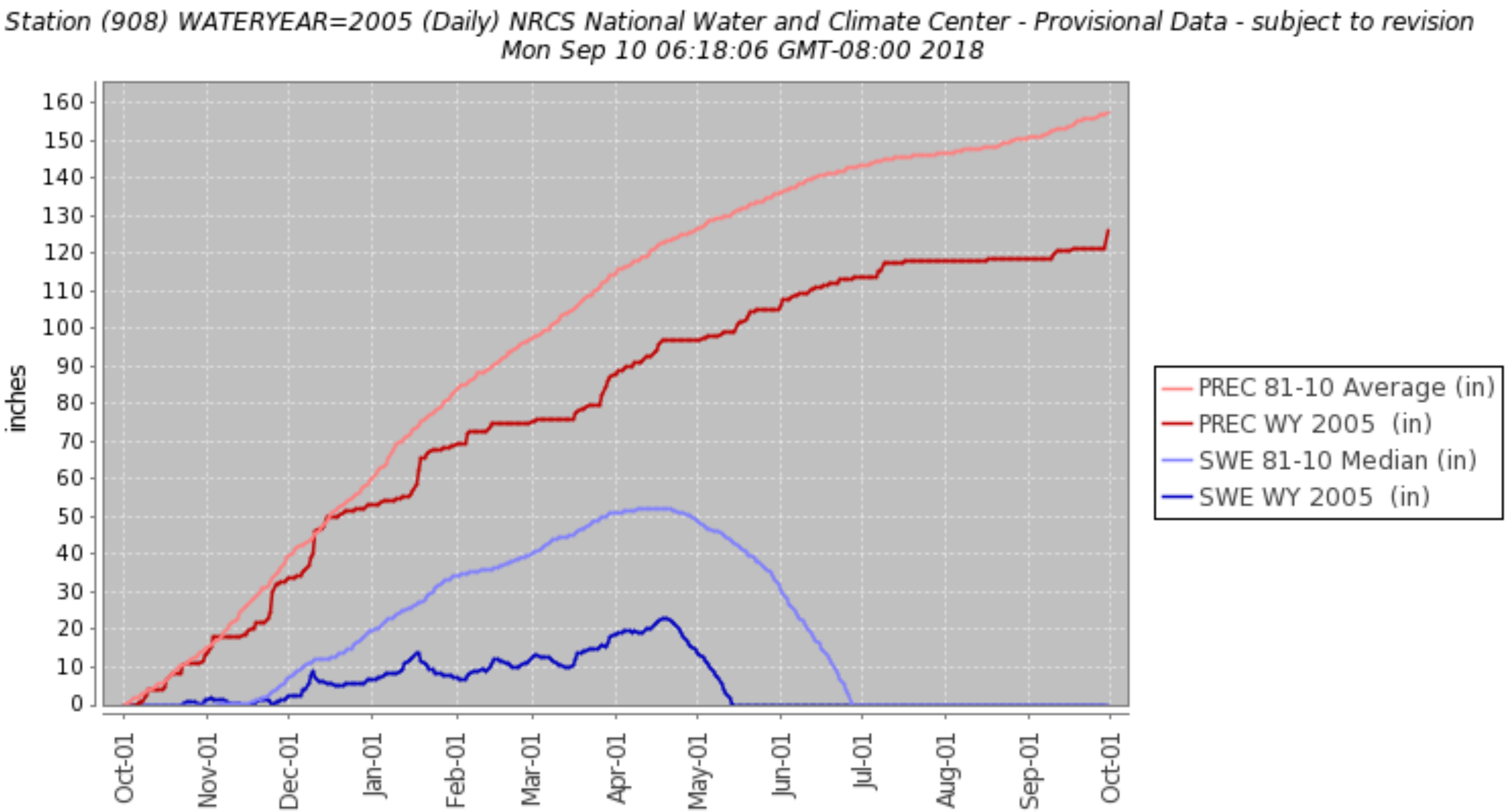
Initial natural system states matter



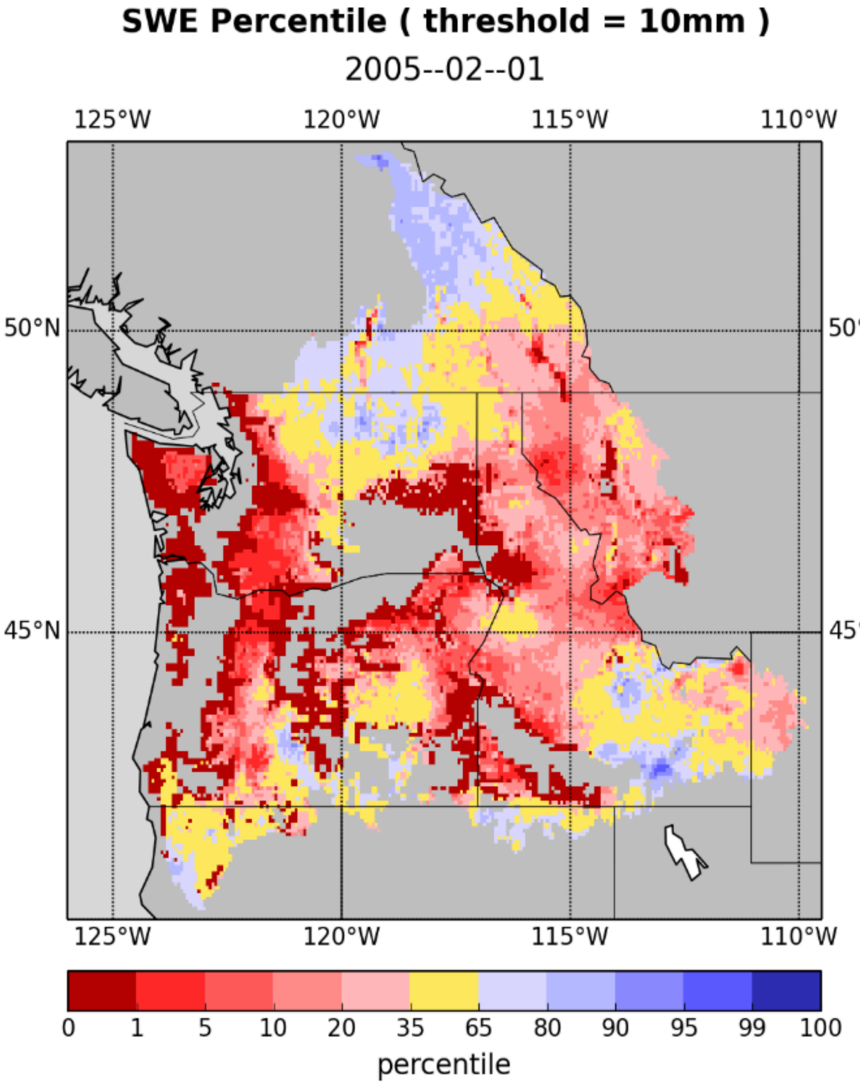
1 month of drying moves system into drought

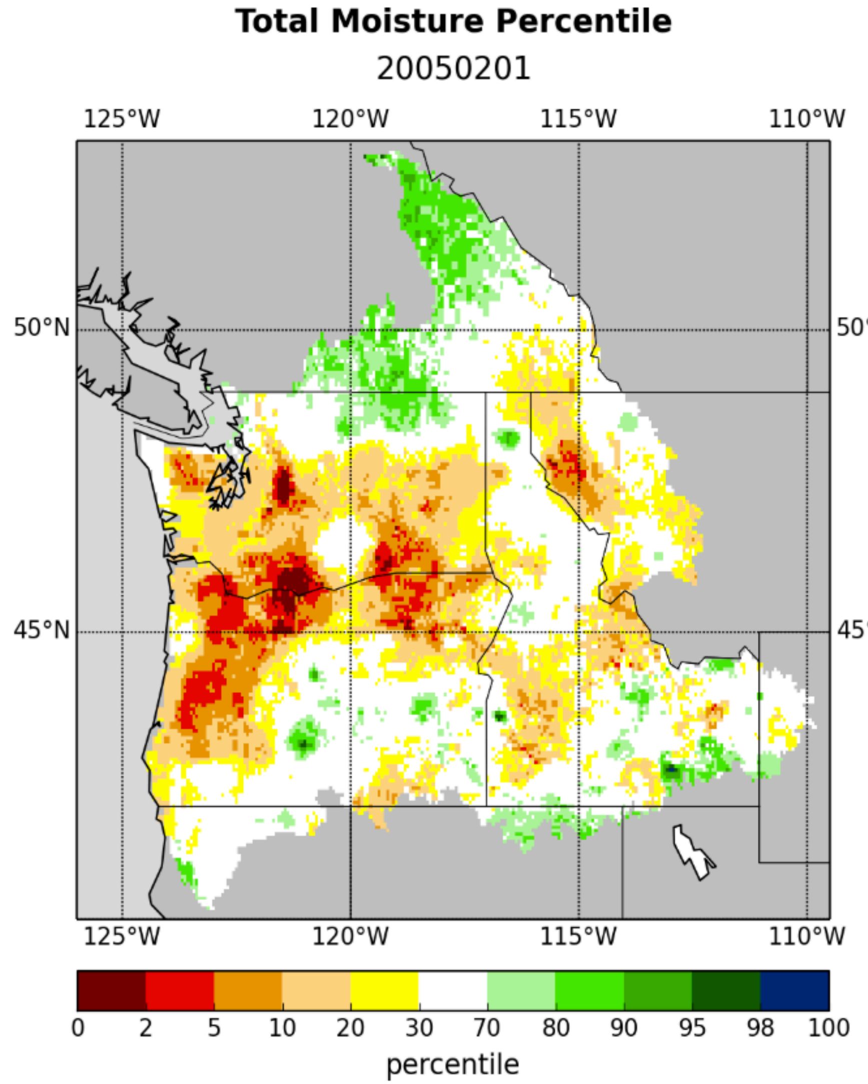


From early deficit, the resource doesn't recover



Stage set for rapid deterioration (~1 month)





from VIC-based modeling systems developed at U. Washington

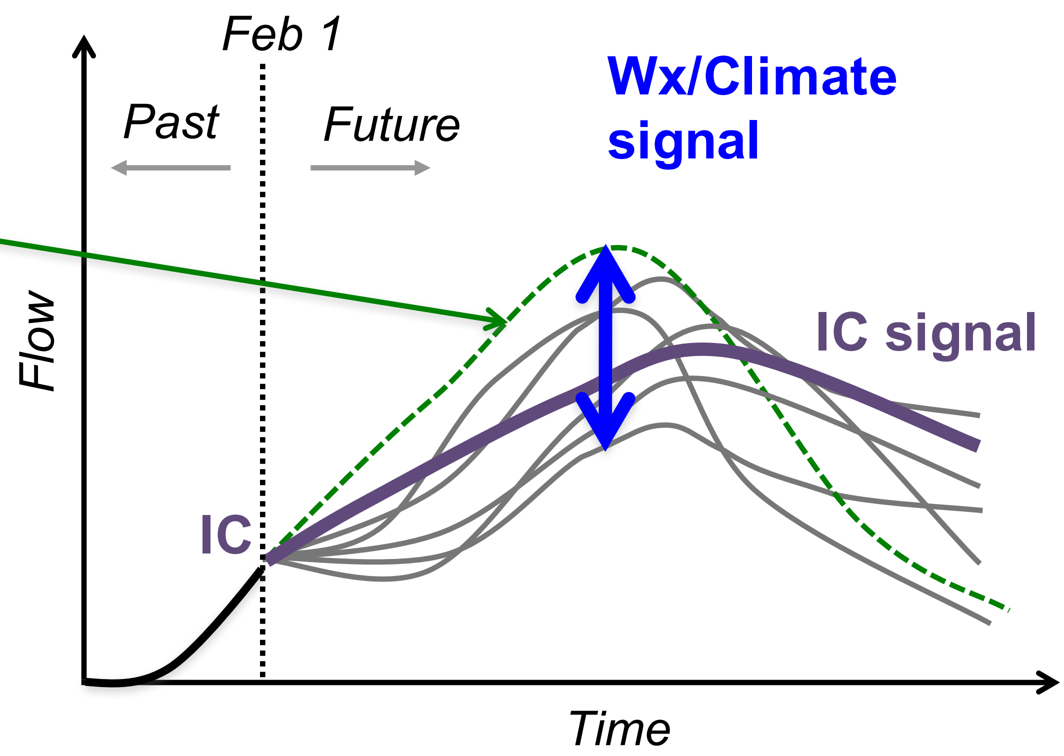
Drought extremes are unfortunately multivariate

Each hydrologic anomaly has a story line. As water year progresses:

- past wx/climate become hydrologic initial conditions and are an increasing part of the plot
- future climate in a prediction is a seasonally varying part of the story
- extremes often involve pattern persistence
- climate variability and may be an explanatory backdrop

e.g., storyline:

- big storm in Feb
- very wet April
- cool May/June

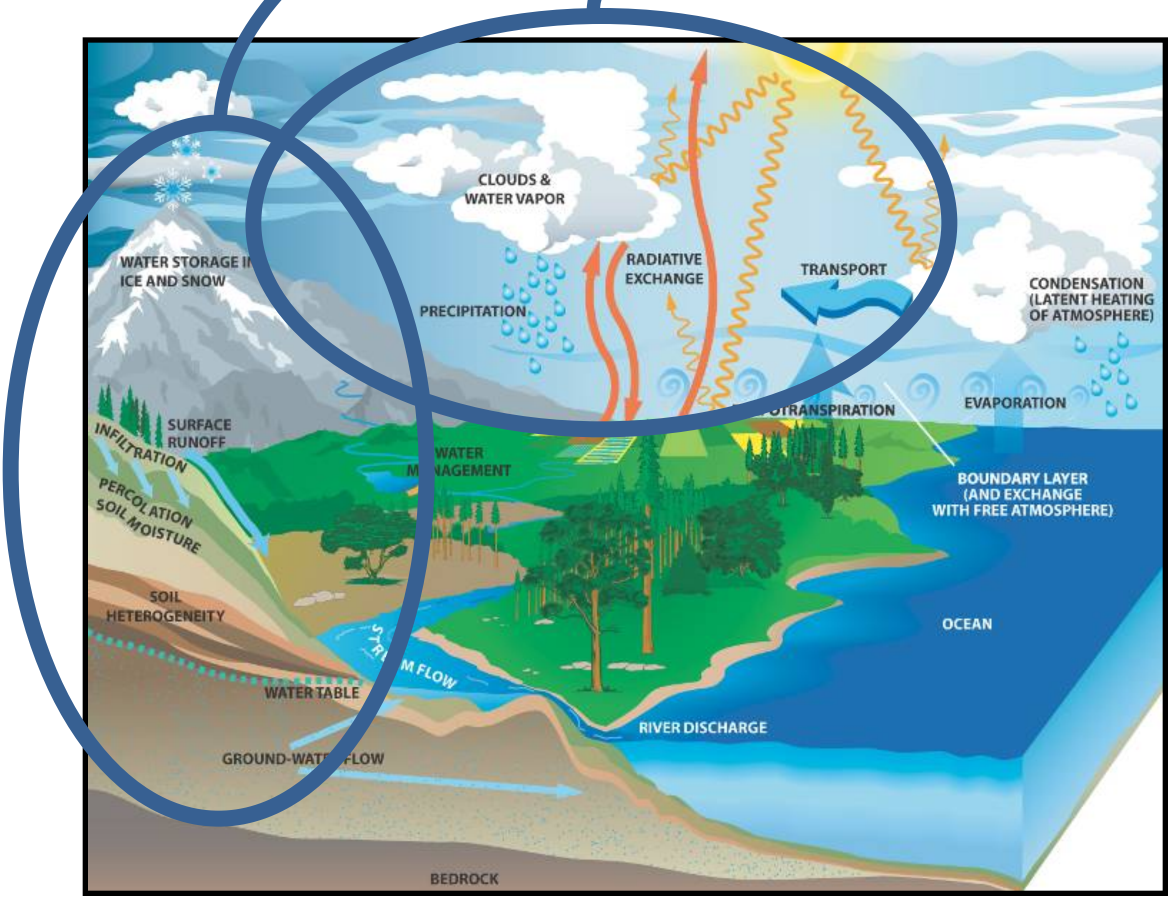


e.g., Wood & Werner, 2011 CDPW

hydrologic prediction science questions

hydrological predictability

meteorological predictability

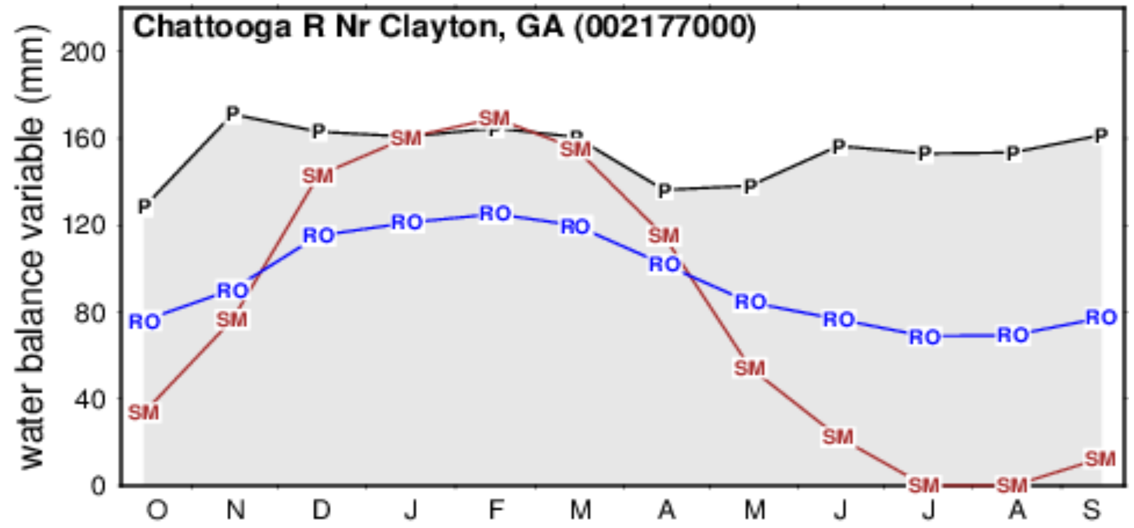


Water Cycle (from NASA)

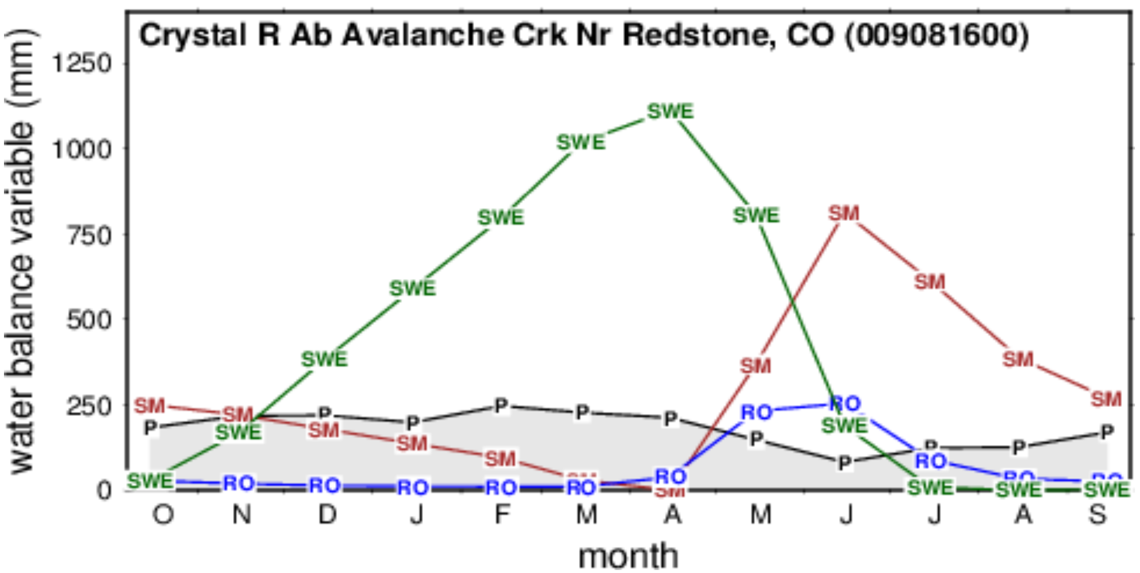
<u>Hydrological Prediction</u>: How well can we estimate catchment moisture dynamics?

<u>Atmospheric predictability</u>: How well can we forecast the weather and climate?

Hydro-climatic/Seasonal Variation in Watershed Moisture



- humid basin
- uniform rainfall
- no snow
- small cycle driven by ET

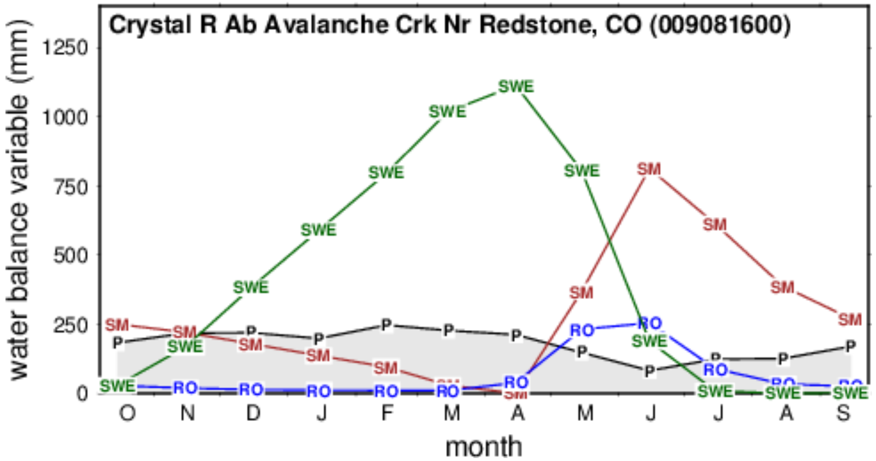


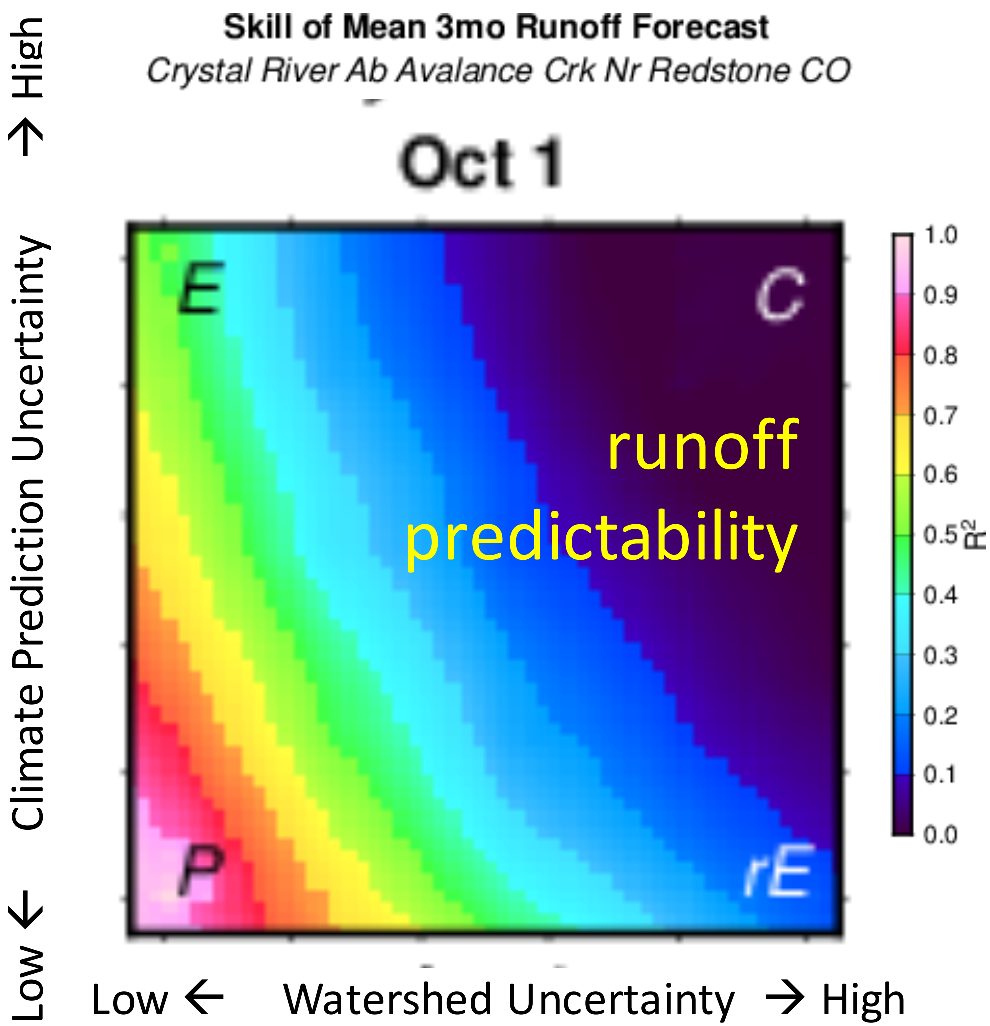
- cold basin
- drier summers
- deep snow
- large seasonal cycle
- April snowmelt dominates May-June runoff

Predictability conditioned by seasonal hydroclimate

Models can be used to understand and quantify sources of predictability

Mean basin hydroclimate

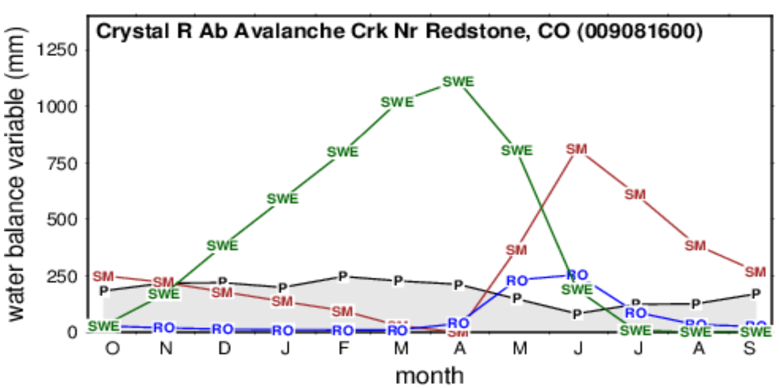


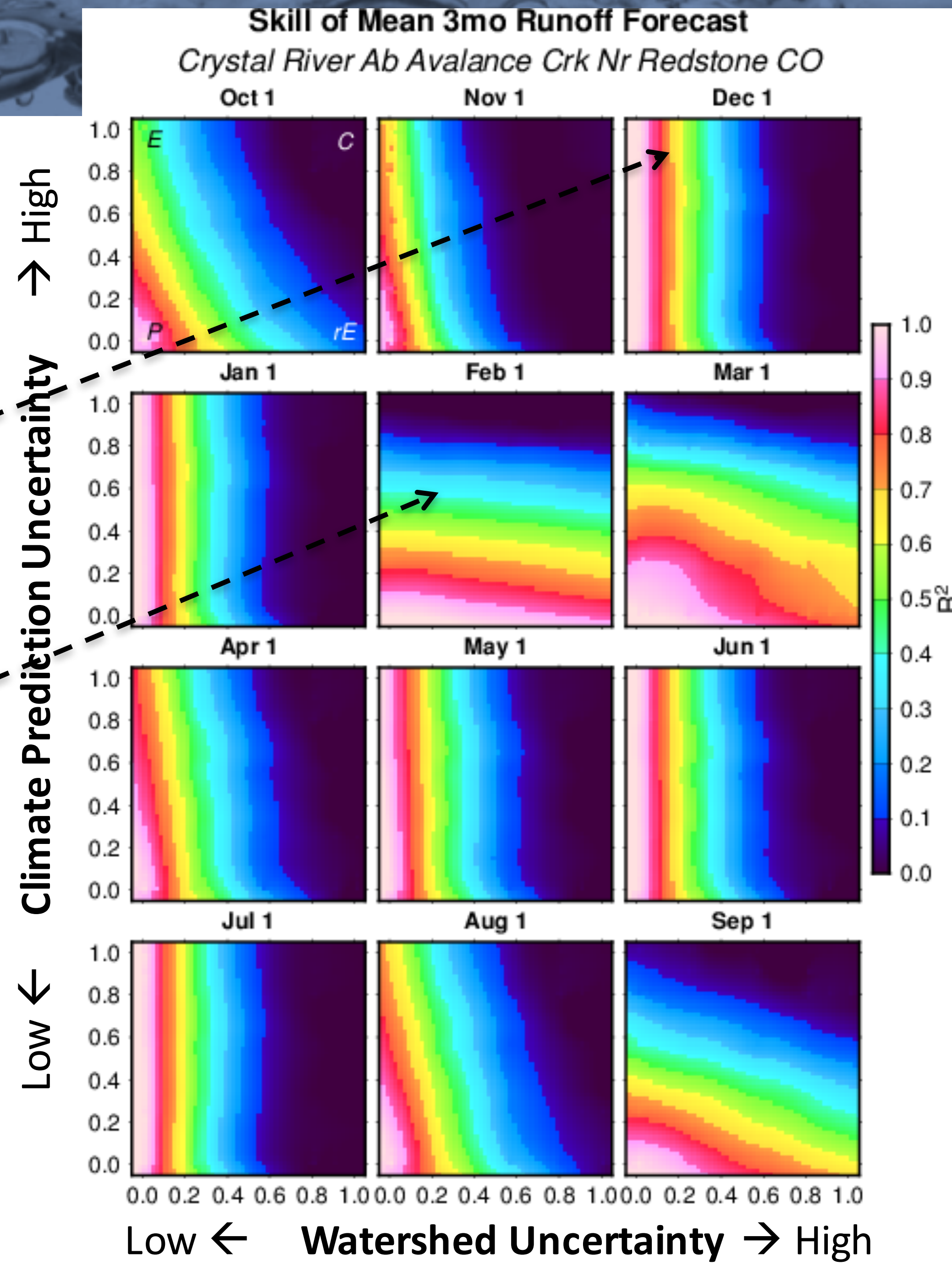


Wood, AW, T Hopson, A Newman, L. Brekke, J. Arnold, M Clark, 2016, Quantifying streamflow forecast skill elasticity to initial condition and climate prediction skill. *J. Hydromet.* **17**, 651–668. doi: http://dx.doi.org/10.1175/JHM-D-14-0213.1

Predictability conditioned by seasonal hydroclimate

- Wide seasonal variations in influence of different skill sources
- cold forecast period (Dec-Feb) -- forecast skill depends mainly on watershed moisture accuracy
- warmer snowmelt forecast period forecast skill depends strongly on climate forecast skill





The urgency of understanding options

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Drought-Hit Sao Paulo Has Two Months of Water Left

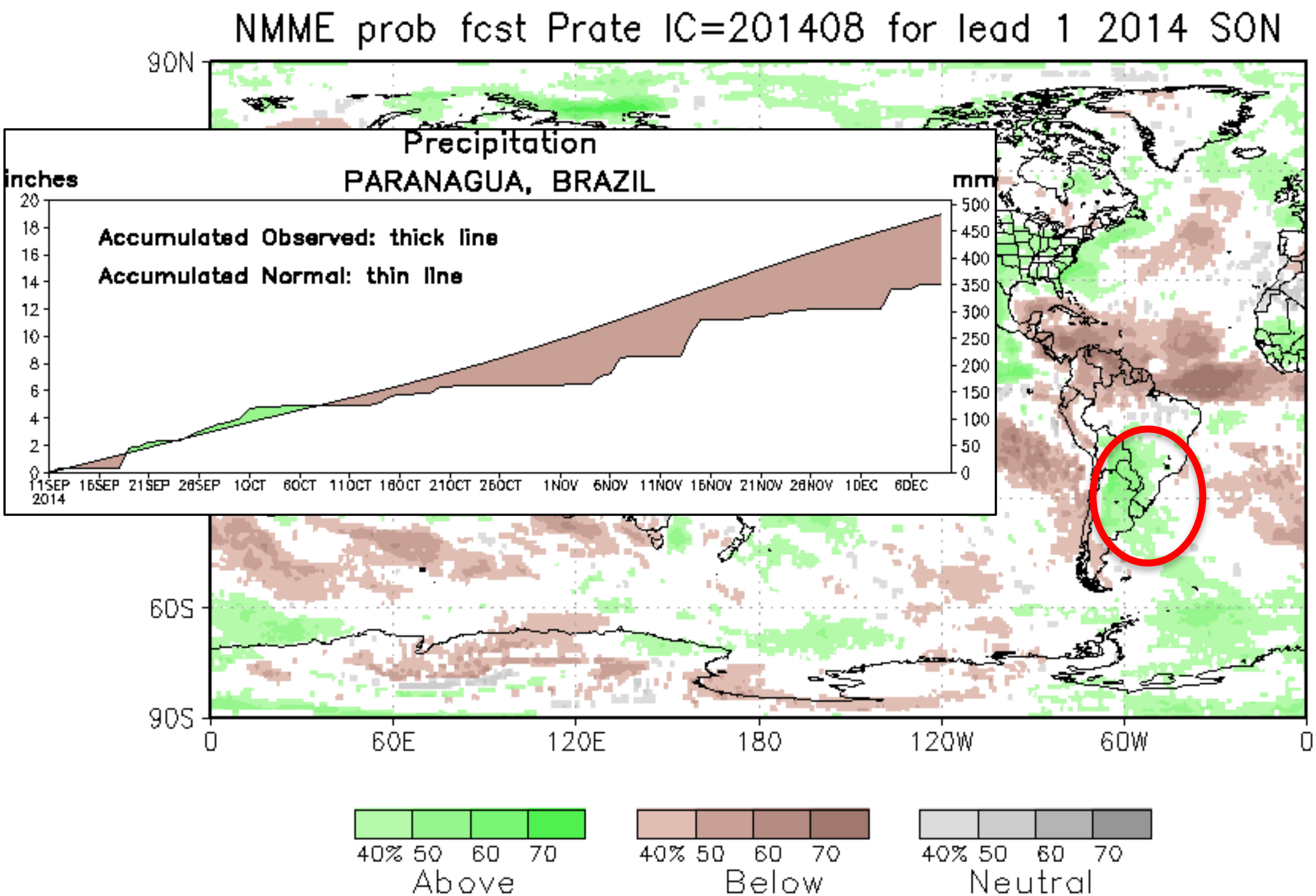
A man looks at the cracked ground of Jaguari dam, part of the Cantareira reservoir in Sao Paulo state, showing record low water levels January 31, 2014. (Photo: Reuters) | Photo: Reuters

Published 8 December 2014

The emergency reserves should last for two months, but water use is also expected to increase during the holiday season.

The urgency of understanding options

NMME forecast for precip (terciles)



Upper Colorado forecast example

- ❑ This forecast verified well for CONUS
- ❑ …but poorly for the upper Colorado R. basin
- ❑ Flow forecasts based on this CFS prediction were worse than using climatology

(from Simon Wang, USU)

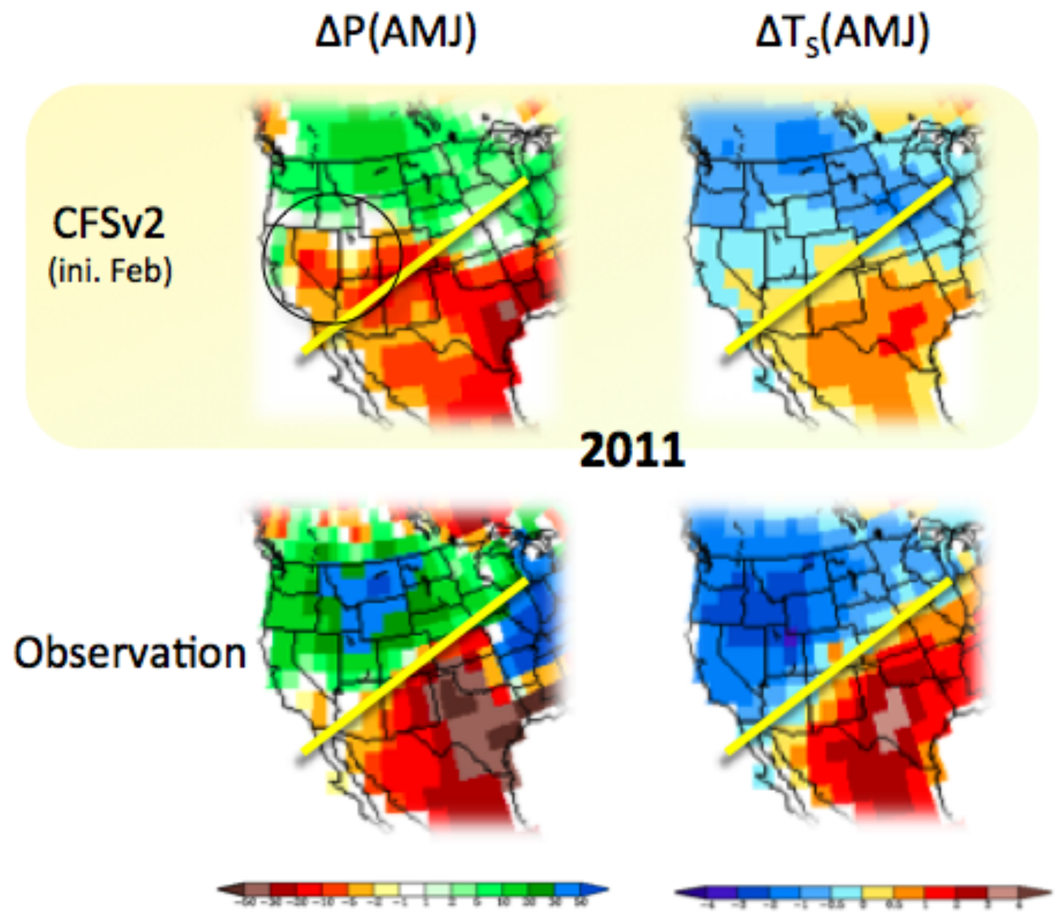


Fig. 1 CFSv2 seasonal precipitation (P) and temperature (T_S) anomaly forecasts from February 2011 and verifying observations. The intermountain West (with low skill) is outlined by black cicle in the upper left panel. ¶

Regional/process specificity is critical

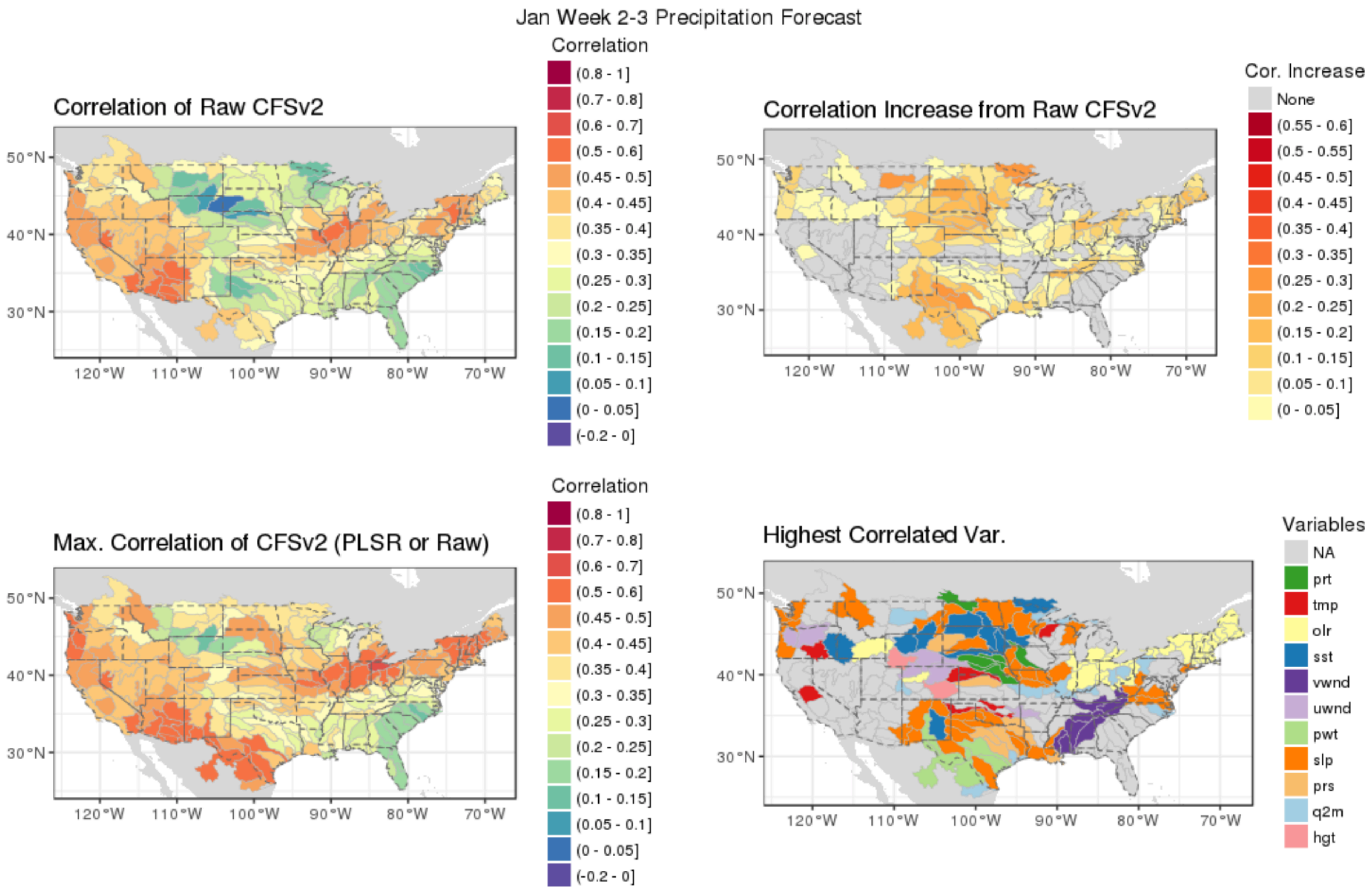
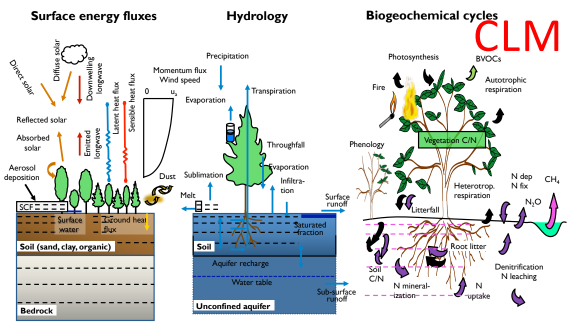


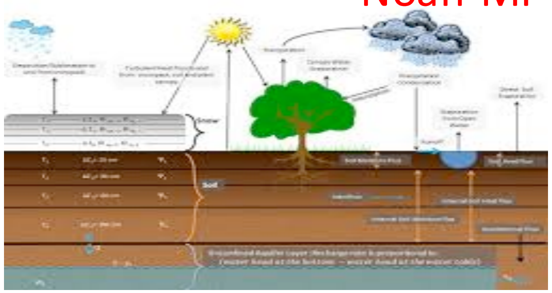
Figure 1: Raw and improved correlation using PLSR with best CFSv2 predictor.

Modeling advances will also help

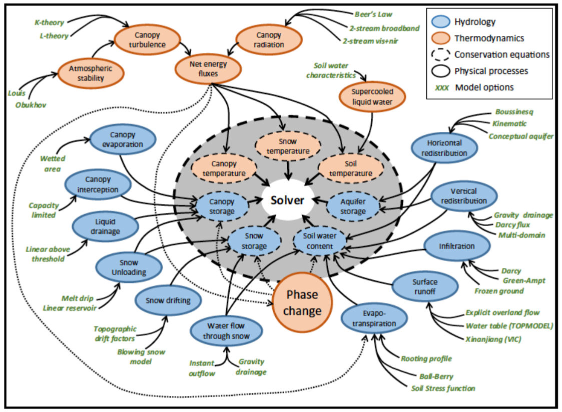
CLM

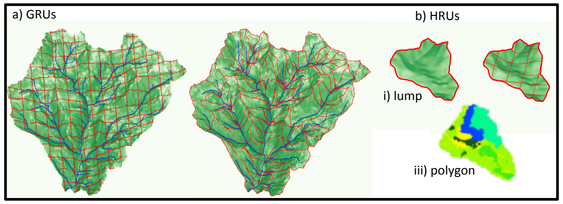


Noah-MP



SUMMA





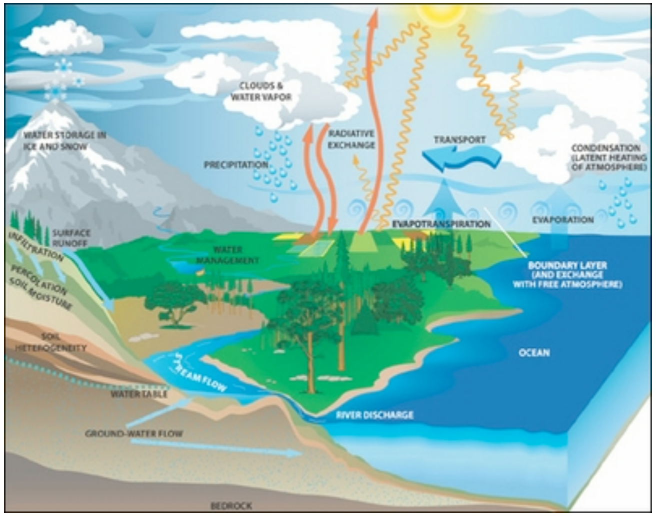
Conceptual basis

- Modelers agree on many aspects of terrestrial system science
- Differences among models relate to
  - ➢ *Flux parameterizations*
  - ➢ *Spatial discretization*
  - ➢ *Numerical solution*

Formulates master model template

- Existing models (*CLM, Noah-MP, WRF-Hydro, etc.*) as a special case
- Flexibility in
  - ➢ *Process representation*
  - ➢ *Spatial architecture*
  - ➢ *Numerical solvers*

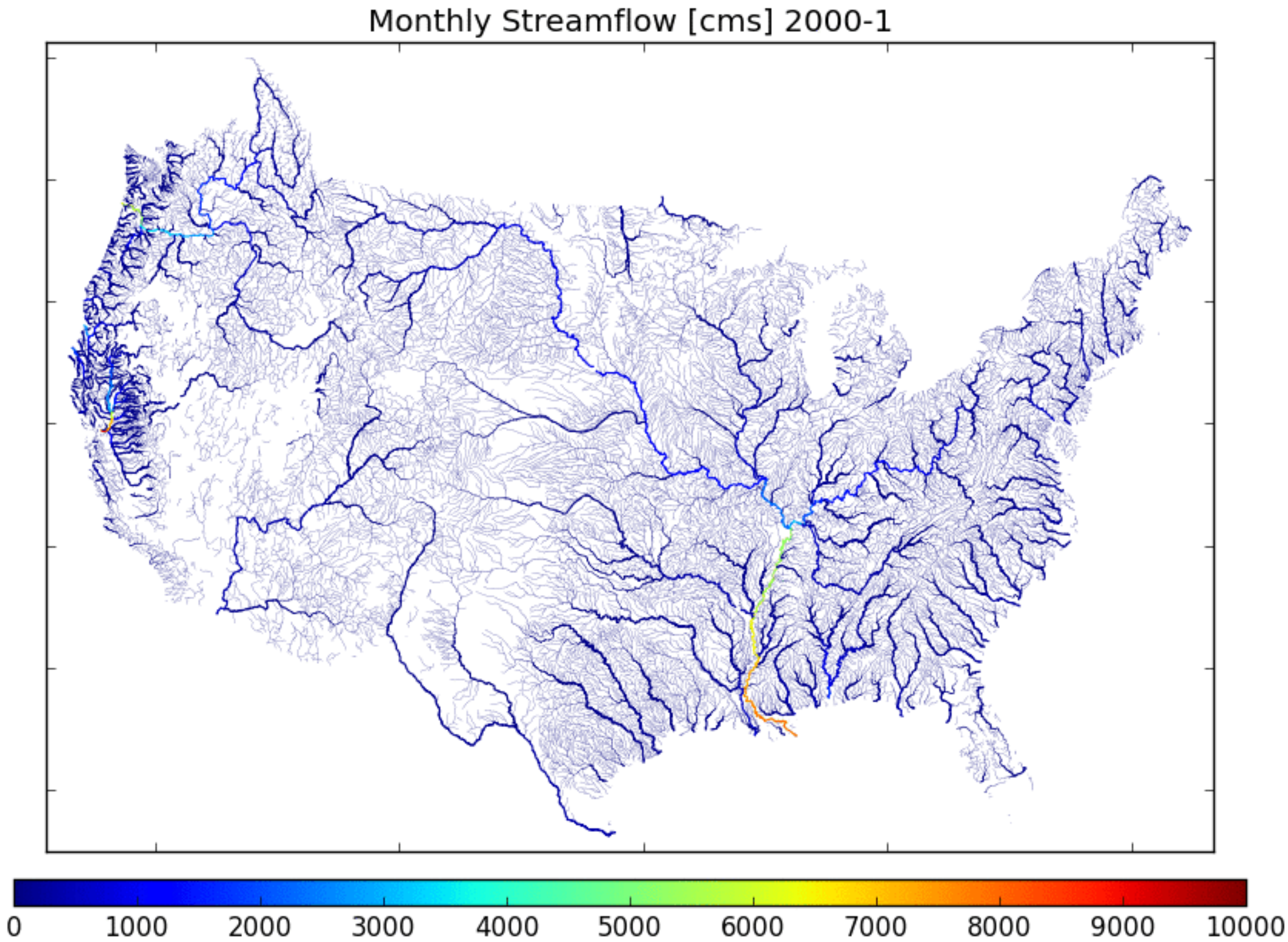
The Community Terrestrial Systems Model (CTSM)



Unifies land models across climate, weather, water, and ecology

- Multiple configurations
- Easy to modify/use
- Centralized support

Increasing convergence of land modeling and hydrology communities

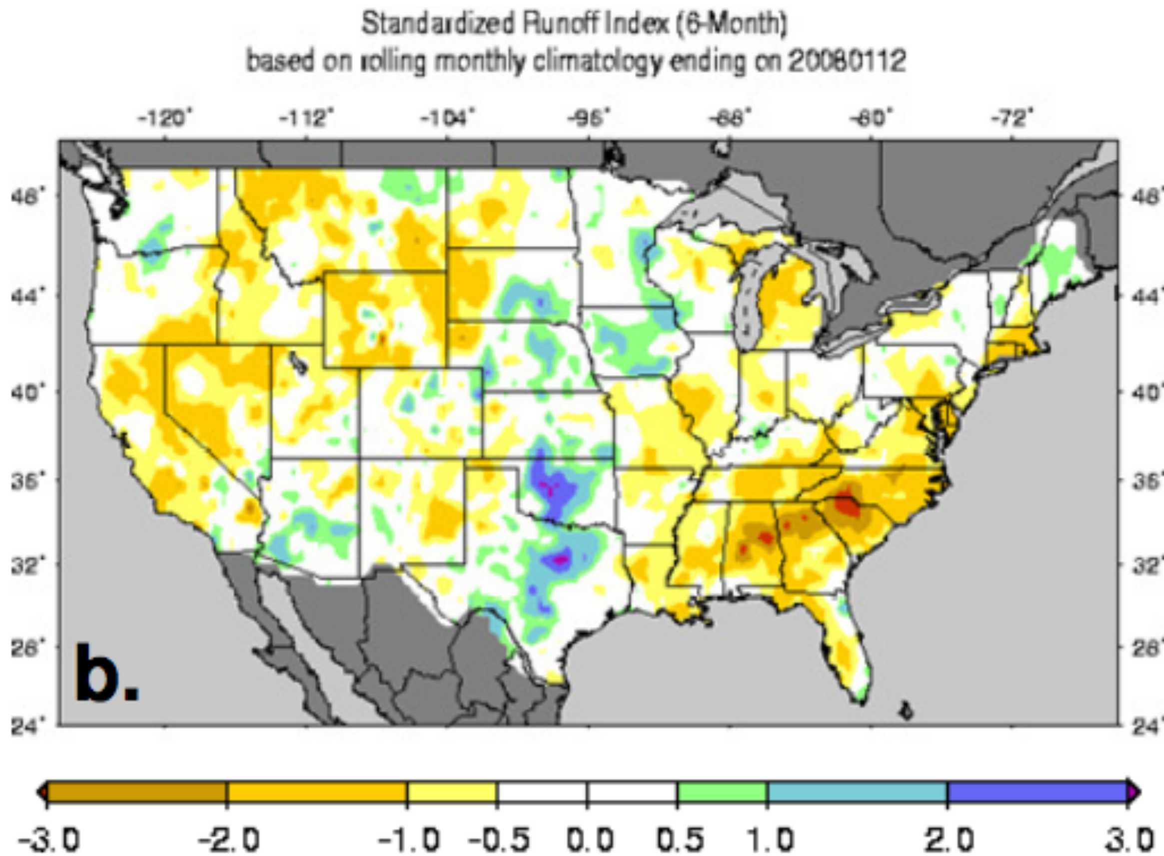


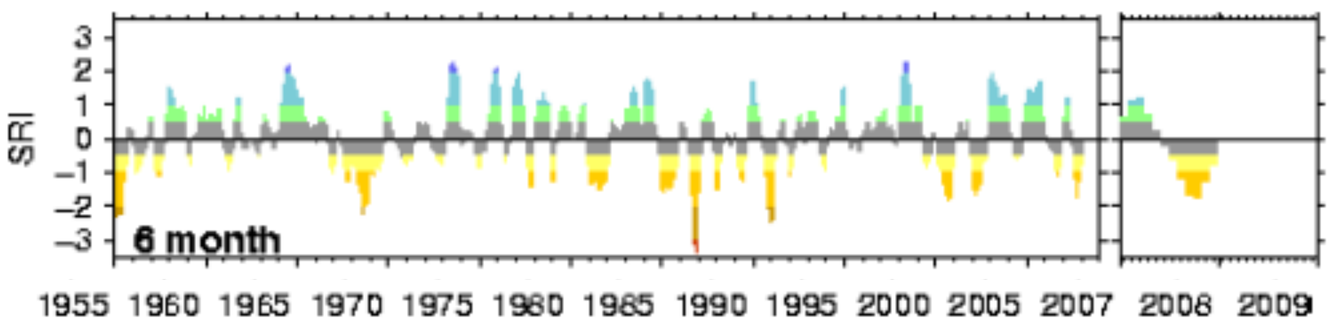
Integrative metrics for drought will help

- metrics that integrate both land surface and meteorology may better capture flash drought risk

- eg, Standardized Runoff Index (SRI) shows hydrologic vulnerability

(SRI: Shukla & Wood, 2008)





UW Surface Water Monitor (Wood, 2008)

Intersectionality – Conditionality

temperature

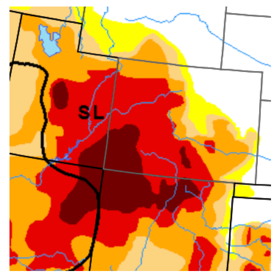
precipitation

seasonality

initial soil moisture

crop commitments

initial snowpack



crop lifecycle

prior year hydroclimate

local water storage

regional water storage

groundwater

background nonstationarity

Takeaways

- *Flash Droughts* are a poster child for the need to understand conditionality
- Climate-related hydrologic and agricultural extremes are highly multivariate
- Impacts on human systems are also conditional on state of the system
- The challenge is deriving high-level understanding if every case is 'different'

Questions?