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

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Outline

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

MWD gets:
1.25 MAF
OR
0.55 MAF
+$150M gap

from B. Hazencamp, MWD
Initial natural system states matter

Station (908) WATERYEAR=2005 (Daily) NRCS National Water and Climate Center - Provisional Data - subject to revision
Mon Sep 10 06:18:06 GMT-08:00 2018

The diagram shows a line graph with the x-axis labeled from October 1 to October 1 and the y-axis labeled in inches. The graph includes multiple lines representing different data series:
- **PREC 81-10 Average (in)**
- **PREC WY 2005 (in)**
- **SWE 81-10 Median (in)**
- **SWE WY 2005 (in)**
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
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

Example 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**

Hydrological Prediction: How well can we estimate catchment moisture dynamics?

Atmospheric predictability: How well can we forecast the weather and climate?

Water Cycle (from NASA)
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

Low Climate Prediction Uncertainty
↓
Low Watershed Uncertainty
→ High

Climate Prediction Uncertainty
→ High

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

Dec 8, 2014

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)

Accumulated Observed: thick line
Accumulated Normal: thin line
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)
Regional/process specificity is critical

Figure 1: Raw and improved correlation using PLSR with best CFSv2 predictor.
Modeling advances will also help

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

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)
Intersectionality – Conditionality

- temperature
- precipitation
- seasonality
- crop commitments
- crop lifecycle
- local water storage
- groundwater
- background
- nonstationarity

- initial soil moisture
- initial snowpack
- prior year hydroclimate
- regional water storage
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?