



Forecasting water flows for a stable & flexible grid

Daniel Palmer



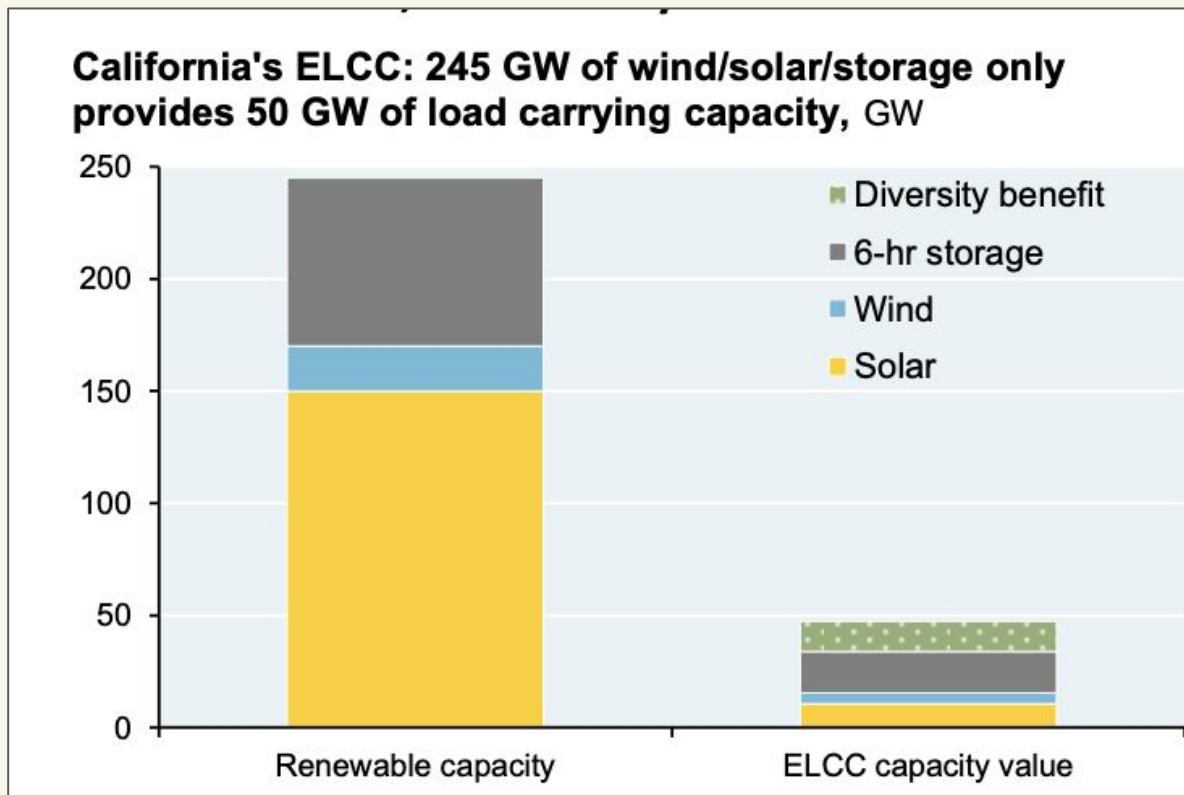
UPSTREAM TECH



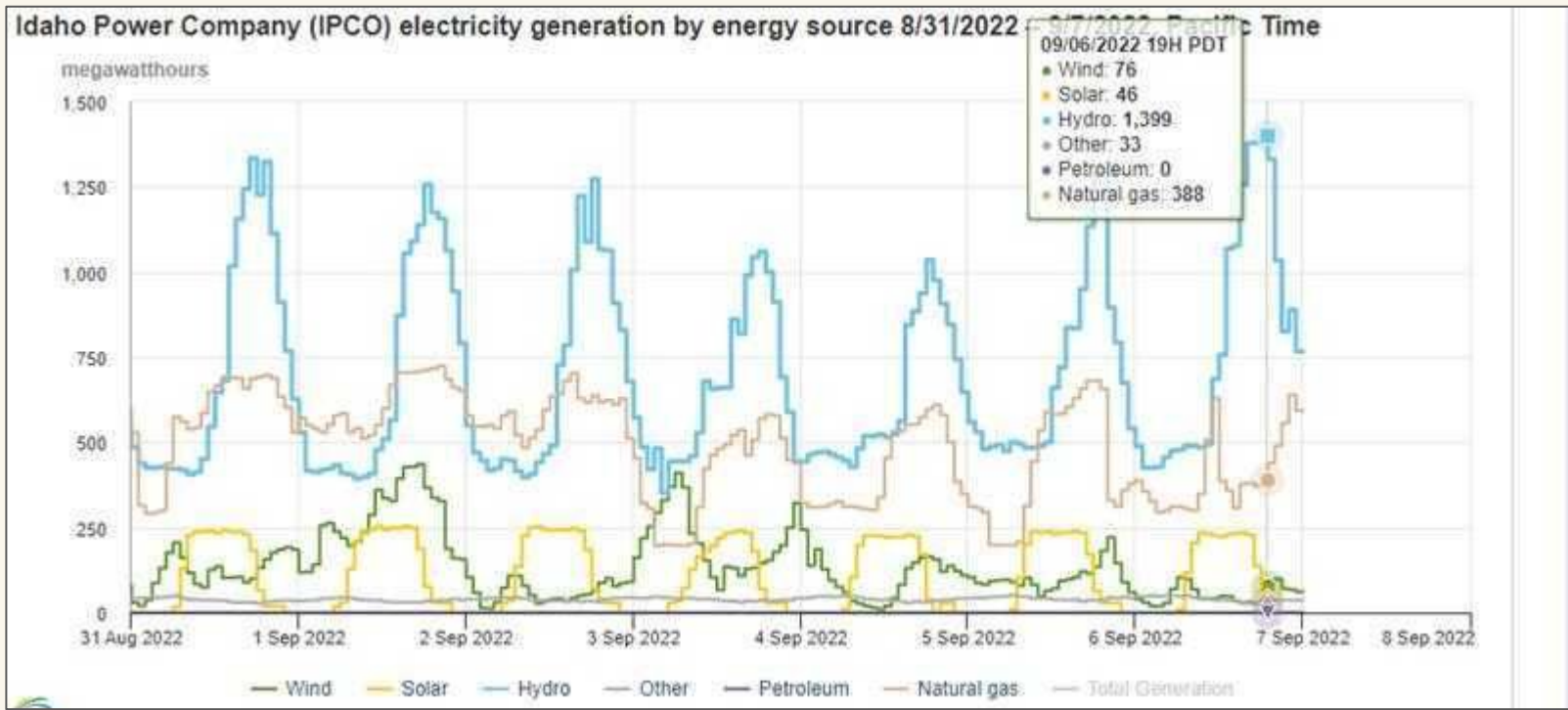


Our changing Landscape

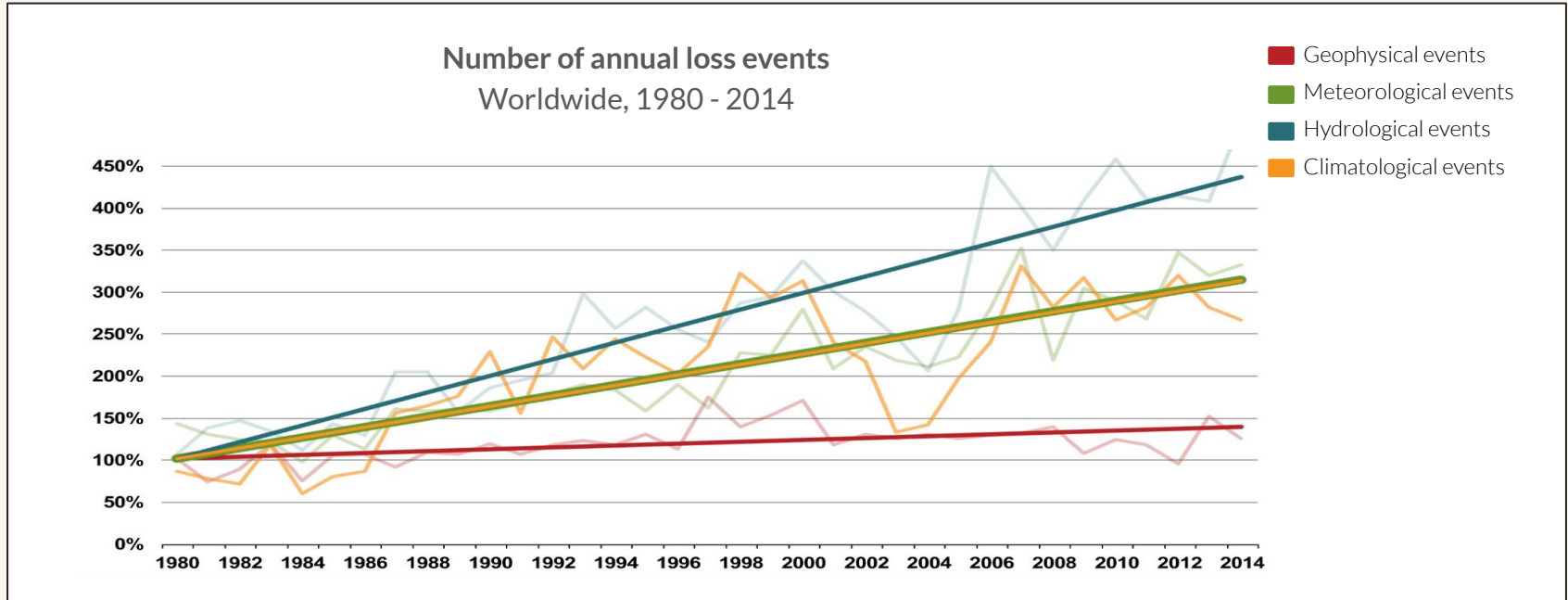
Firm resources becoming especially important as intermittents increase



Hydropower helped carry the West during last fall's heat

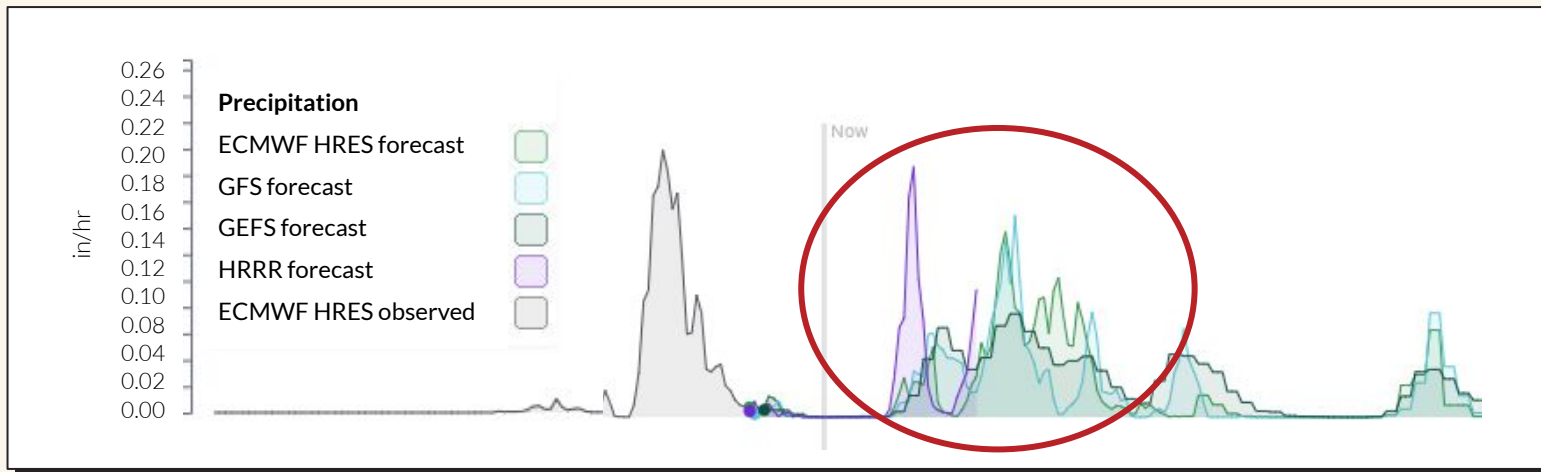


Natural catastrophes are increasing globally, driven by storms & floods



Streamflow is increasingly less predictable

- ❖ Historical records $\neq$ future conditions. Climate change means a future that is both wetter and drier, hotter and colder.
- ❖ Weather forecasts (e.g., NOAA and ECMWF) often disagree
- ❖ Historical relationships for runoff generation no-longer hold true (e.g., California & CO River 2021)¹



1. Colorado Sun, As Colorado warms, dry soil sucks up more water. That's bad news for rivers and farmers, 2/6/2022





Can new forecasting methods improve outcomes?

Combining Hydrologic Theory & AI Advances Skill

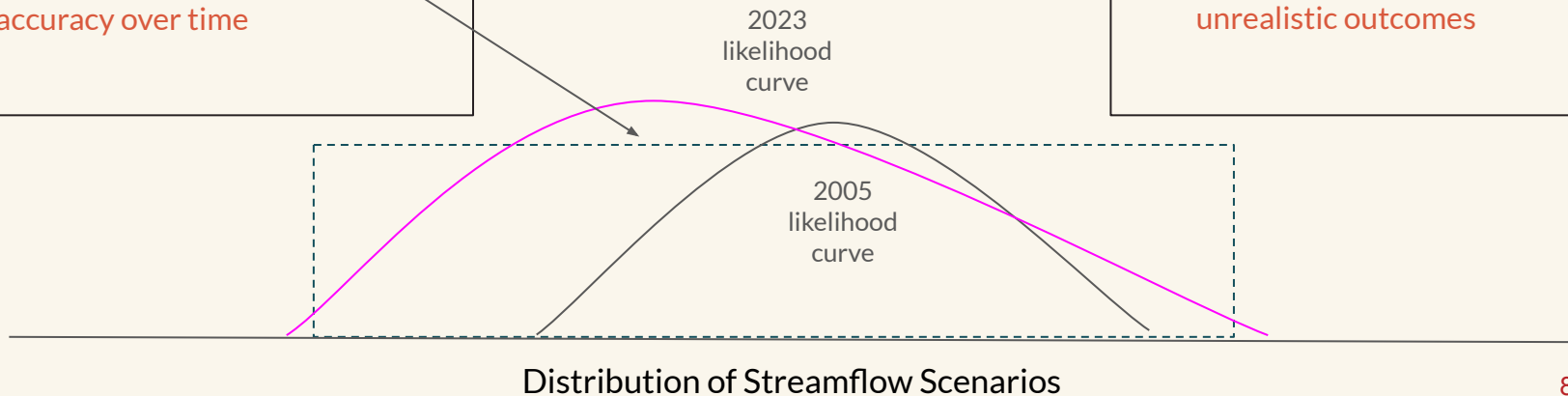
HydroForecast's theory-guided machine learning uses the best of both approaches

Physical models

- ❖ Equations we know
- ❖ Each part explicitly represented
- ❖ Single basin observed data used to calibrate and *constrain*
- ❖ Changing conditions reduce accuracy over time

Statistical models

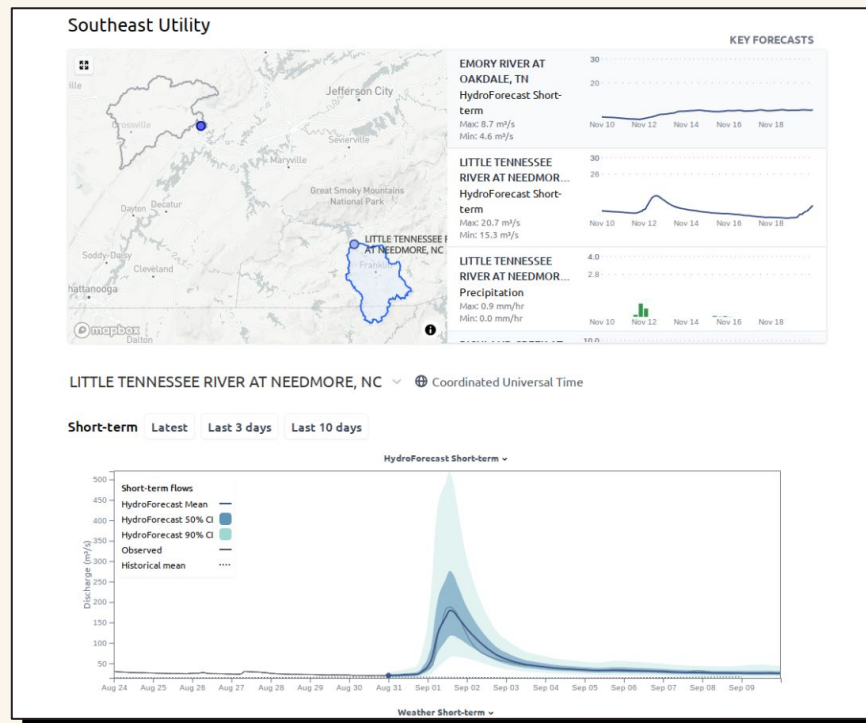
- ❖ Empirical and data-driven
- ❖ Learns over time
- ❖ Highly flexible and adaptive
- ❖ Unconstrained
- ❖ Prone to false correlations and unrealistic outcomes



Streamflow modeling for safe & efficient operations

Theory-guided machine learning employs:

- ❖ Multiple advanced weather forecasts
- ❖ Satellite data
- ❖ Land surface datasets
- ❖ In situ observations



Putting it in practice: HydroForecast

HydroForecast is trusted by dozens of leading hydropower producers, water utilities, and government agencies

830,000+ km² of drainage area forecasted

9,400+ MW of hydropower informed

Live in 13 countries and 5 continents



**US Army Corps
of Engineers.**



Brookfield
Renewable



Seattle City Light



TACOMA POWER
TACOMA PUBLIC UTILITIES

The Nature
Conservancy



Mercury



Industry Leading Short-term Performance

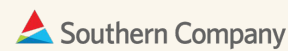
First place in all regions in a yearlong forecasting competition

Results from Forecast Rodeo					
	U.S. West	U.S. Southeast	Alabama	Quebec	U.S. Mtn. West
All Arounder All metrics					
Flood Forecaster Highest flow range					
Quick Draw Shortest forecast horizon					
Eagle Eye Longest forecast horizon					
Straight Shooter Lowest bias					

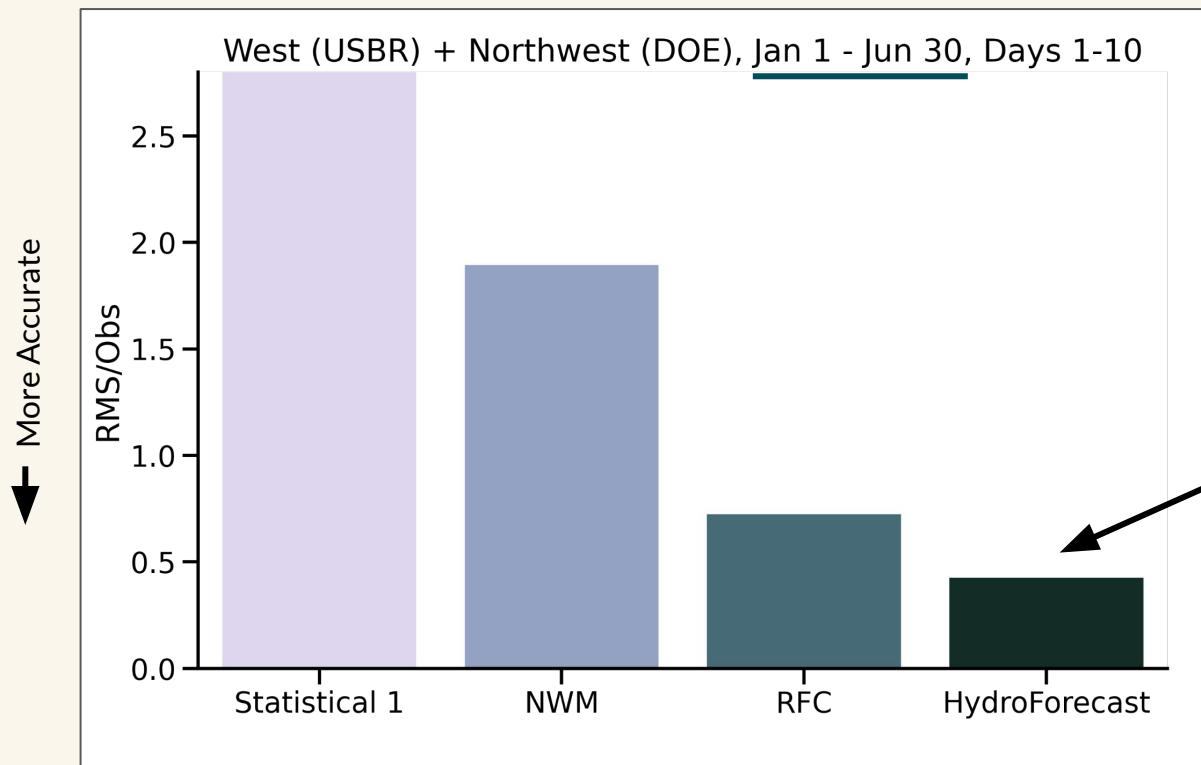
ALSO PARTICIPATING



OFFICE OF
WATER
PREDICTION



Evaluation snapshot: US West, spring freshet

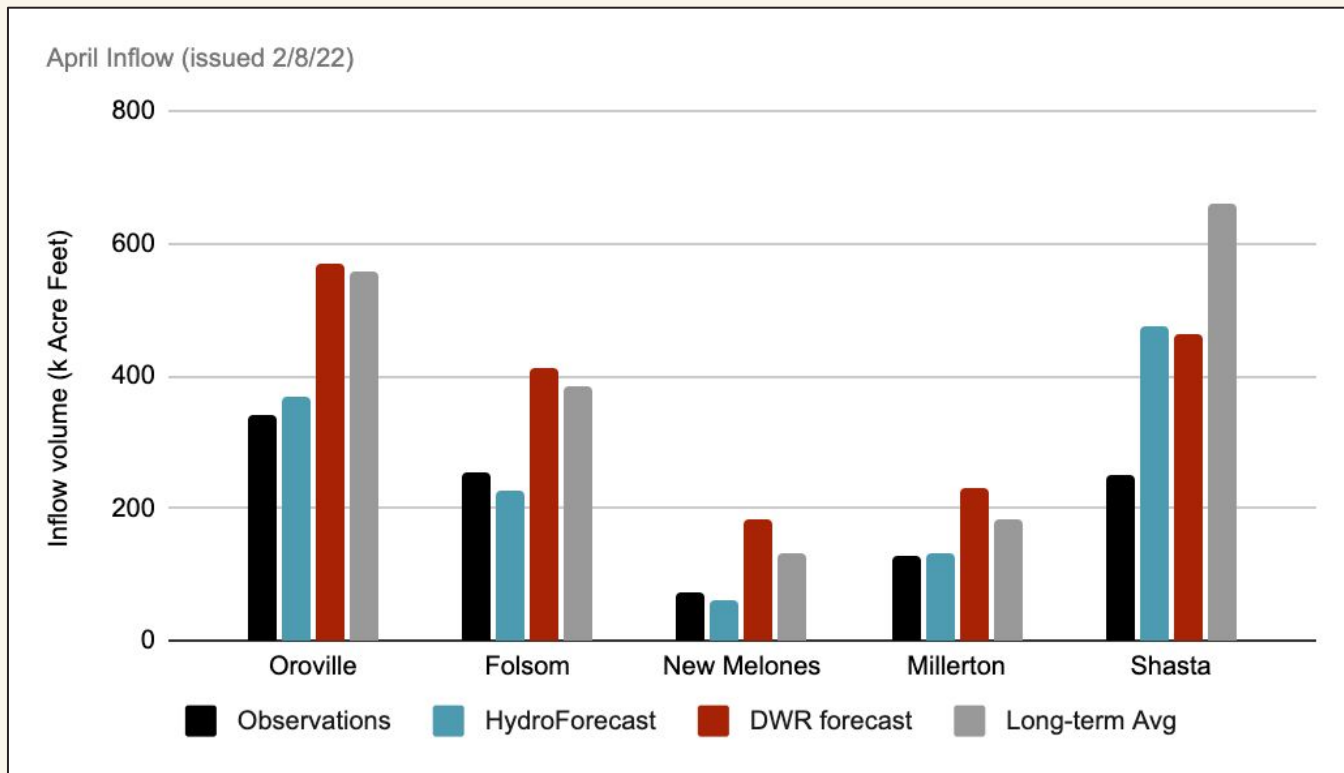


Snow melt:
41% reduction
in error over
industry
standard



Improved Seasonal Skill

More accurate than California Dept. of Water Resources in a freshet evaluation



Implications for operators and the grid

- ❖ Firm resource like hydro are increasingly important
- ❖ But...water supplies are becoming more volatile
- ❖ New forecasting technologies are up to the task
- ❖ Forecasting can help operators improve hydro safety and profitability
- ❖ Improved hydro operations can help stabilize the grid(e.g., more confident day-ahead bidding)



Thanks!

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