



# Forecasting water flows for a stable & flexible grid

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UPSTREAM TECH

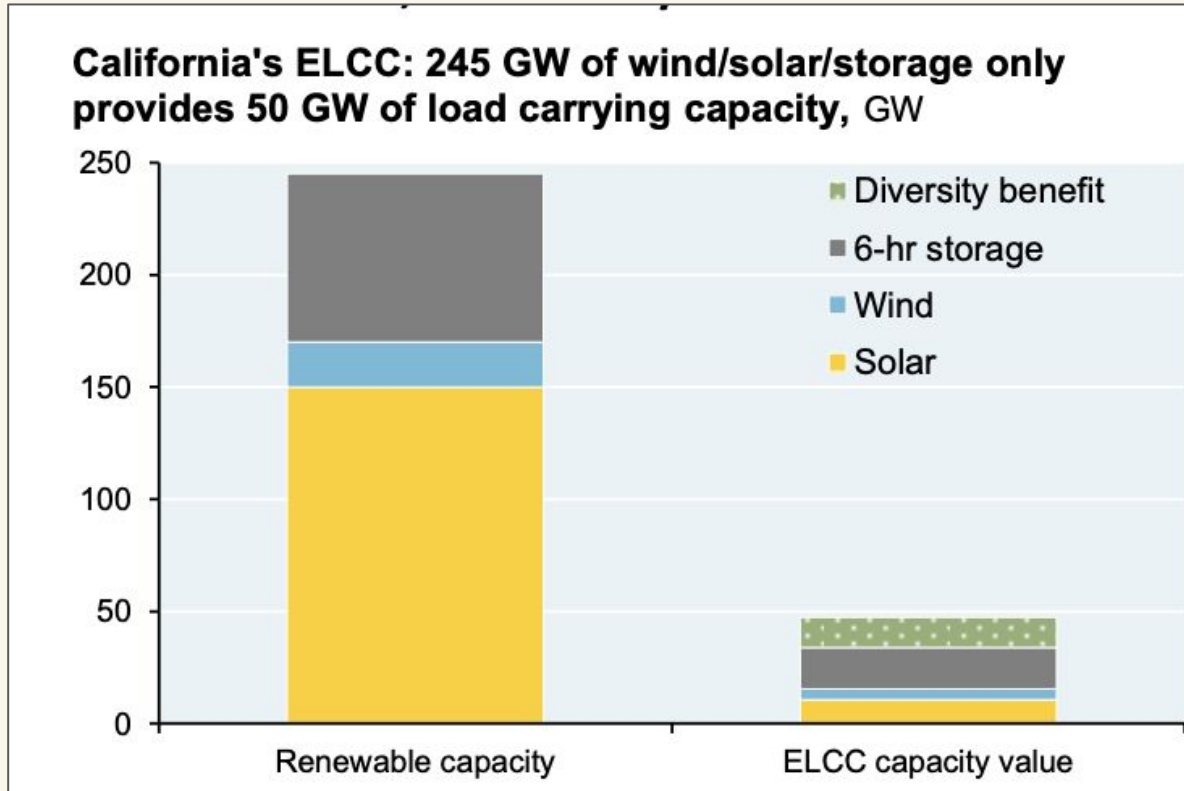




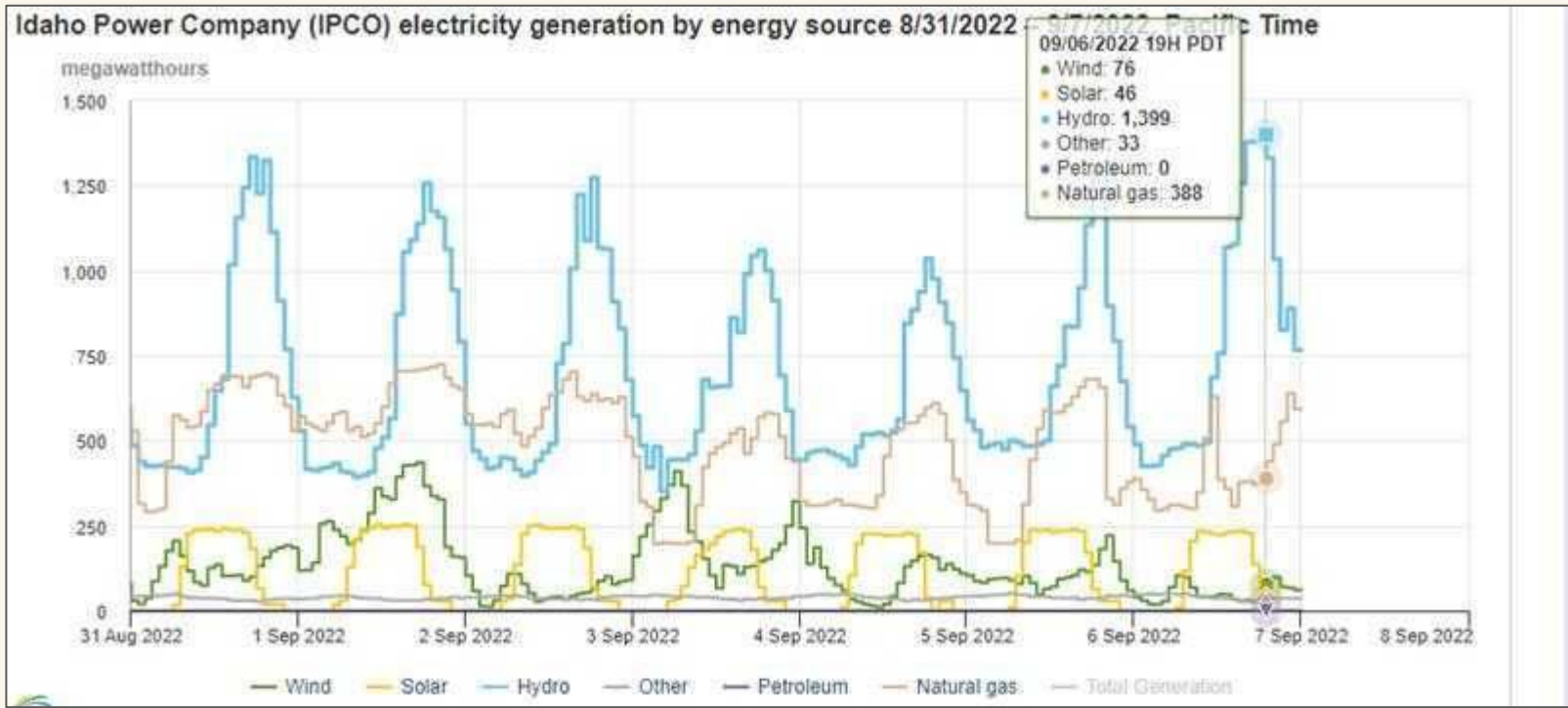
# Our changing Landscape

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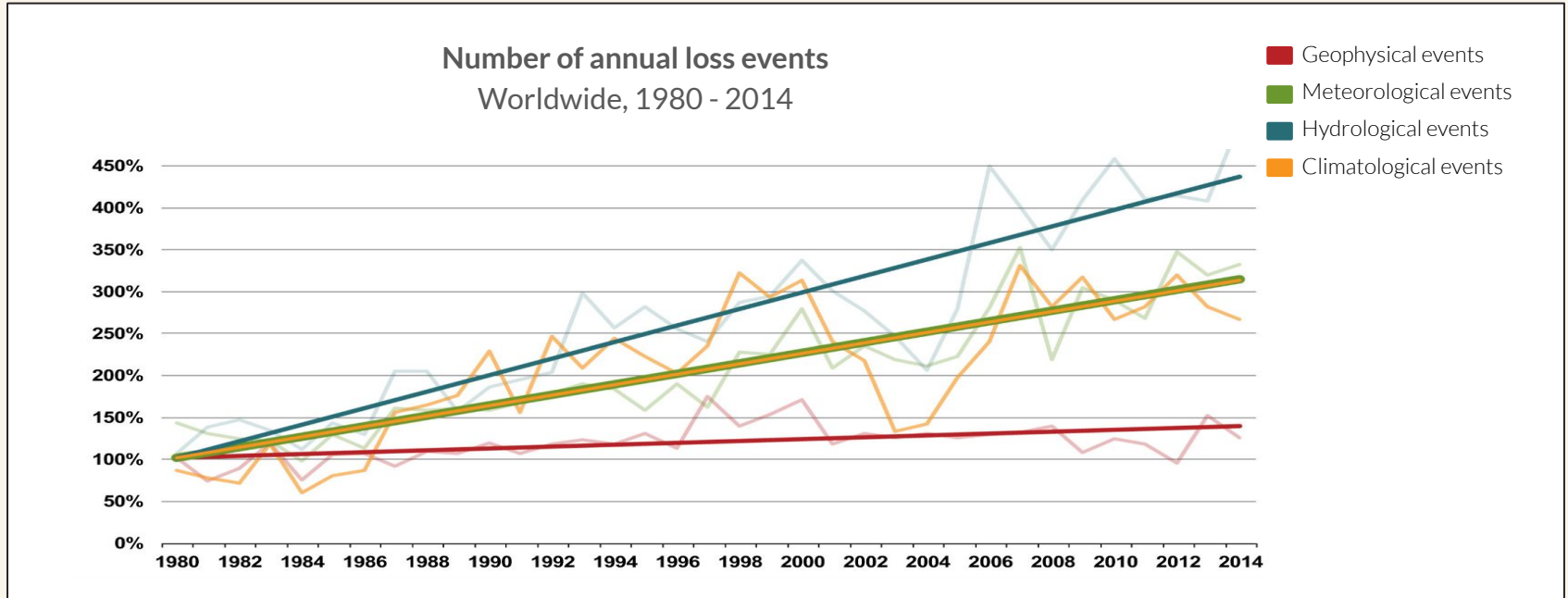
# Firm resources becoming especially important as intermittents increase



# Hydropower helped carry the West during last fall's heat

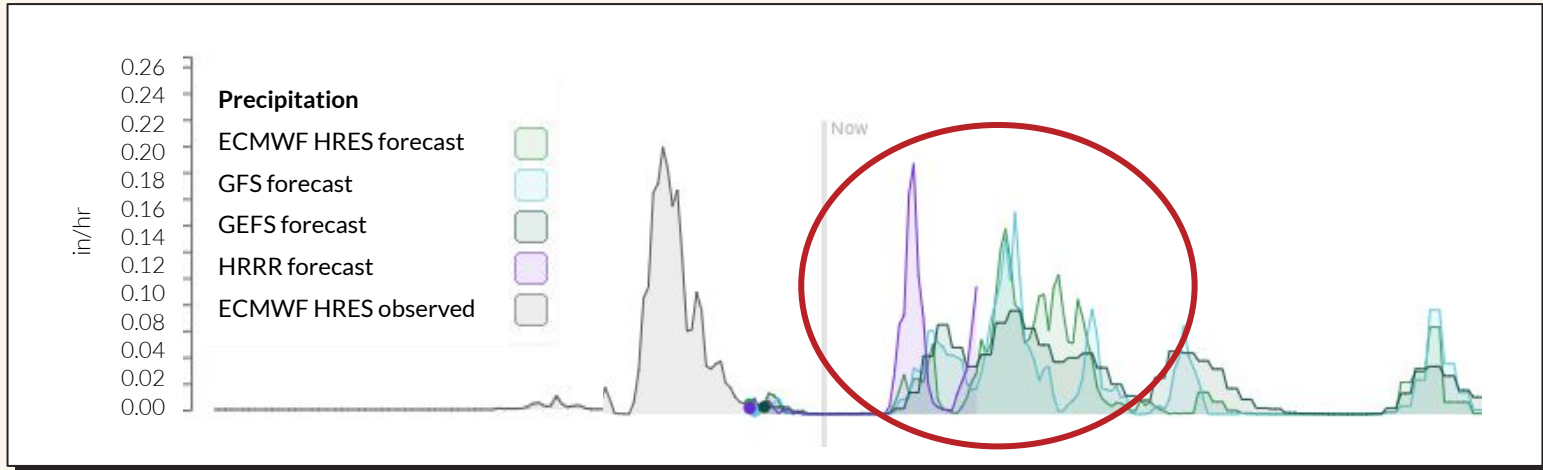


# Natural catastrophes are increasing globally, driven by storms & floods



# 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)<sup>1</sup>



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?

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# Combining Hydrologic Theory & AI Advances Skill

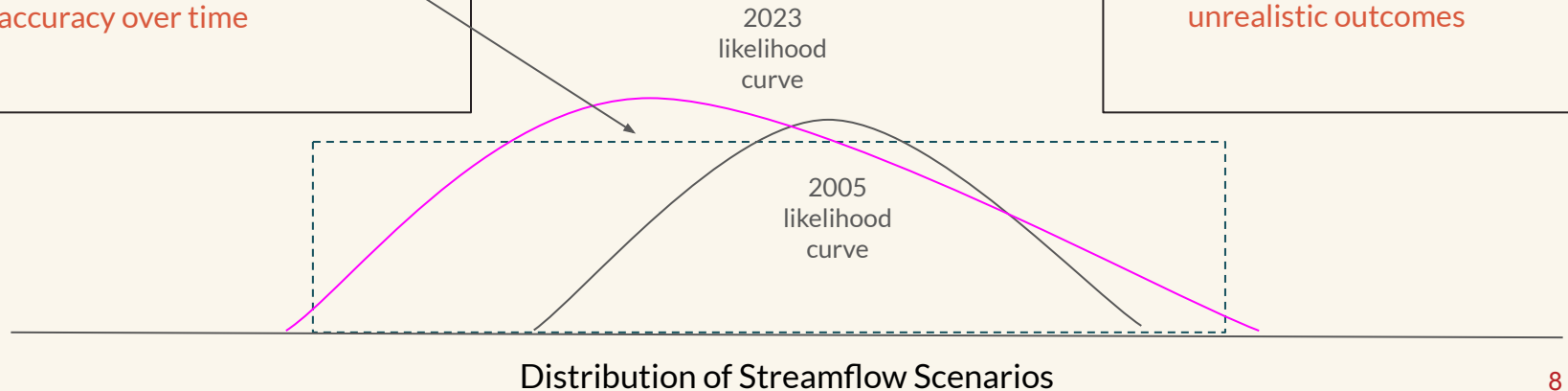
HydroForecast's theory-guided machine learning uses the best of both approaches

## 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



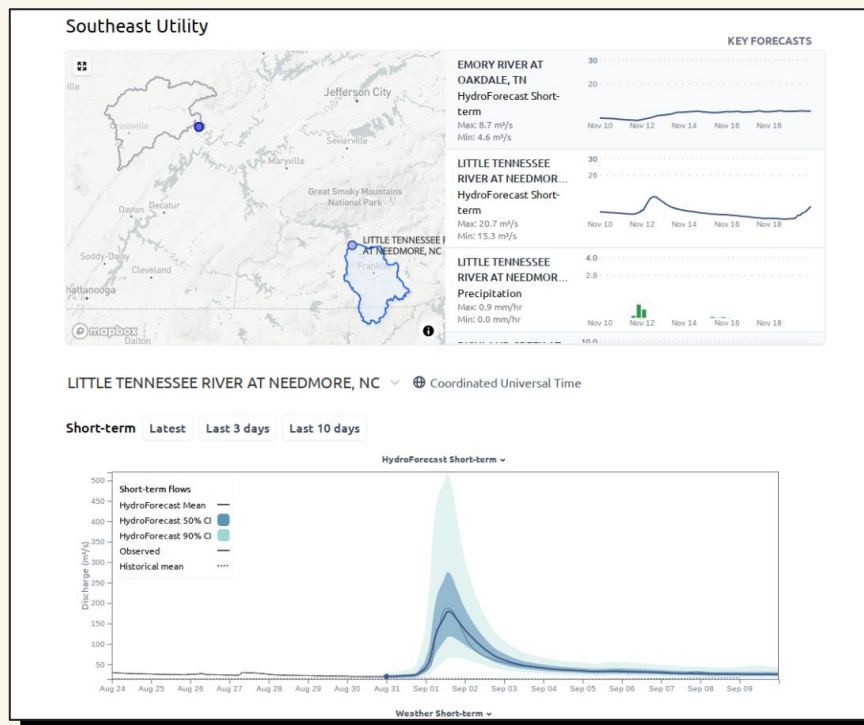


# Streamflow modeling for safe & efficient operations

## 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+** km<sup>2</sup> 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 




























**Ameren**



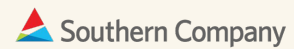
# Industry Leading Short-term Performance

First place in all regions in a yearlong forecasting competition

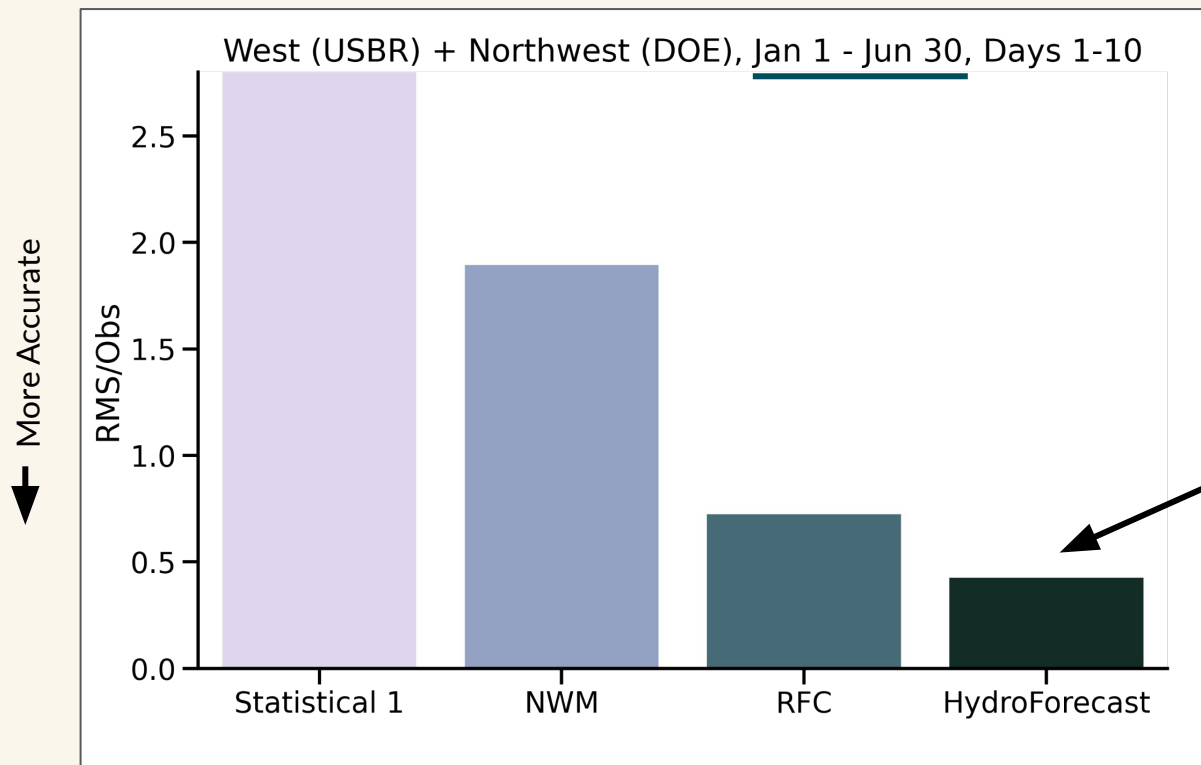


Results from Forecast Rodeo					
	U.S. West	U.S. Southeast	Alabama	Quebec	U.S. Mtn. West
<b>All Arounder</b> All metrics					
<b>Flood Forecaster</b> Highest flow range					
<b>Quick Draw</b> Shortest forecast horizon					
<b>Eagle Eye</b> Longest forecast horizon					
<b>Straight Shooter</b> Lowest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

ALSO PARTICIPATING



# Evaluation snapshot: US West, spring freshet

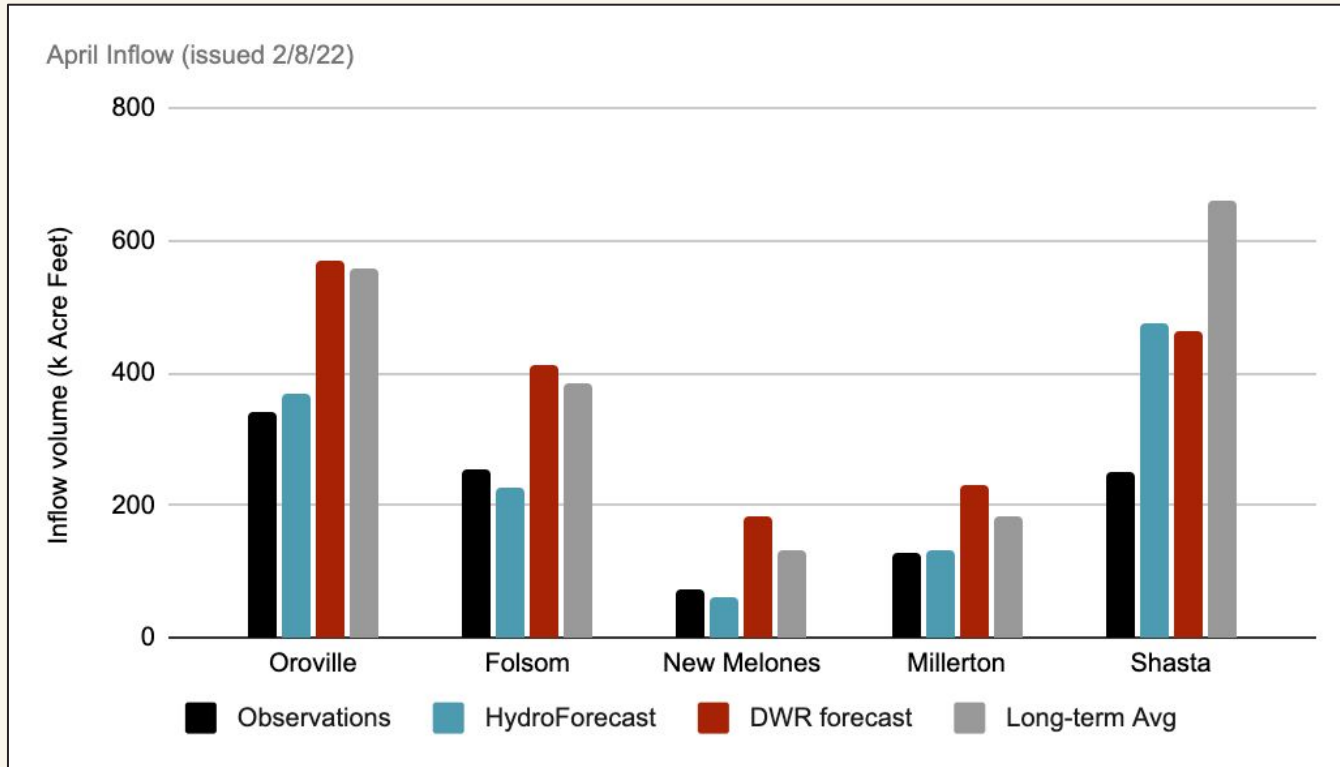


Snow melt:  
**41% reduction**  
in error over  
industry  
standard



# Improved Seasonal Skill

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



# Implications for operators and the grid

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- ❖ 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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