A stylized map of California is the background. Overlaid on the map is a large dam with water flowing through its spillways. To the right of the dam, several high-voltage power transmission towers are connected by power lines, extending across the state. The map uses a color gradient from light orange at the top to light blue at the bottom.

Using CALFEWS to forecast hydropower generation and consumption in the Central Valley Project

Yash Amonkar¹, Eric Mork², H.B. Zeff¹ & Gregory W Characklis¹

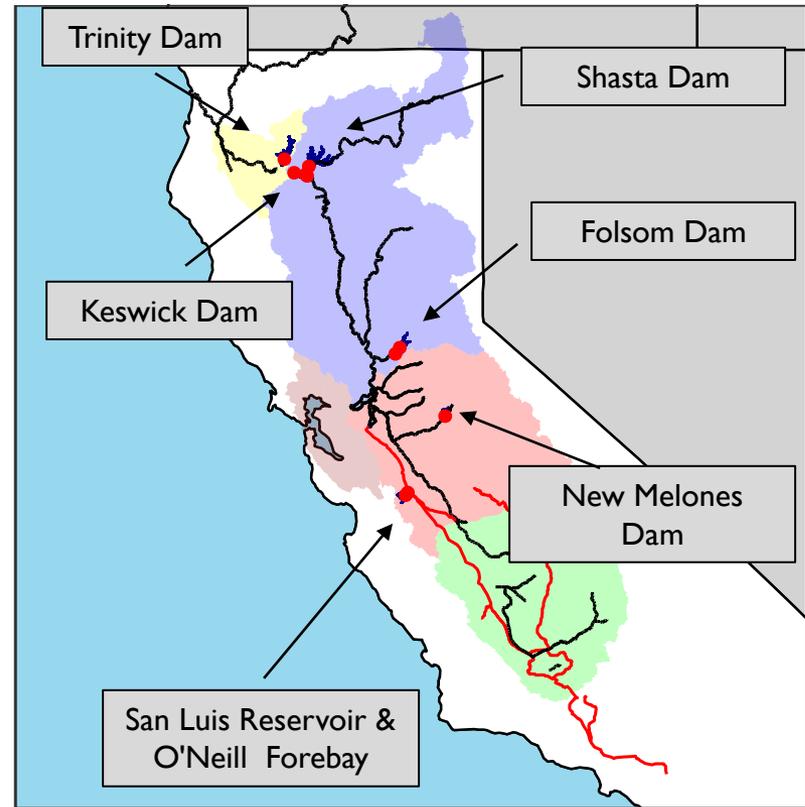
1- Institute for Risk Management & Insurance Innovation (IRMI), UNC Chapel Hill

2 – Western Area Power Administration

14th March 2025

Central Valley Project (CVP) & Hydropower

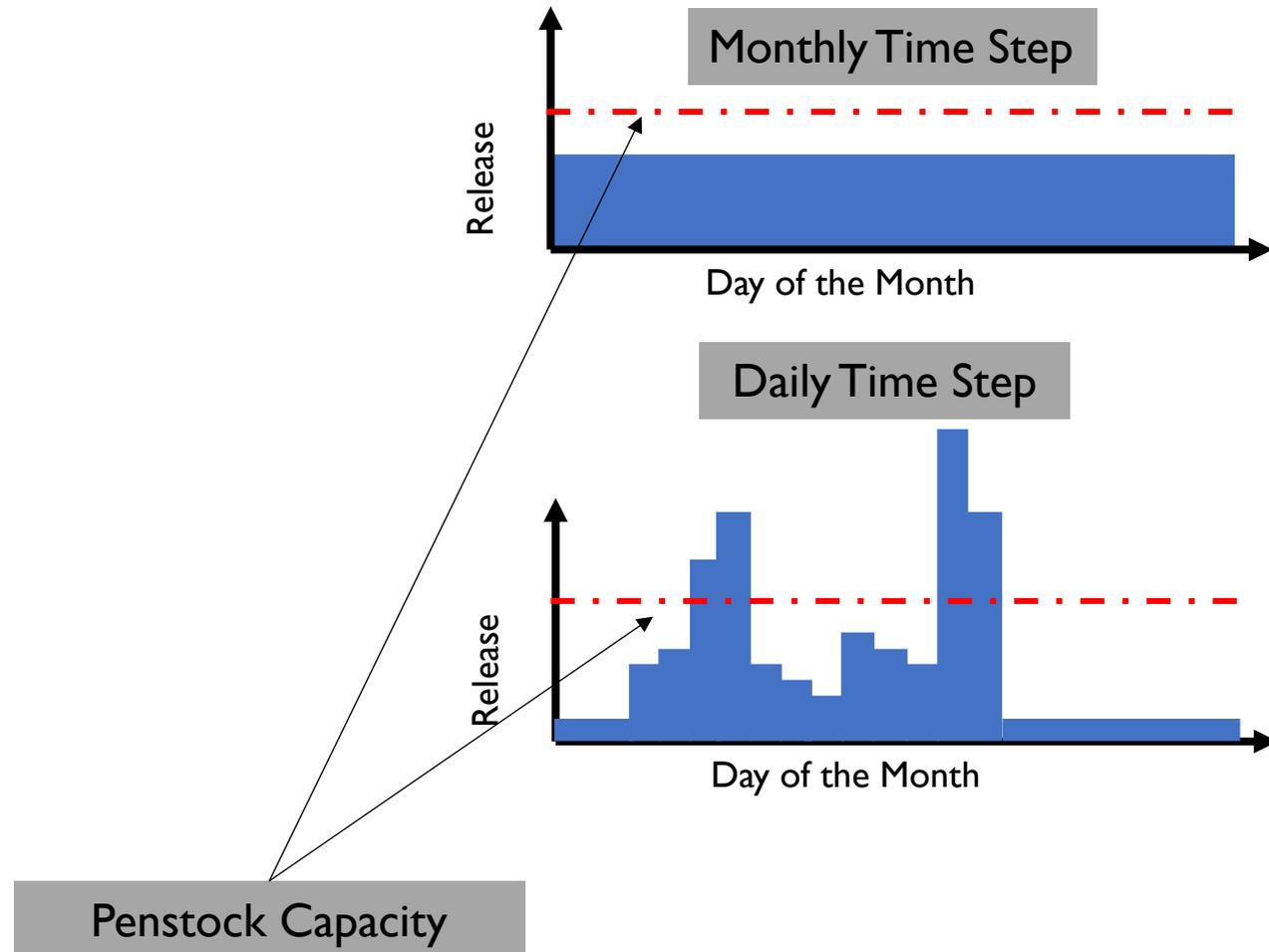
- CVP is a federally operated power and water management project in California



Water Resource Models & Temporal Resolution

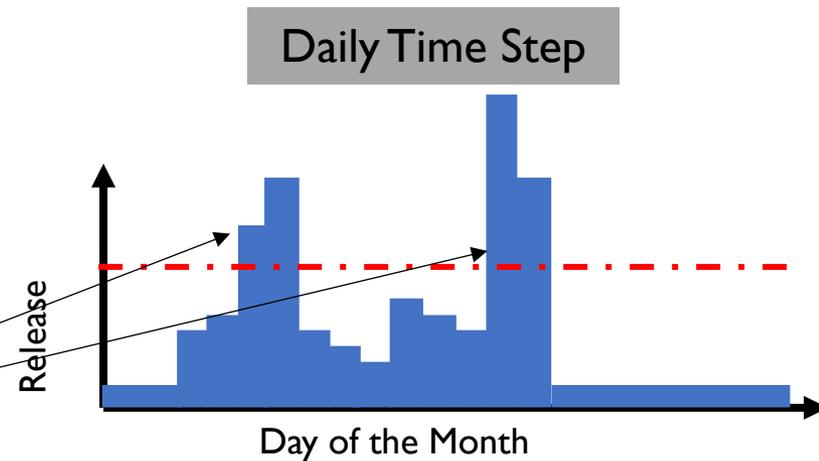
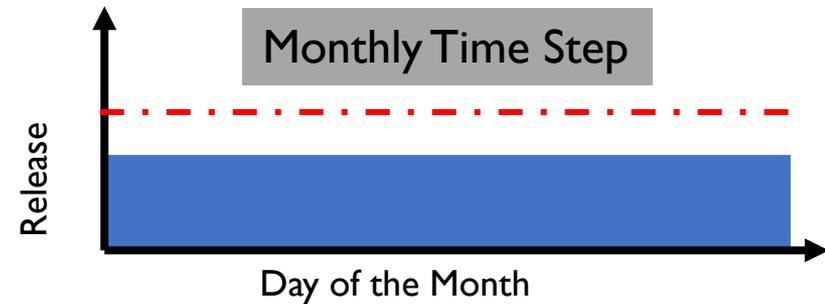
Same volume of water is released
(blue shaded region)

Water Resource Models & Temporal Resolution



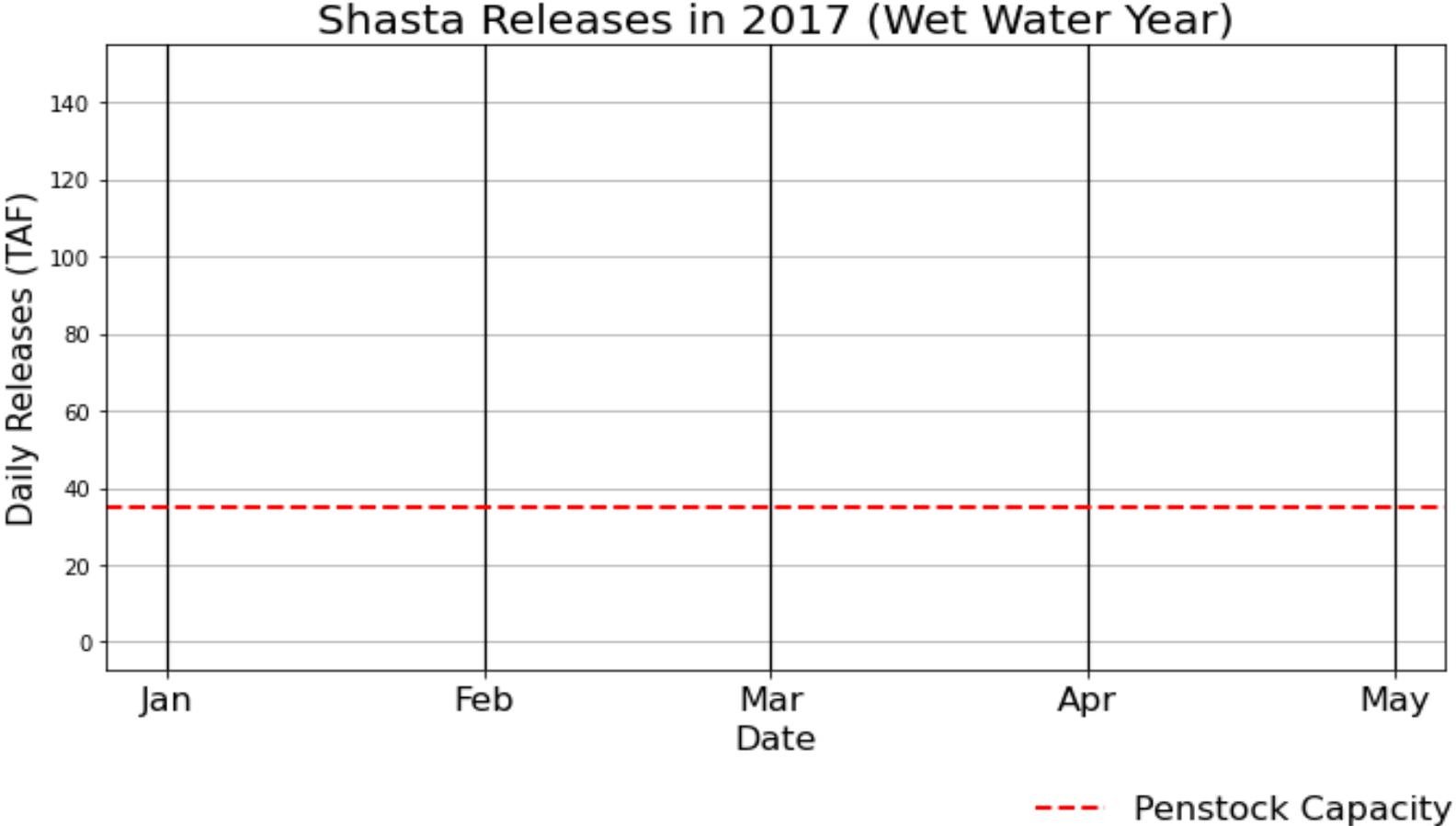
Water Resource Models & Temporal Resolution

- Implications for power generation → Reservoir releases are of consequence only if they pass through the penstock.
- No flow through penstock = No power generation
- Why would operators release water if they cannot send it through the turbine ?
 - Flood Operations & Safety
 - Environmental Pulse Flows



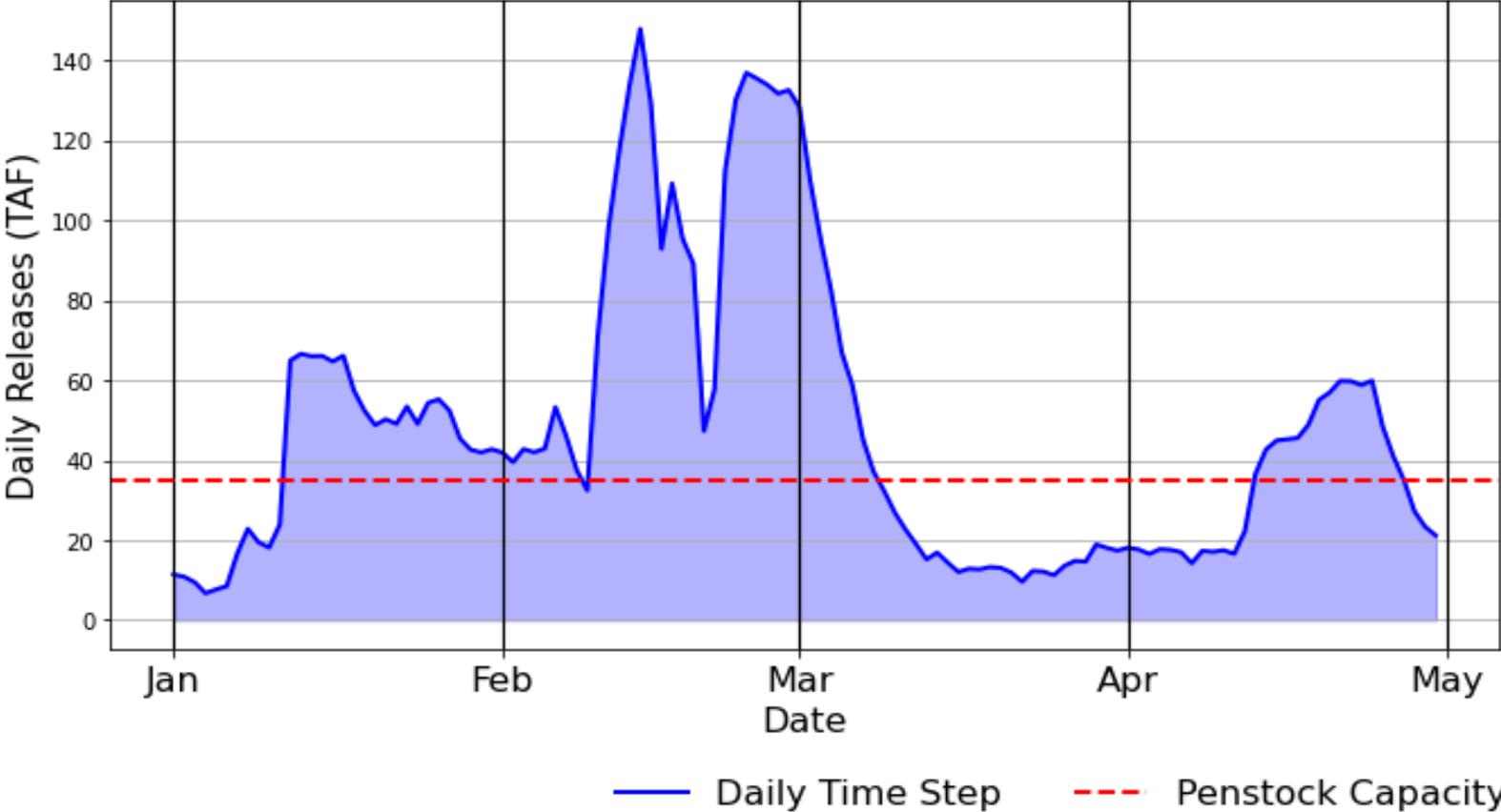
Spill

Shasta



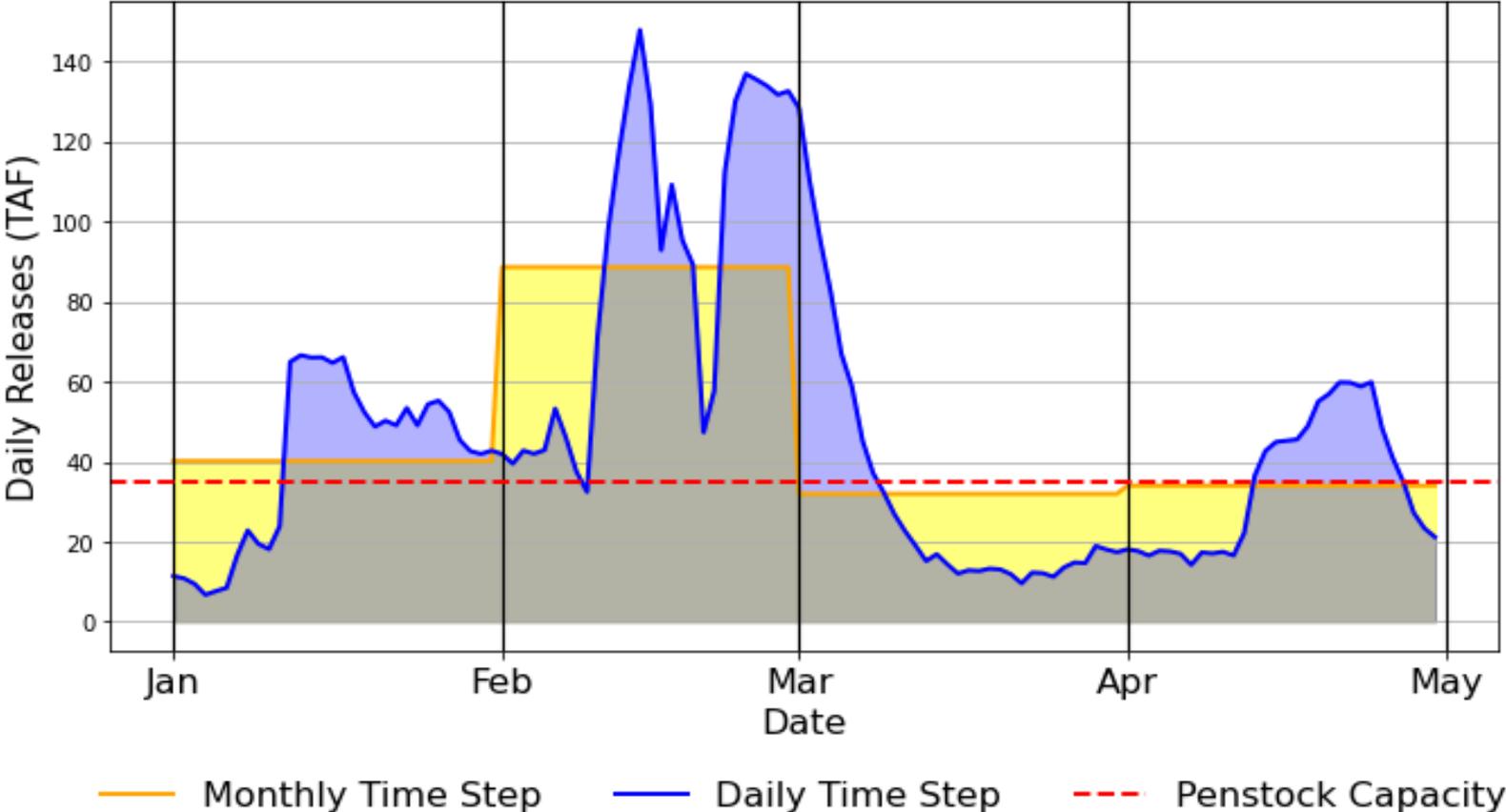
Shasta

Shasta Releases in 2017 (Wet Water Year)



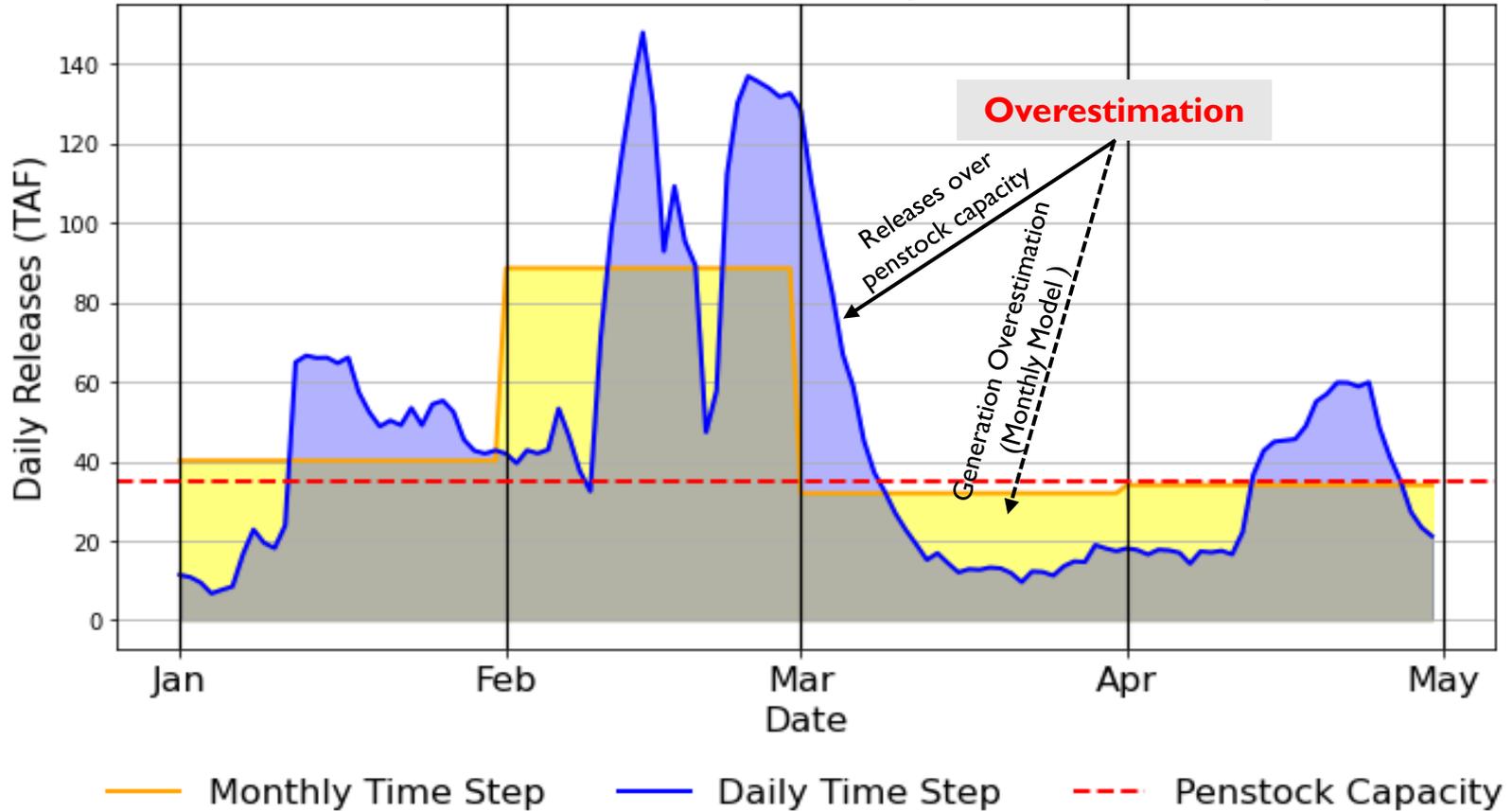
Shasta

Shasta Releases in 2017 (Wet Water Year)



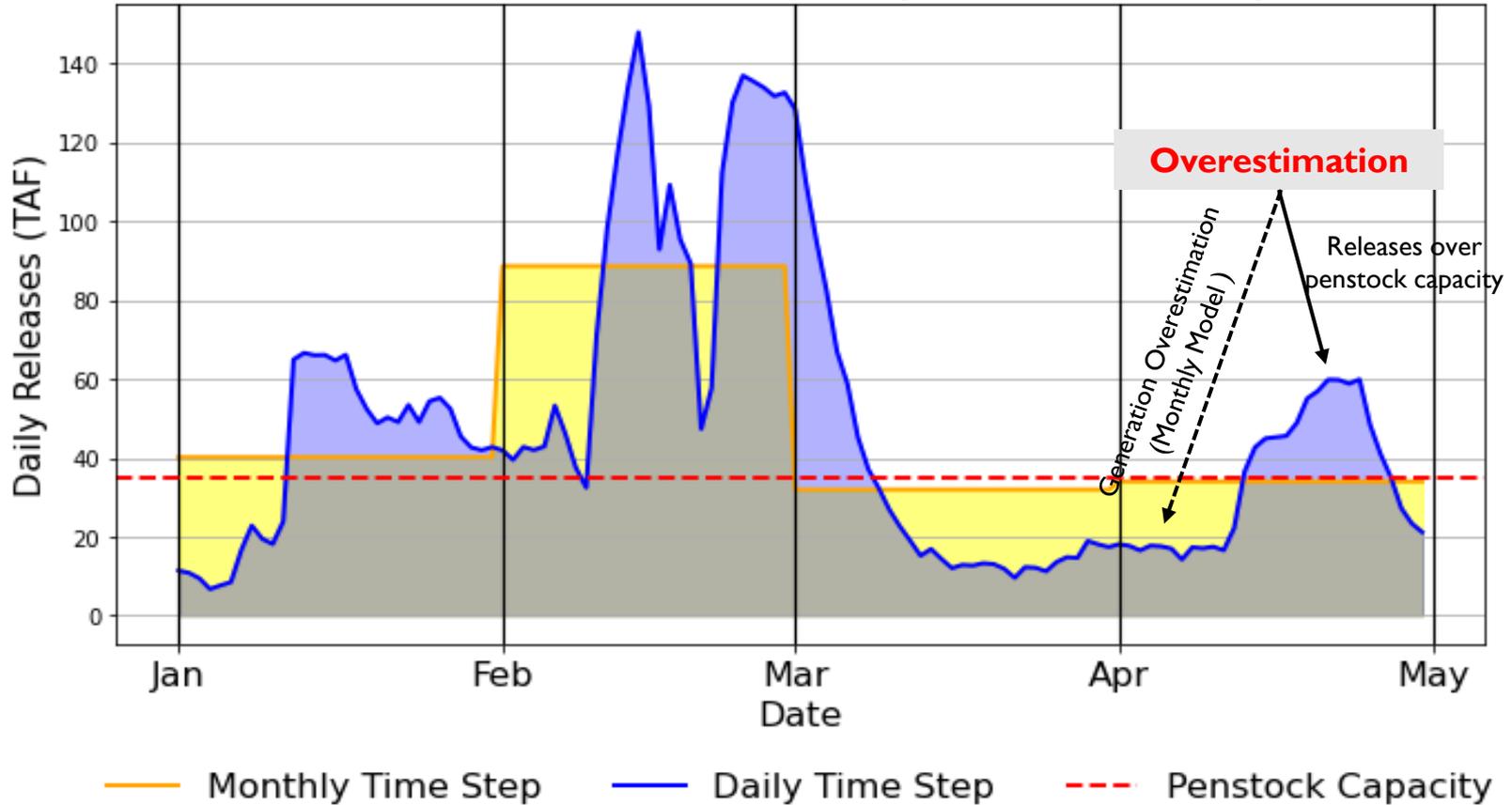
Shasta

Shasta Releases in 2017 (Wet Water Year)



Shasta

Shasta Releases in 2017 (Wet Water Year)



Monthly timestep models overestimate penstock flow!

Overestimation of penstock flow = Overestimation of hydropower generation

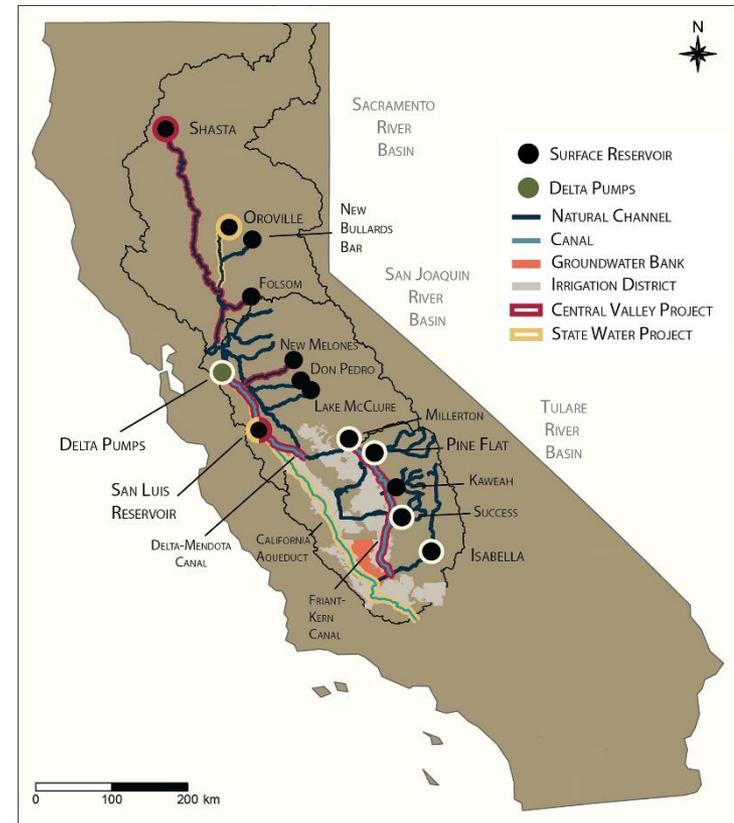
Overestimation of Penstock Flow

Overestimation of flow through penstock = Overestimation of power generation

Why do we need a daily timestep model ?

CALFEWS

- The California Food-Energy-Water System (CALFEWS) is a rules based open-source simulation model (Zeff *et al.* (2021))



Source: Gupta, Rohini S., Scott Steinschneider, and Patrick M. Reed. "Exploring water system vulnerabilities in California's Central Valley under the late Renaissance megadrought and climate change." *Earth's Future* 13.4 (2025): e2024EF005465.

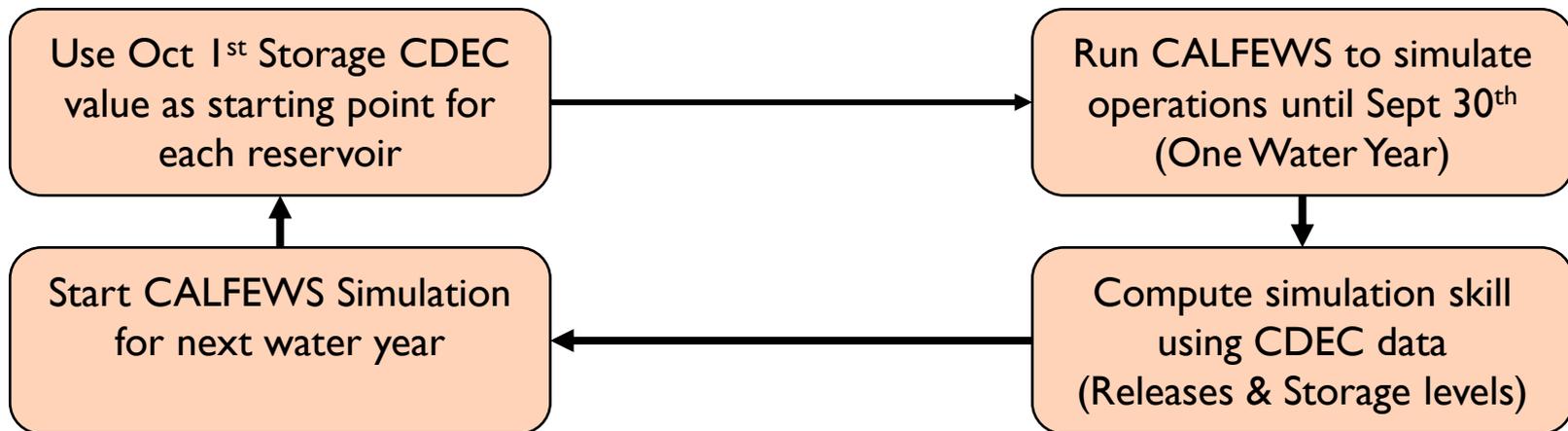
Overall, CALFEWS is powerful integrated systems tool to model and forecast hydropower generation in a complex system such as the Central Valley Project

Research Question: Can we utilize CALFEWS to make hydropower forecasts over a 1–5-year time horizon ?

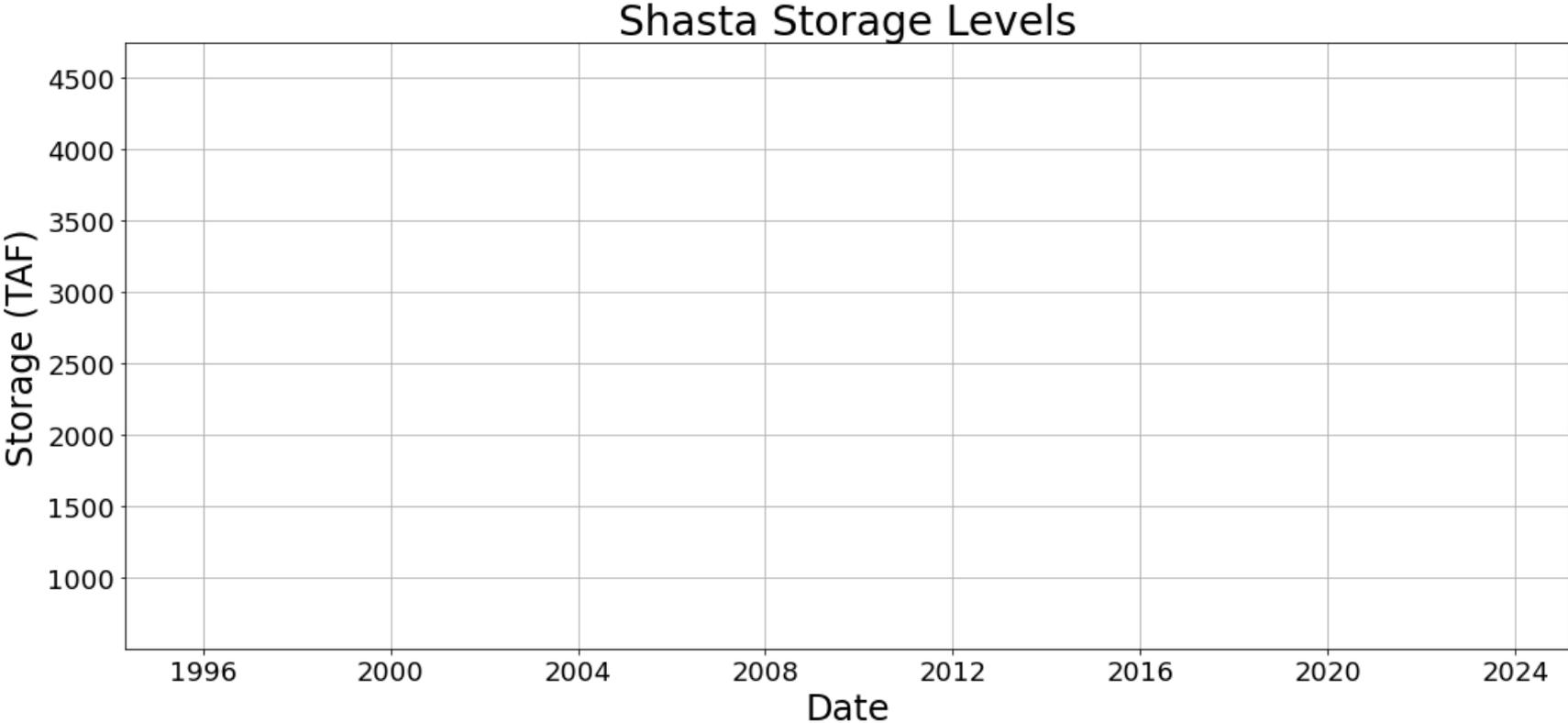
I-yr Forecast Methodology

I-yr Forecast Methodology

- Simulations → Annual simulations with storage updated only once.
- Simulations begin on Oct 1st and end Sept 30th, corresponding to a water year, at which point storage is updated based on historic values.
- Simulation data → Historic full natural flow & snowpack observation values.
- CALFEWS uses the input simulation data one day at a time.
 - It only sees the information what operators would see to make decisions.

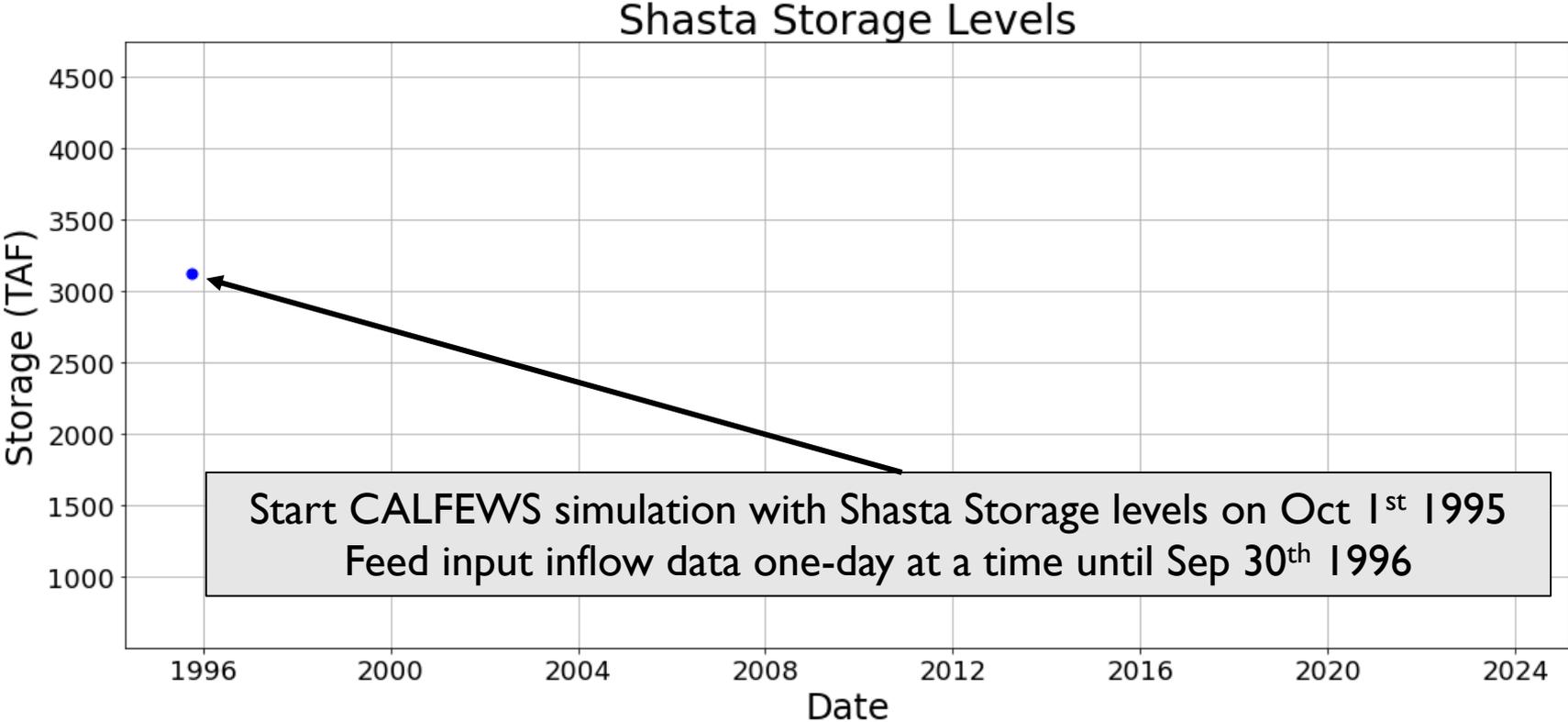


Storage Results

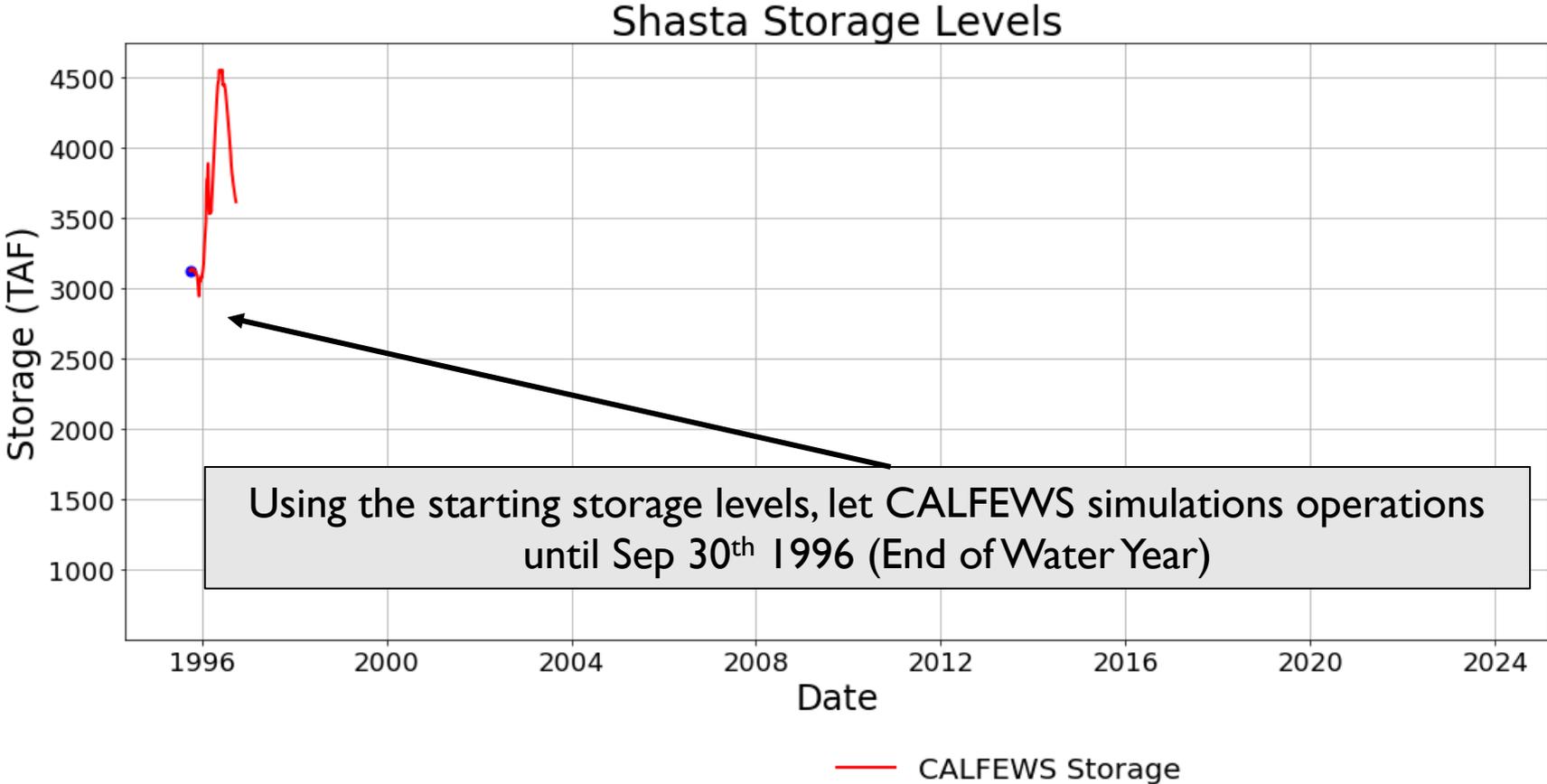


Let us analyze CALFEWS simulations through storage level modelling at Shasta.
This is done across all reservoirs

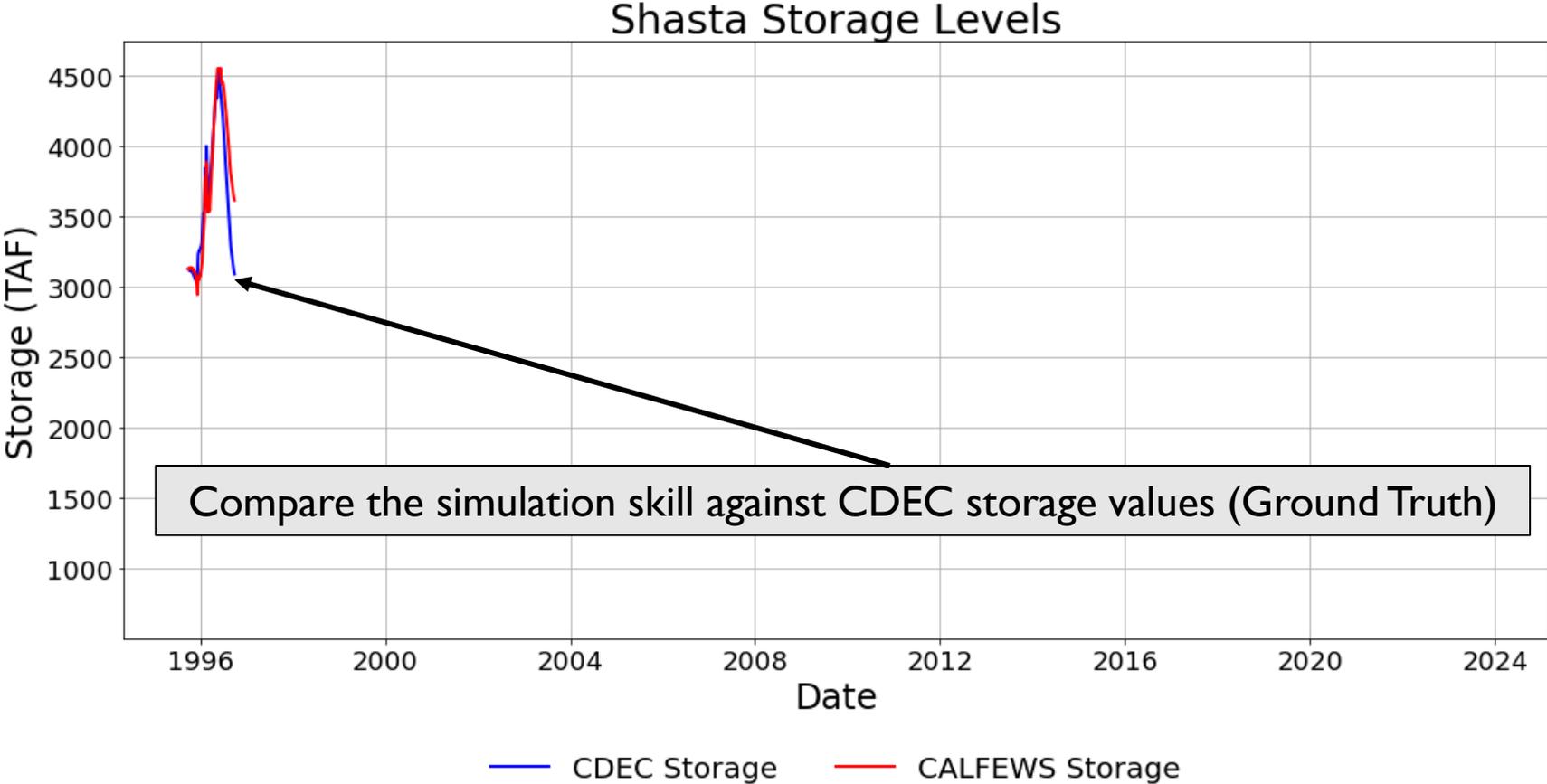
Storage Results



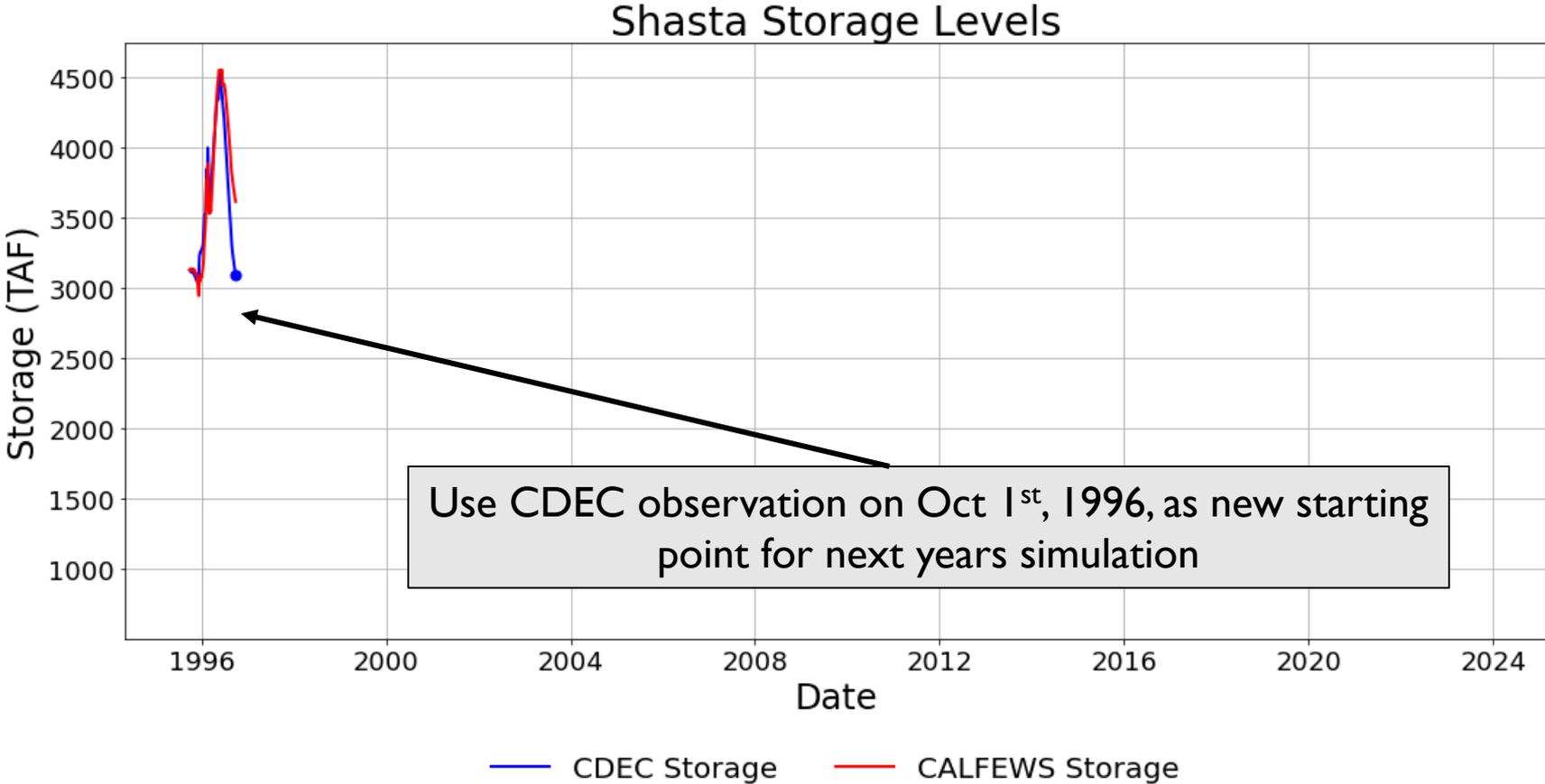
Storage Results



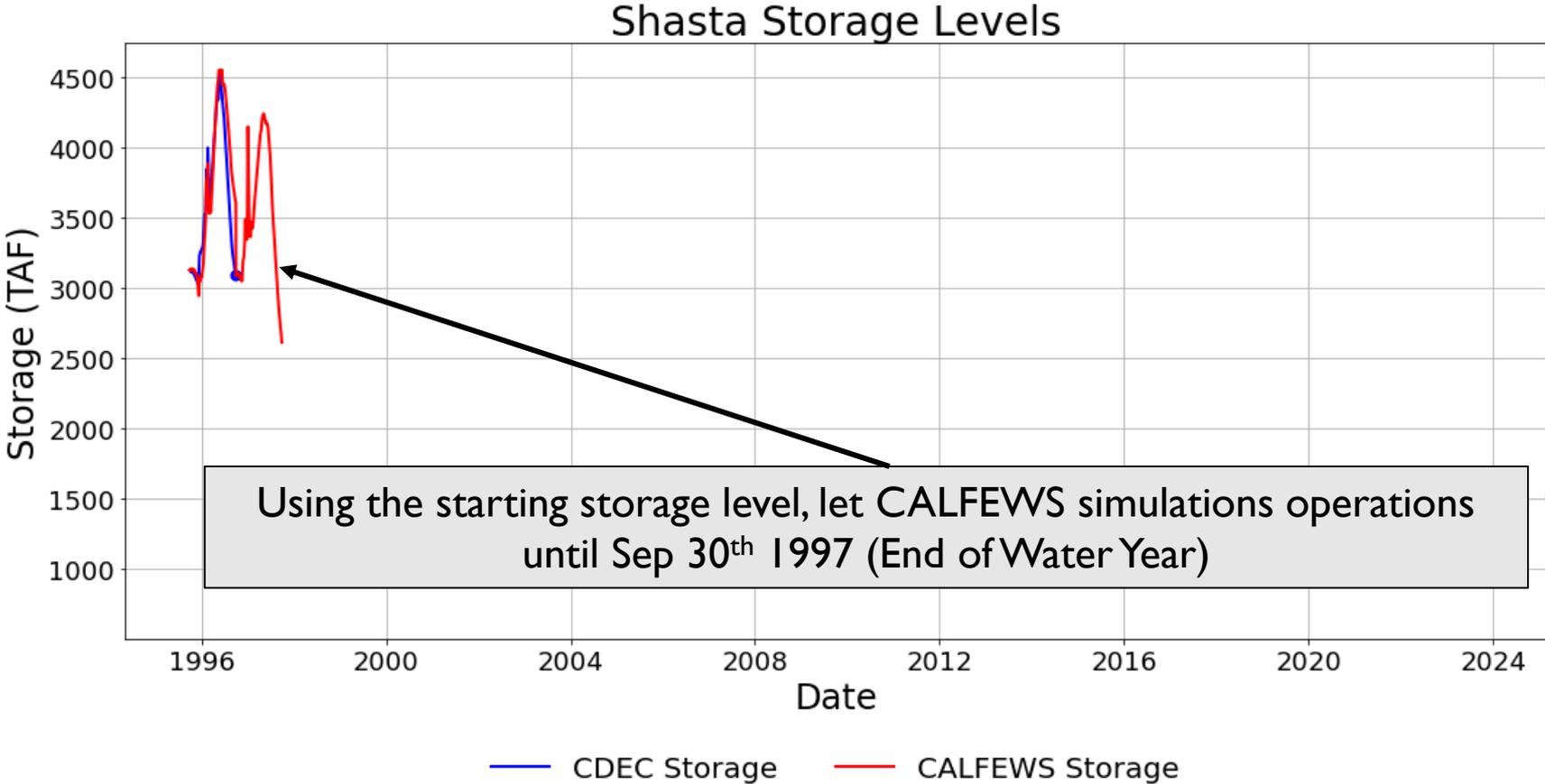
Storage Results



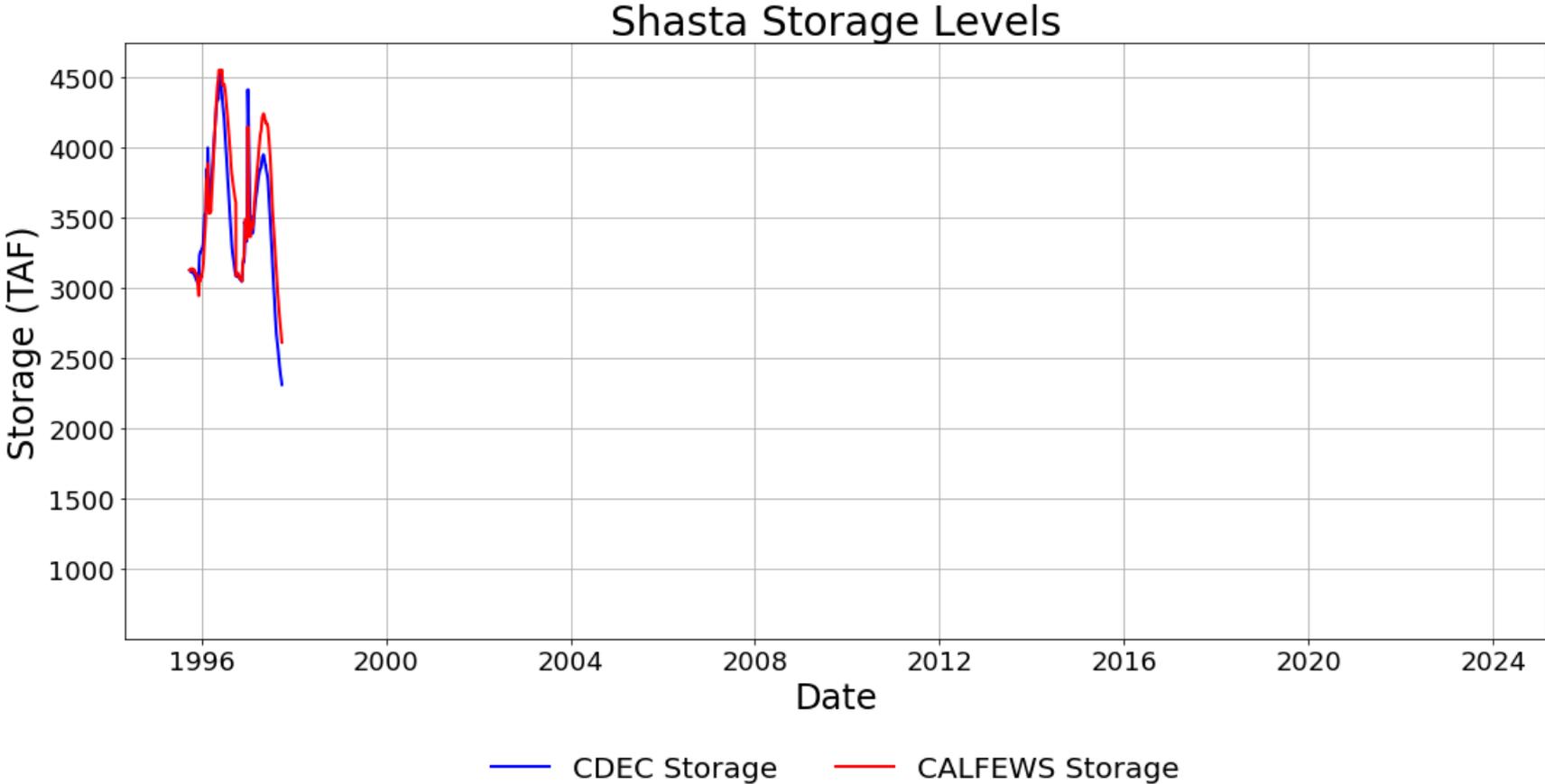
Storage Results



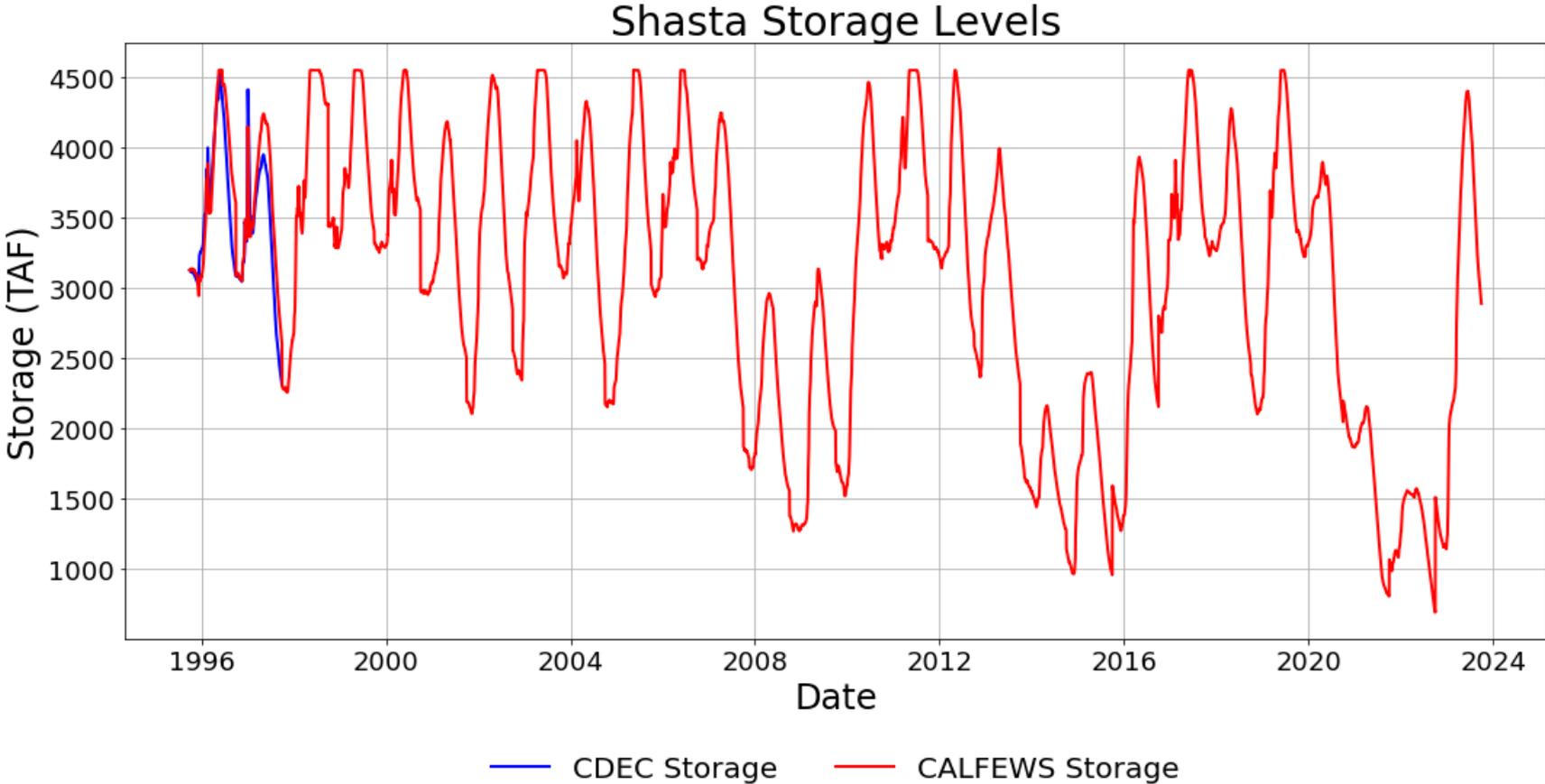
Storage Results



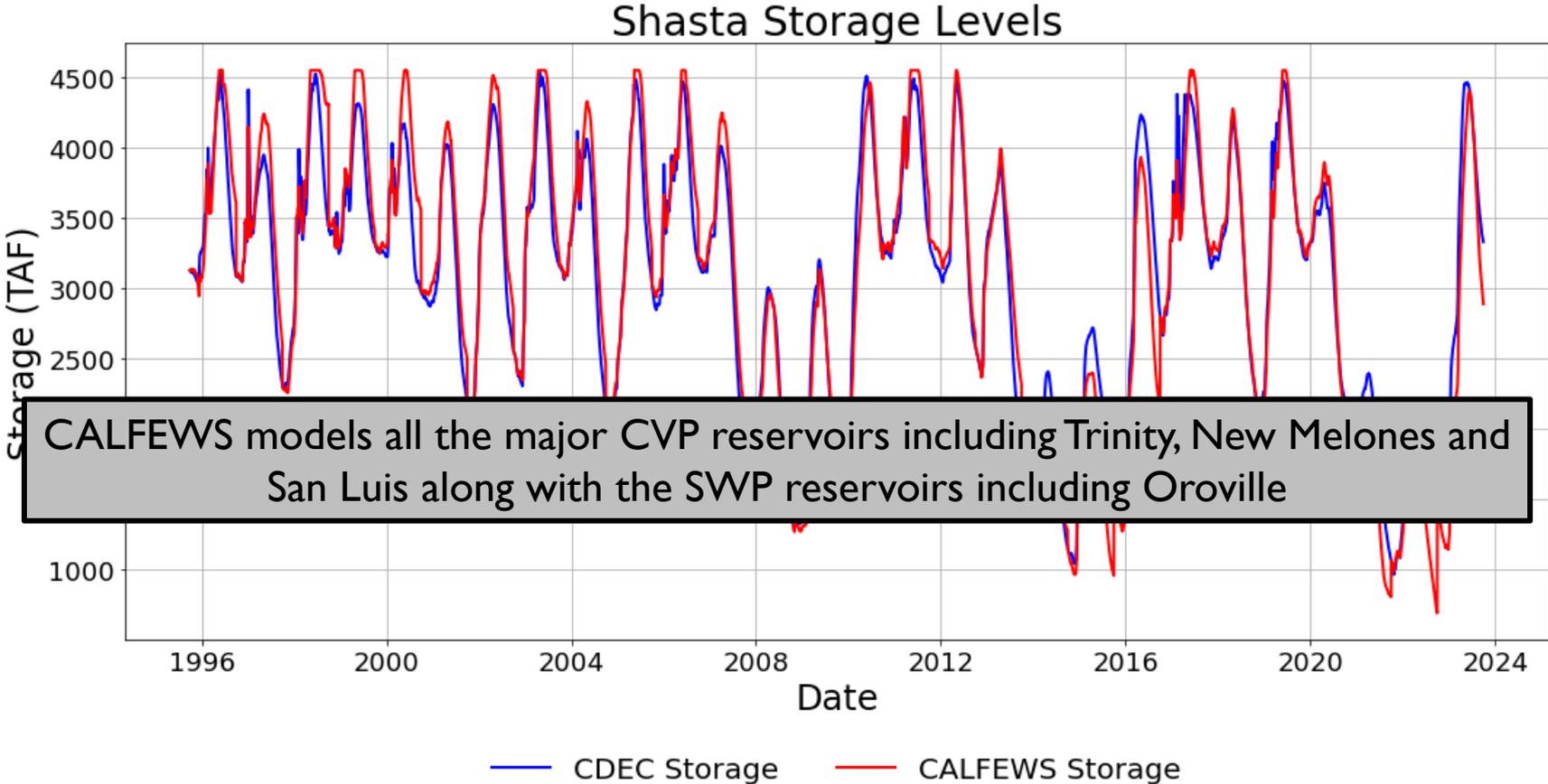
Storage Results



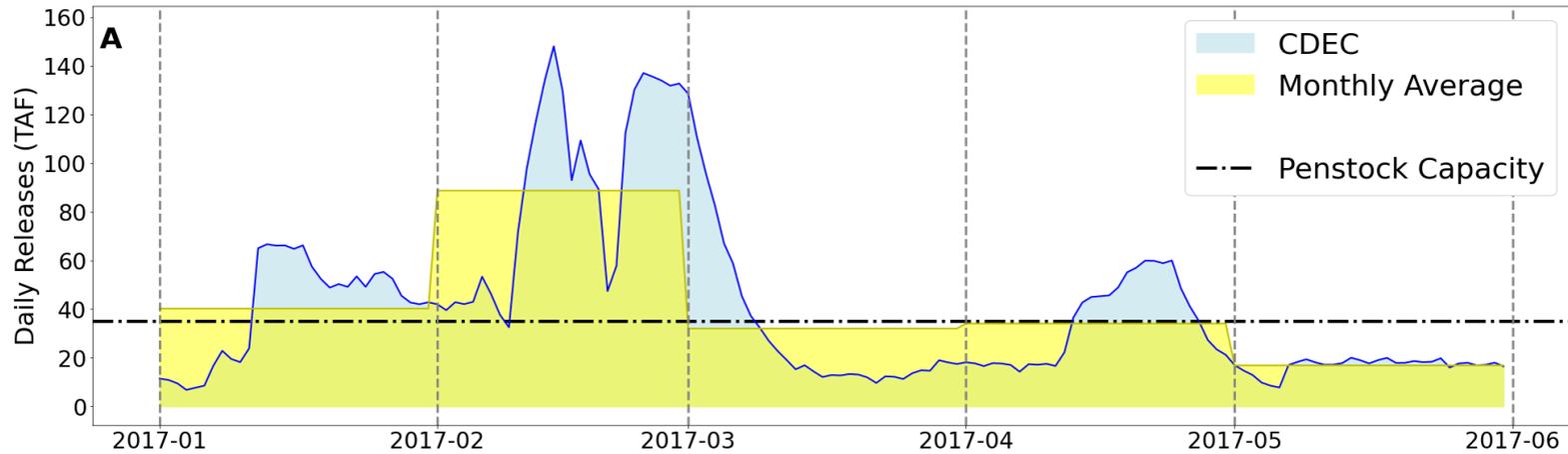
Storage Results



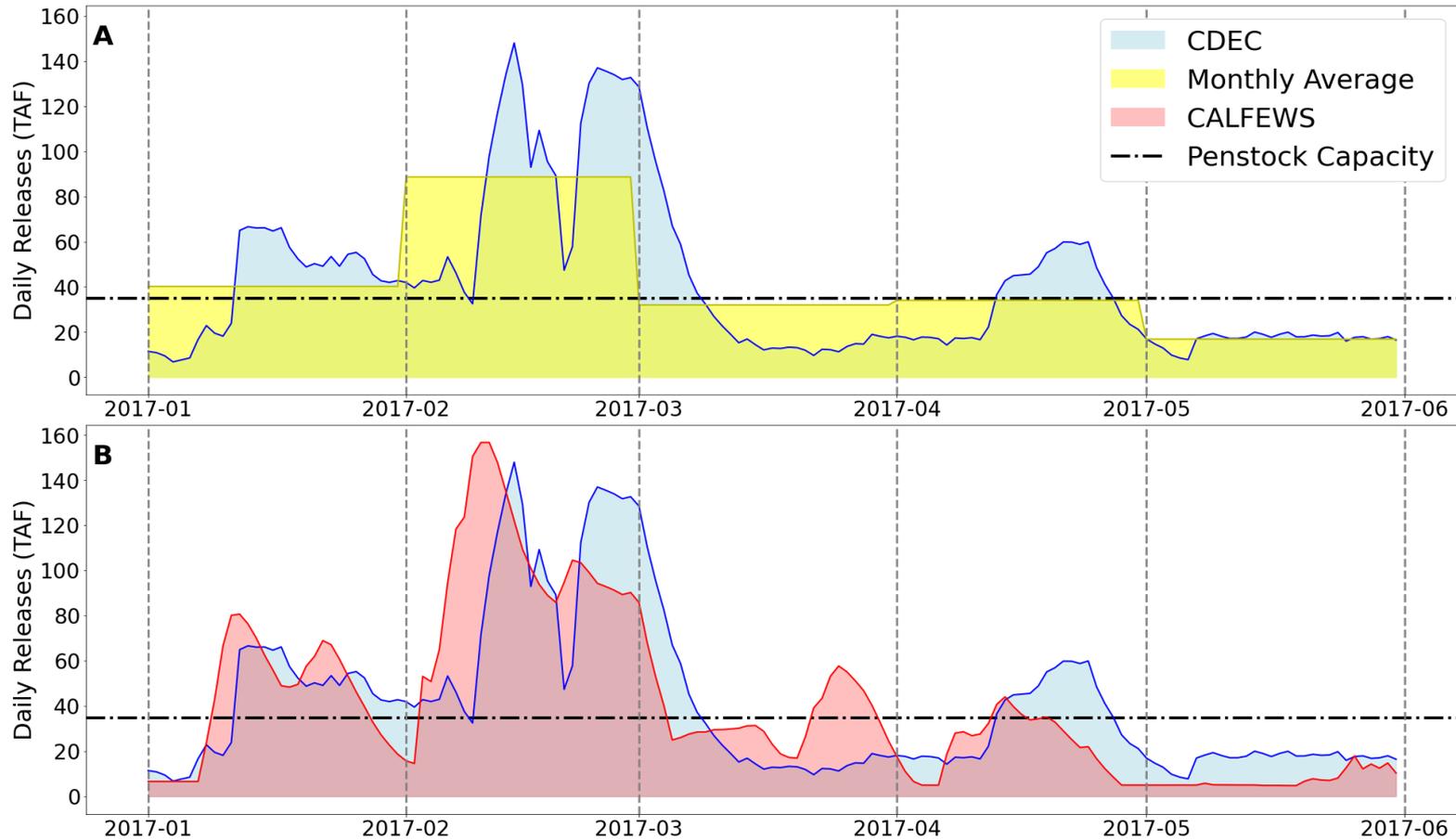
Storage Results



Let's investigate performance in WY 2017

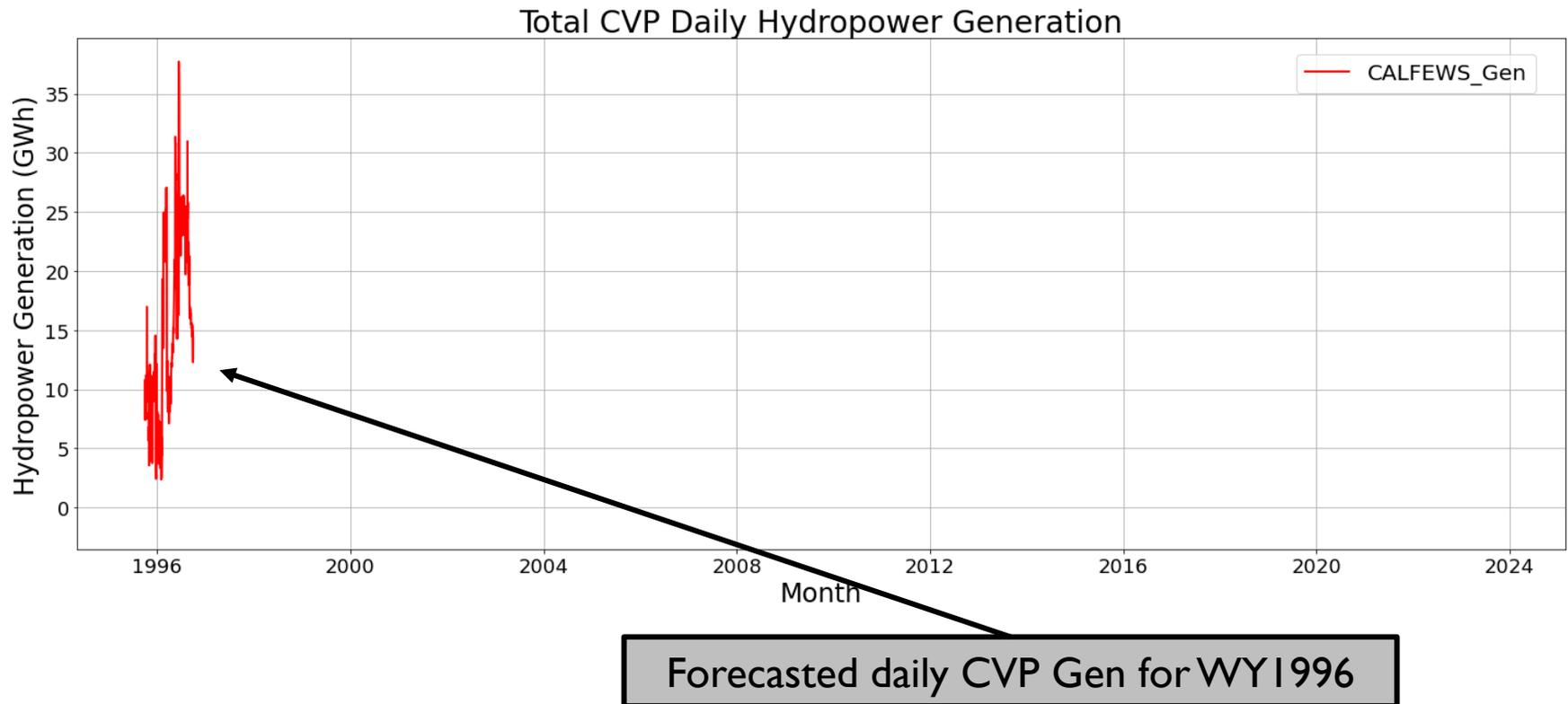


Let's investigate performance in WY 2017



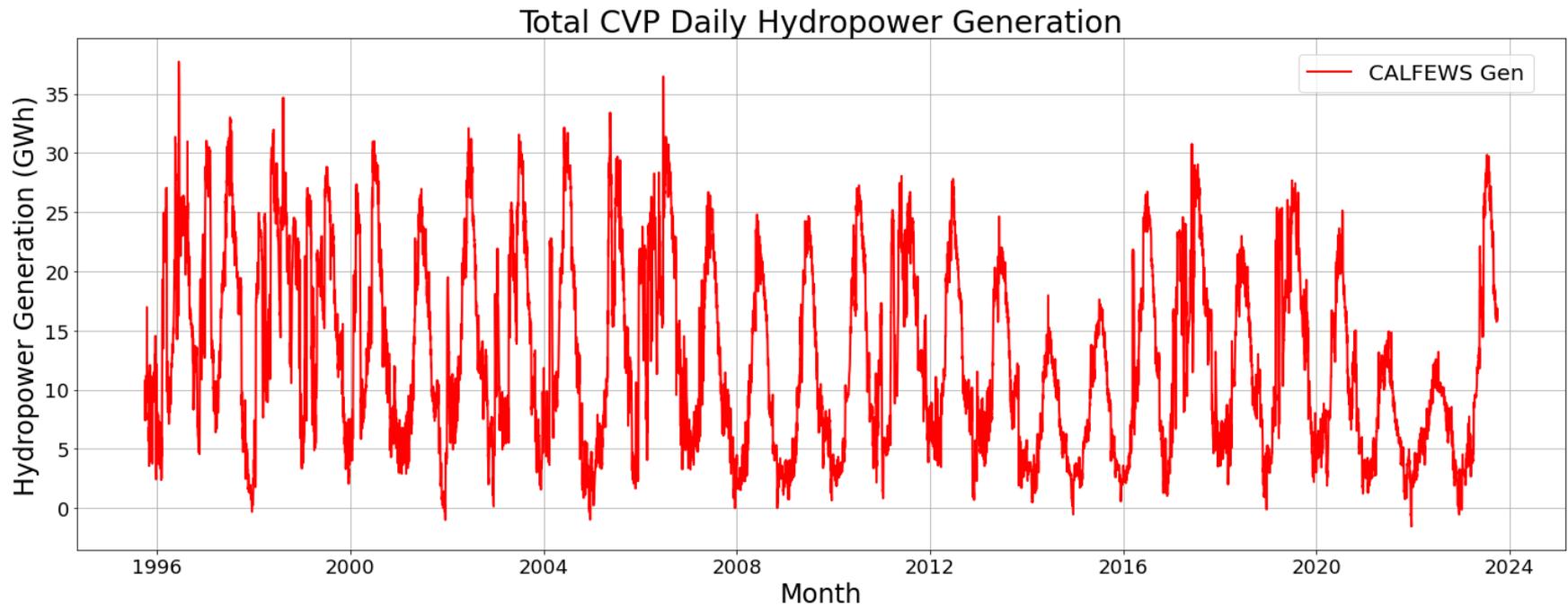
CVP Hydropower Generation Forecasting

- Total CVP Hydropower Generation is computed using forecasted storage and release values.



CVP Hydropower Generation Forecasting

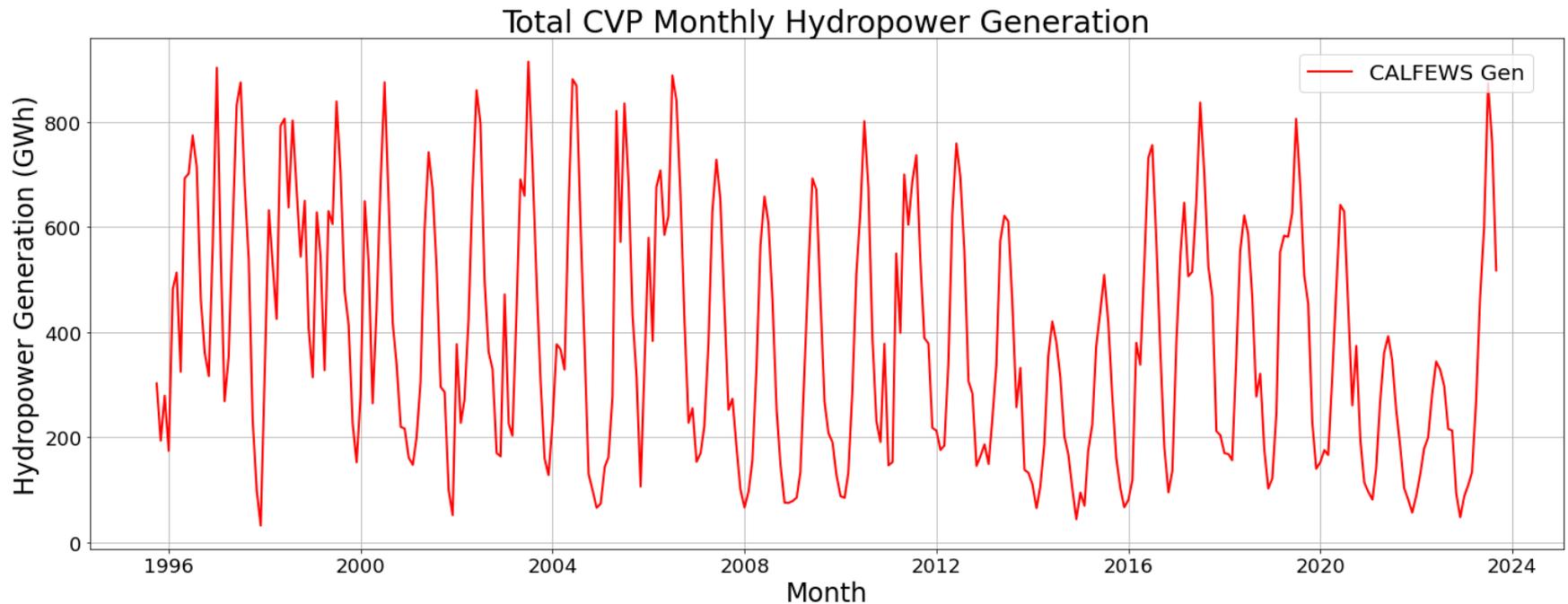
- Total CVP Hydropower Generation is computed using forecasted storage and release values.
- Total CVP Generation includes Shasta, Keswick, Trinity, J F Carr, Spring Creek, Folsom, Nimbus & New Melones powerplants



Forecasted daily CVP Gen for WY1996 – WY2023

CVP Hydropower Generation Forecasting

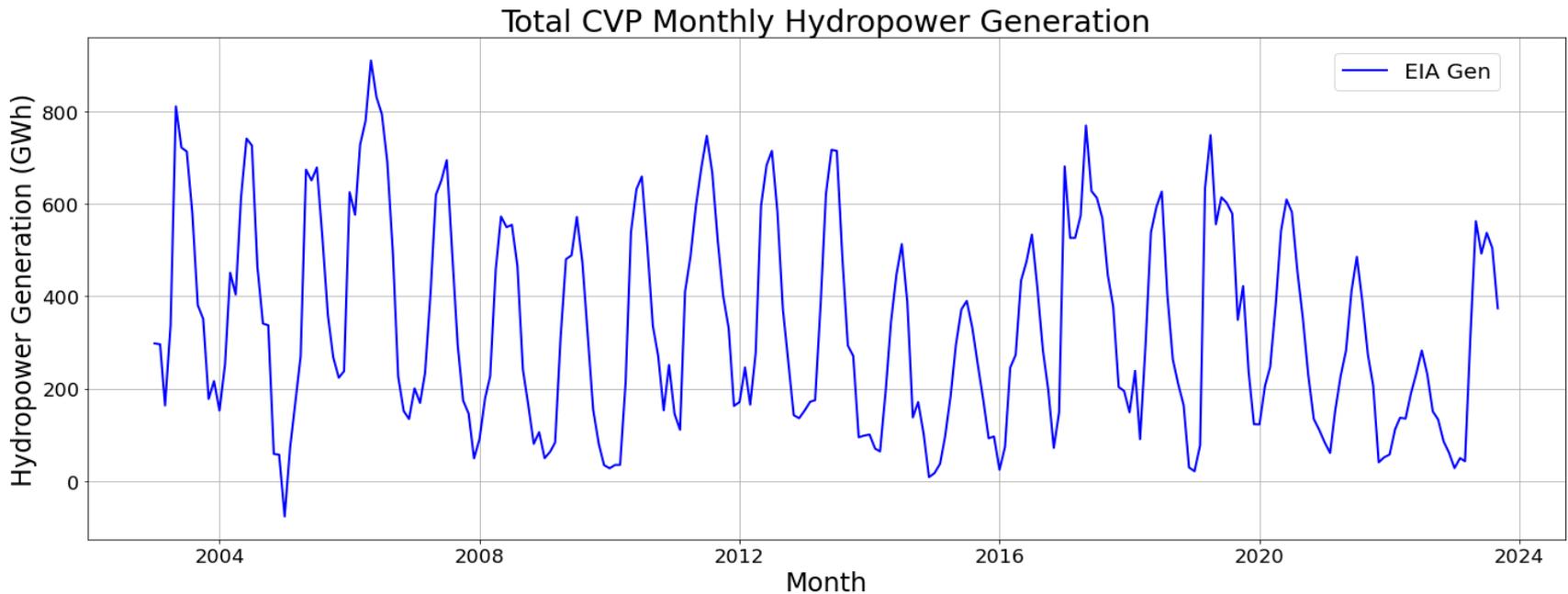
- Total CVP Hydropower Generation is computed using forecasted storage and release values.
- Total CVP Generation includes Shasta, Keswick, Trinity, J F Carr, Spring Creek, Folsom, Nimbus & New Melones powerplants



Forecasted monthly CVP Gen for WY1996 – WY2023

CVP Hydropower Generation Forecasting

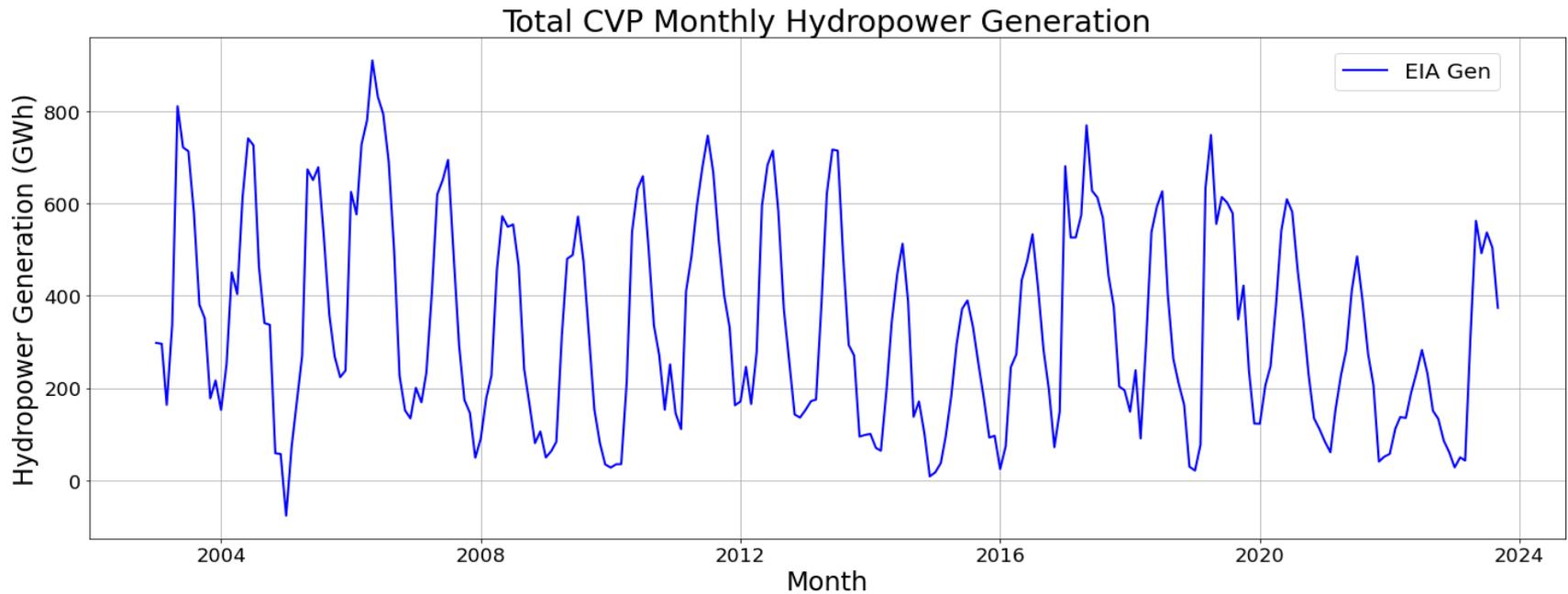
All powerplants in the USA are required to provide monthly generation values to the Energy Information Administration (EIA), which provides the data to the public



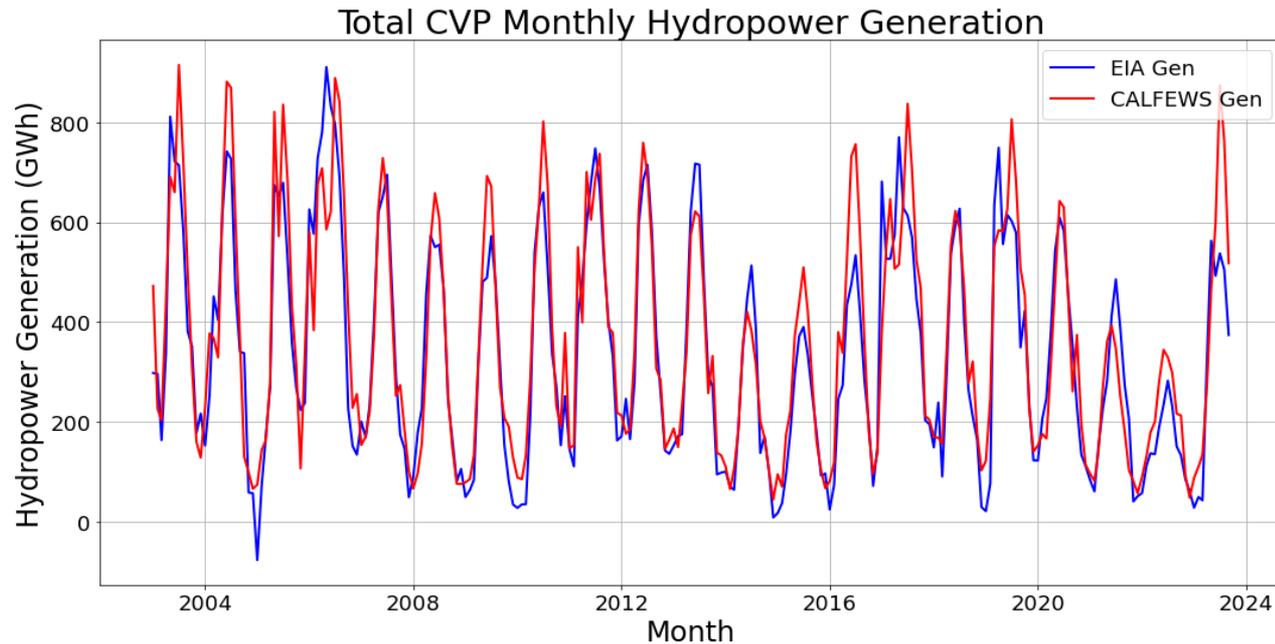
The Powerplants considered in the CVP Hydropower Generation are: Shasta, Trinity, J F Carr, Spring Creek, Keswick, Folsom, Nimbus, New Melones

CVP Hydropower Generation Forecasting

EIA Dataset = Validation Dataset



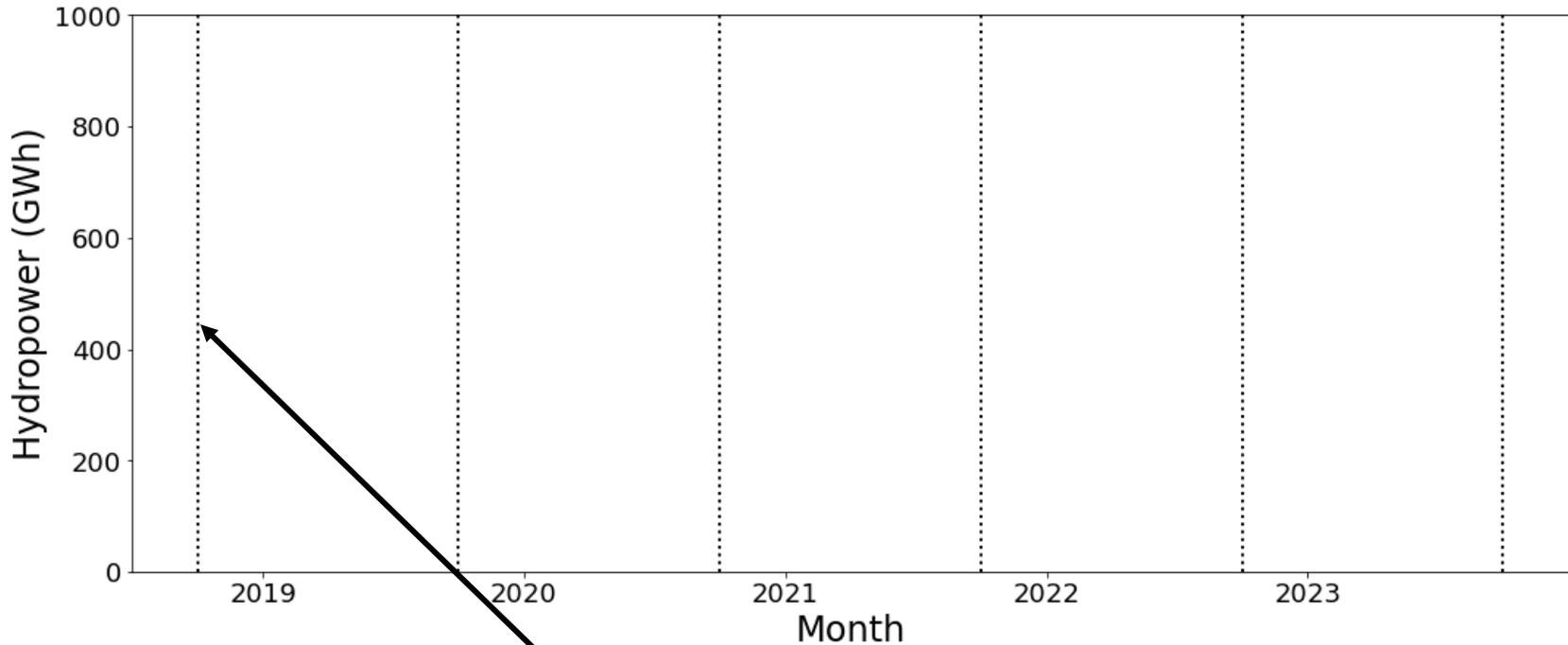
CVP Hydropower Generation Forecasting



Overall CALFEWS shows considerable skill in modelling total CVP hydropower generation over a year

5-yr Ensemble Forecasting

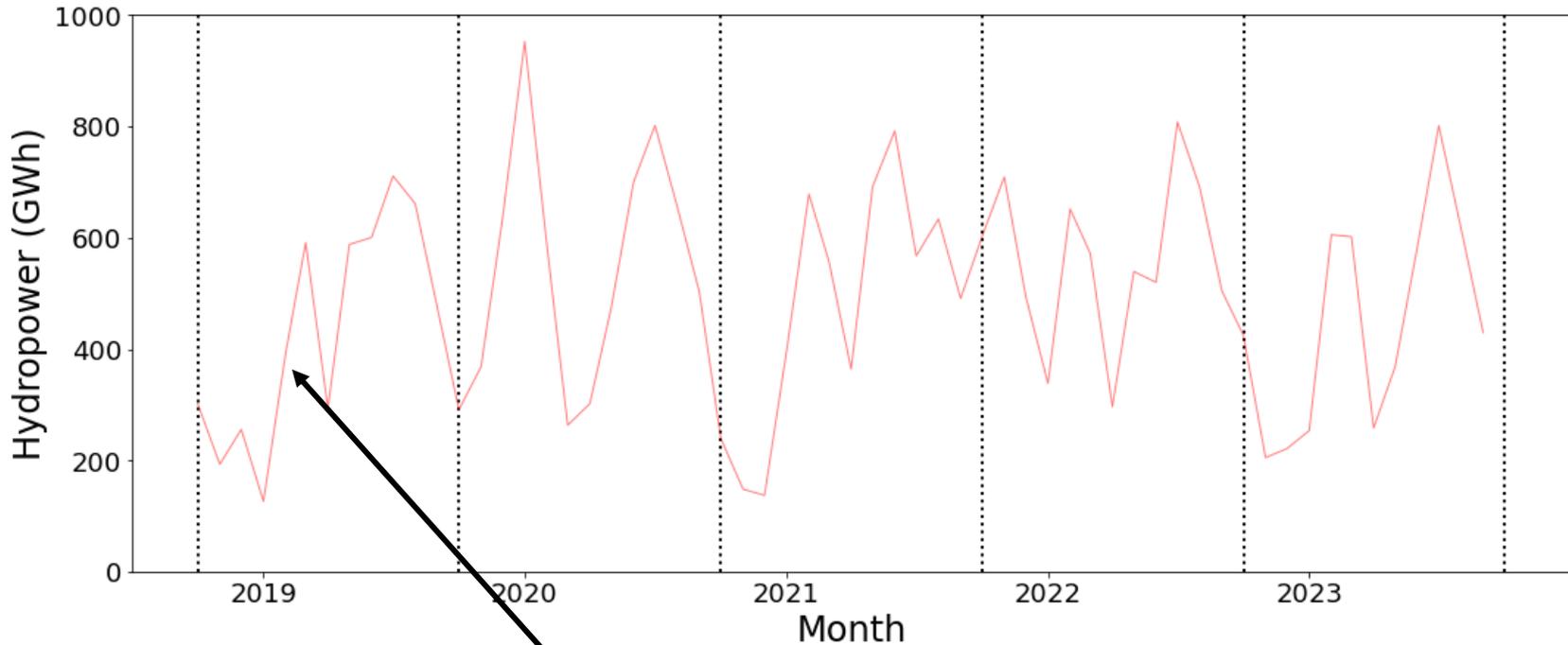
CVP Total Hydropower Generation (GWh)



Let's start simulations with initial conditions (storage levels) as on Oct-1st 2018

5-yr Ensemble Forecasting

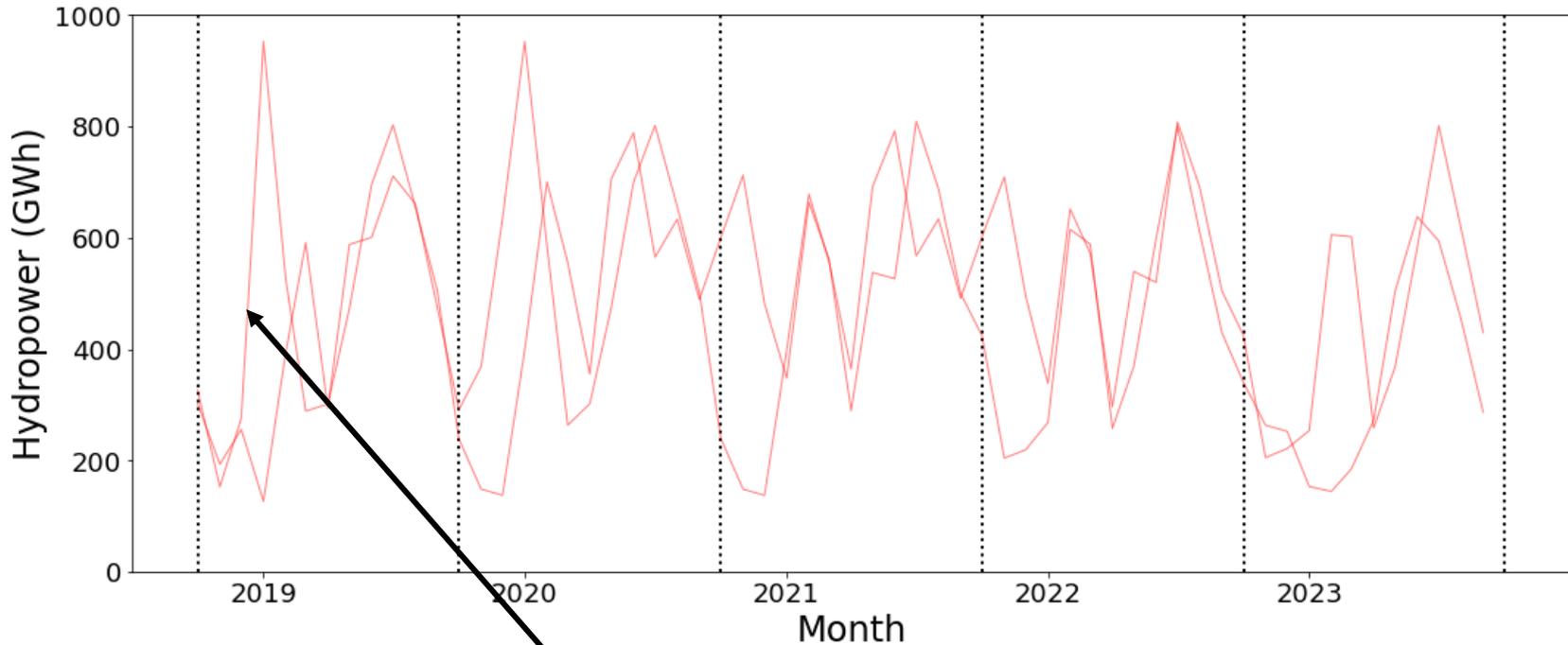
CVP Total Hydropower Generation (GWh)



Simulated hydropower from WY2019-2023 using input hydrology from WY1996-2000

5-yr Ensemble Forecasting

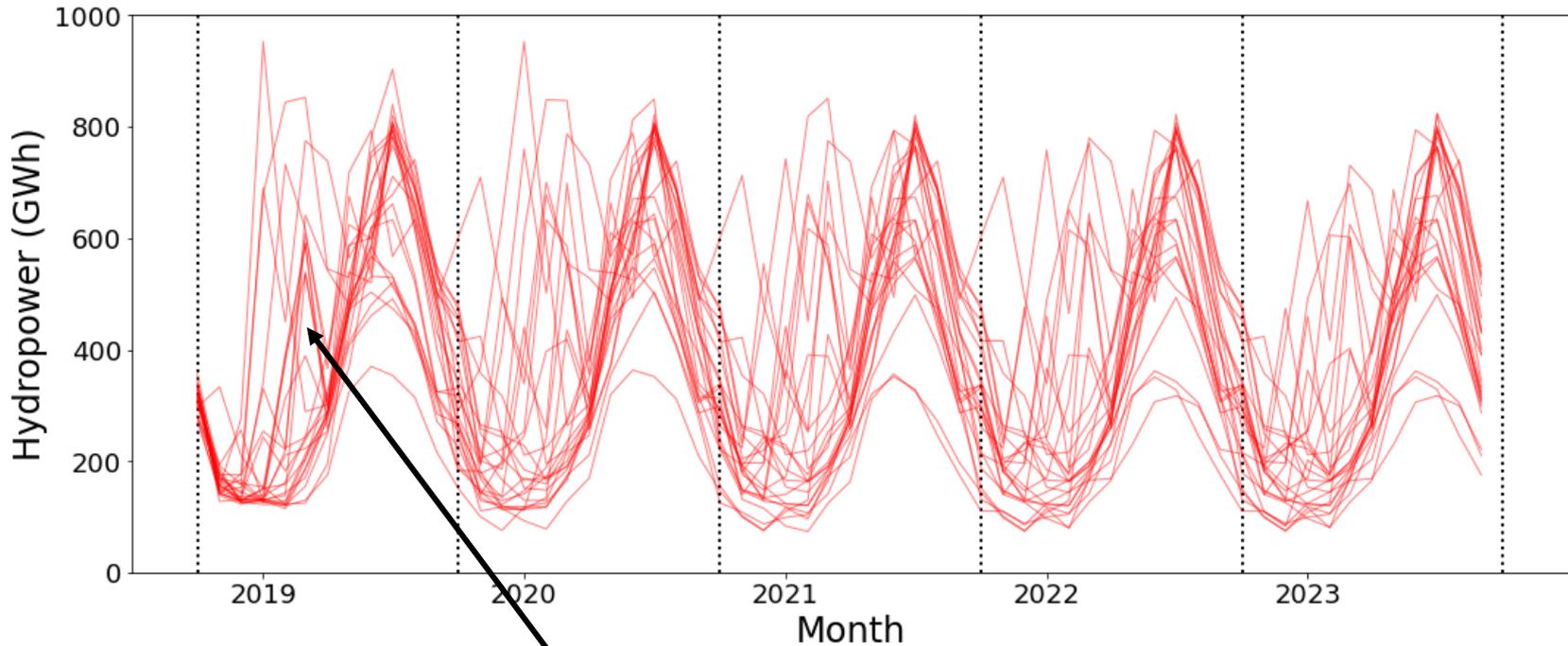
CVP Total Hydropower Generation (GWh)



Simulated hydropower from WY2019-2023 using input hydrology from WY1997-2001

5-yr Ensemble Forecasting

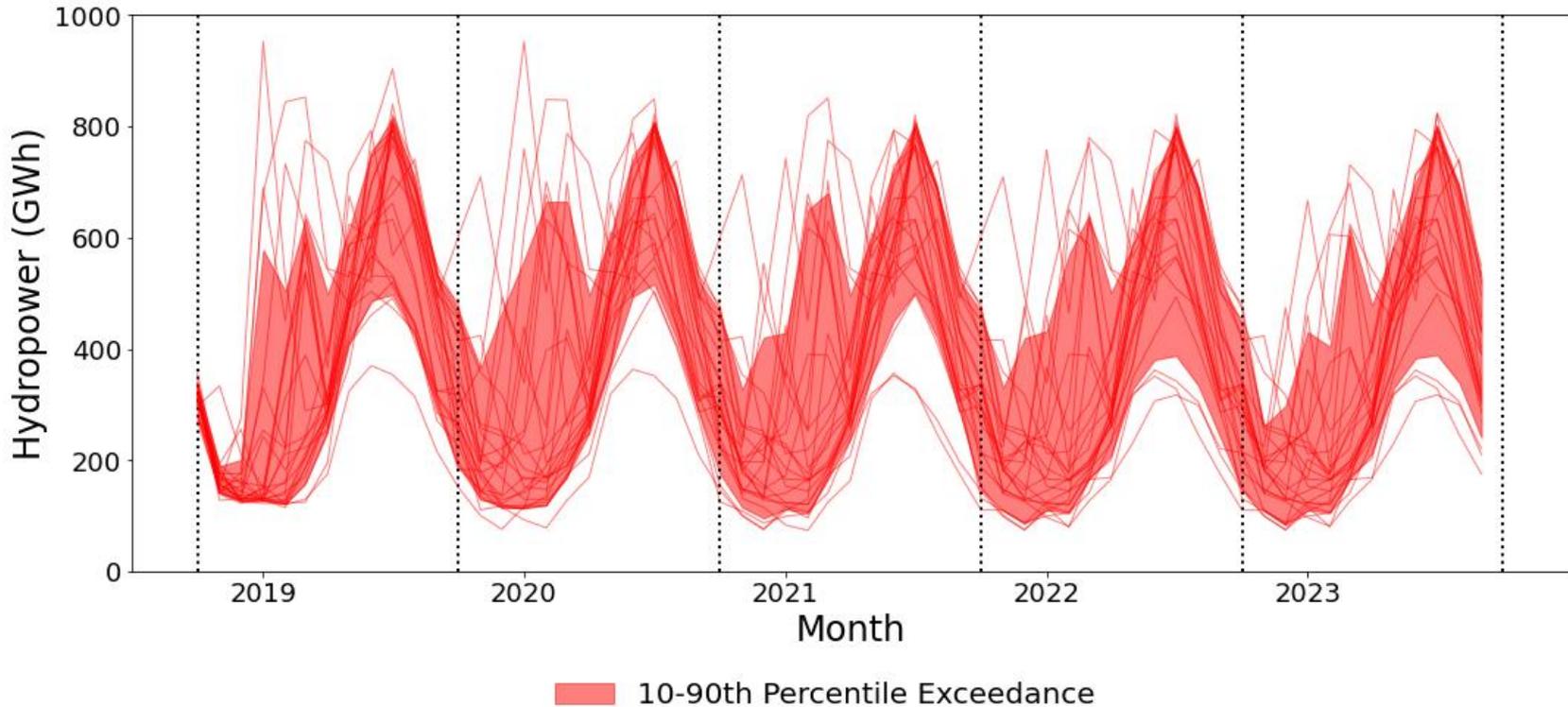
CVP Total Hydropower Generation (GWh)



Simulated hydropower from WY2019-WY2023 using input hydrology from all 5-yr combinations

5-yr Ensemble Forecasting

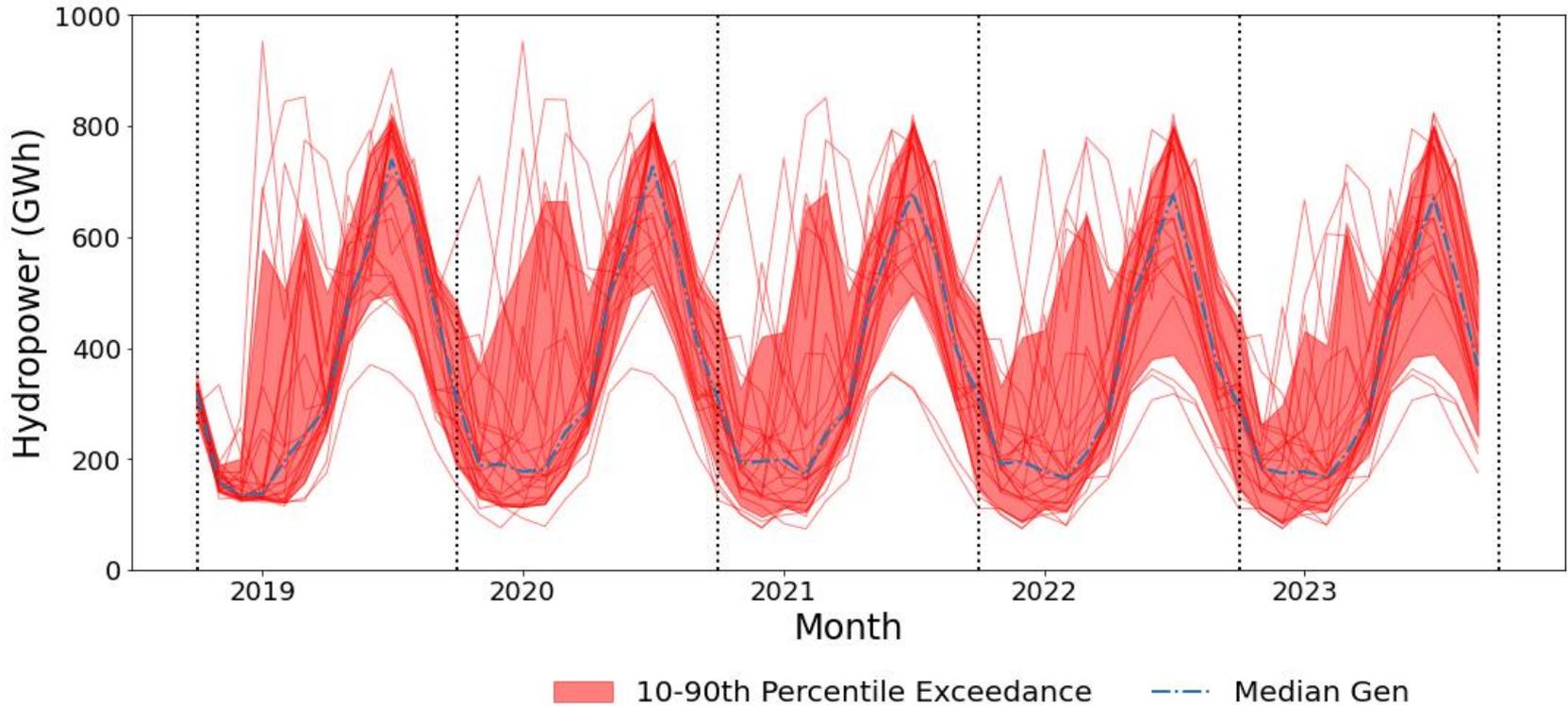
CVP Total Hydropower Generation (GWh)



10th – 90th Percentile Exceedance = 80% Probability Range

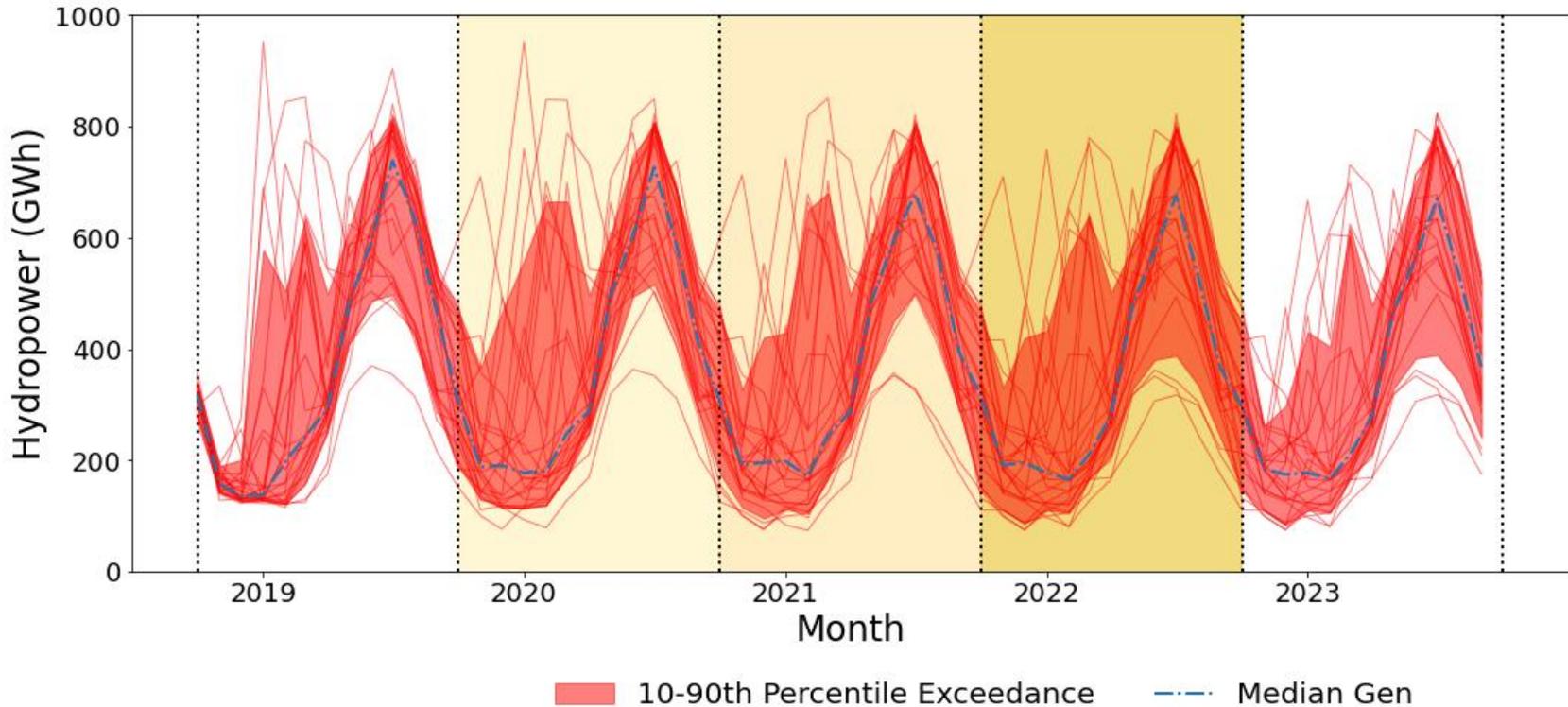
5-yr Ensemble Forecasting

CVP Total Hydropower Generation (GWh)



5-yr Ensemble Forecasting

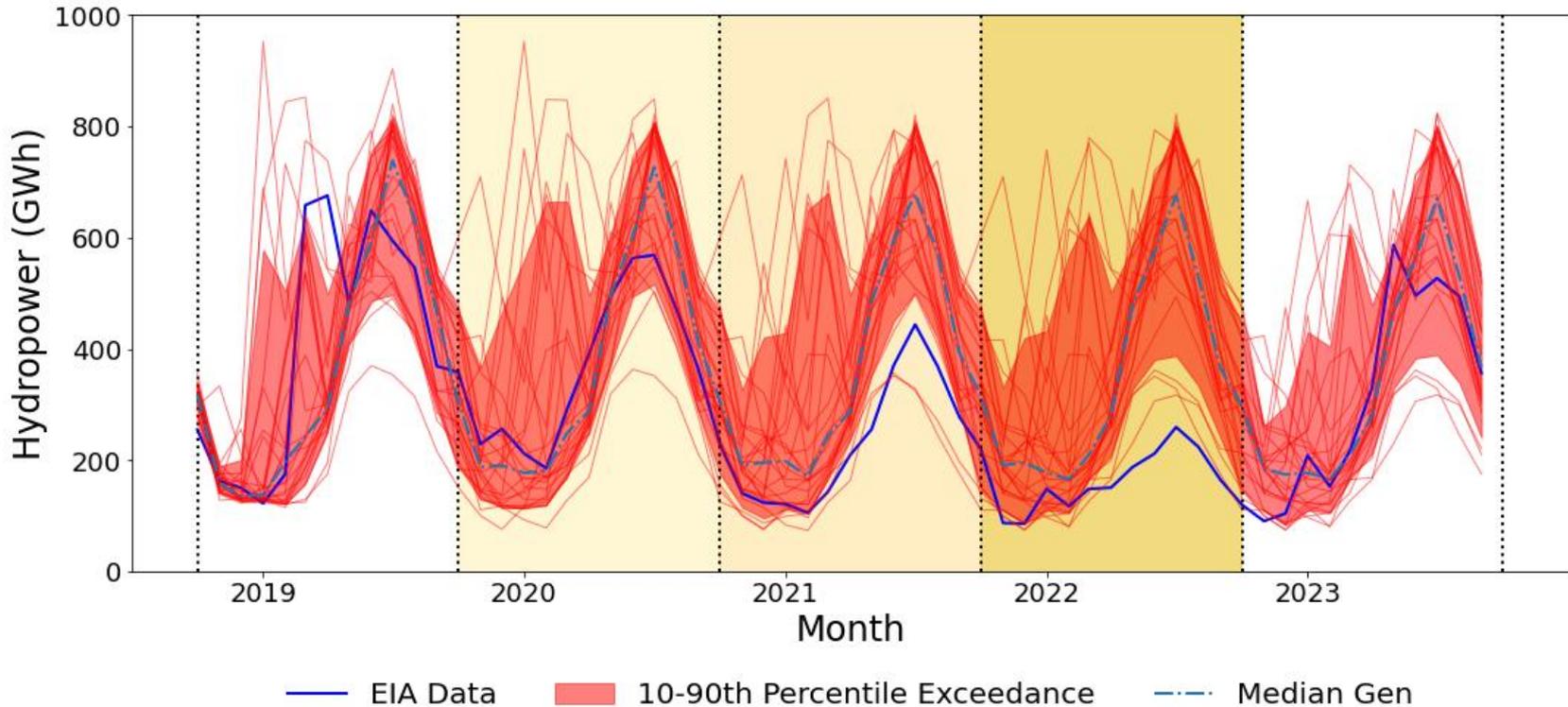
CVP Total Hydropower Generation (GWh)



Consecutive dry water years in California

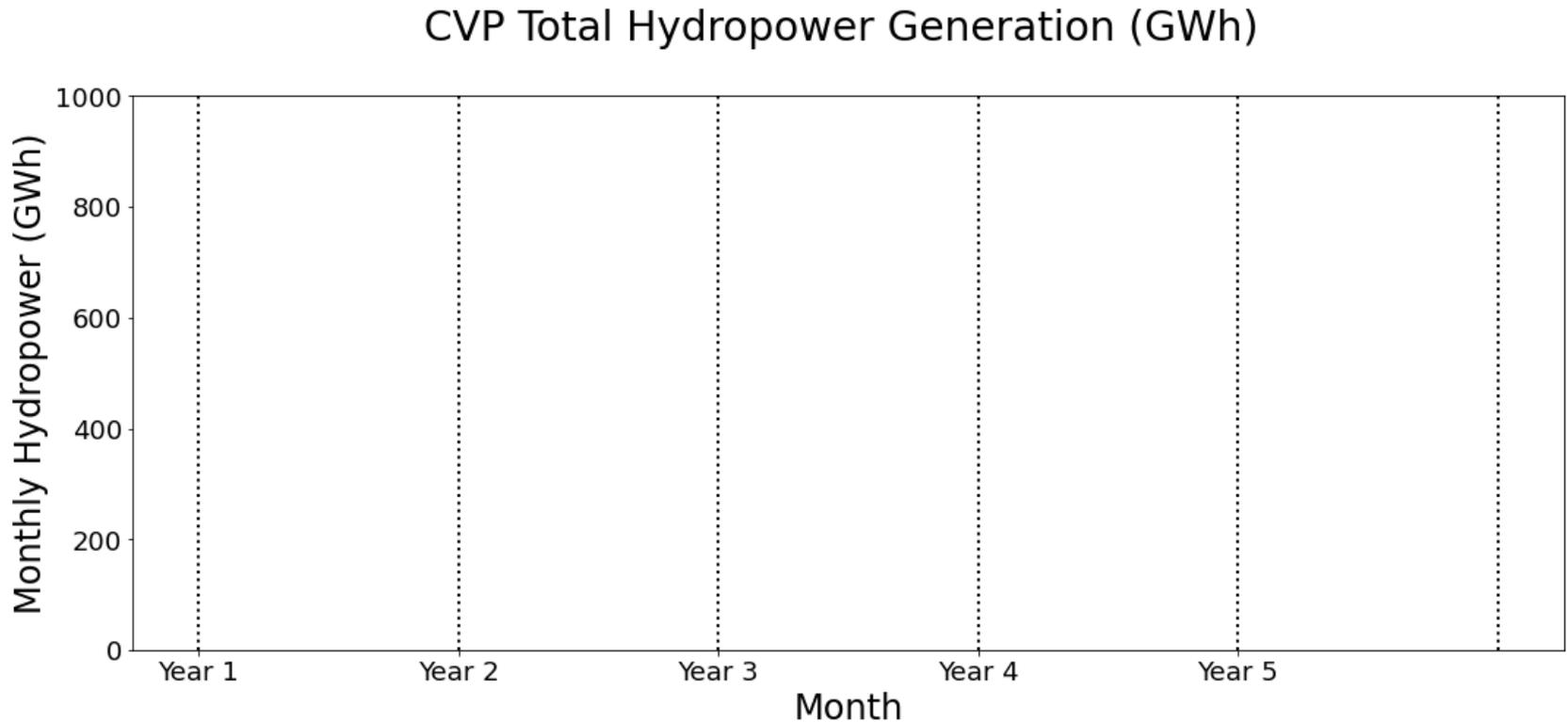
5-yr Ensemble Forecasting

CVP Total Hydropower Generation (GWh)



Overall CALFEWS shows considerable skill in long-term ensemble forecasting of total CVP hydropower

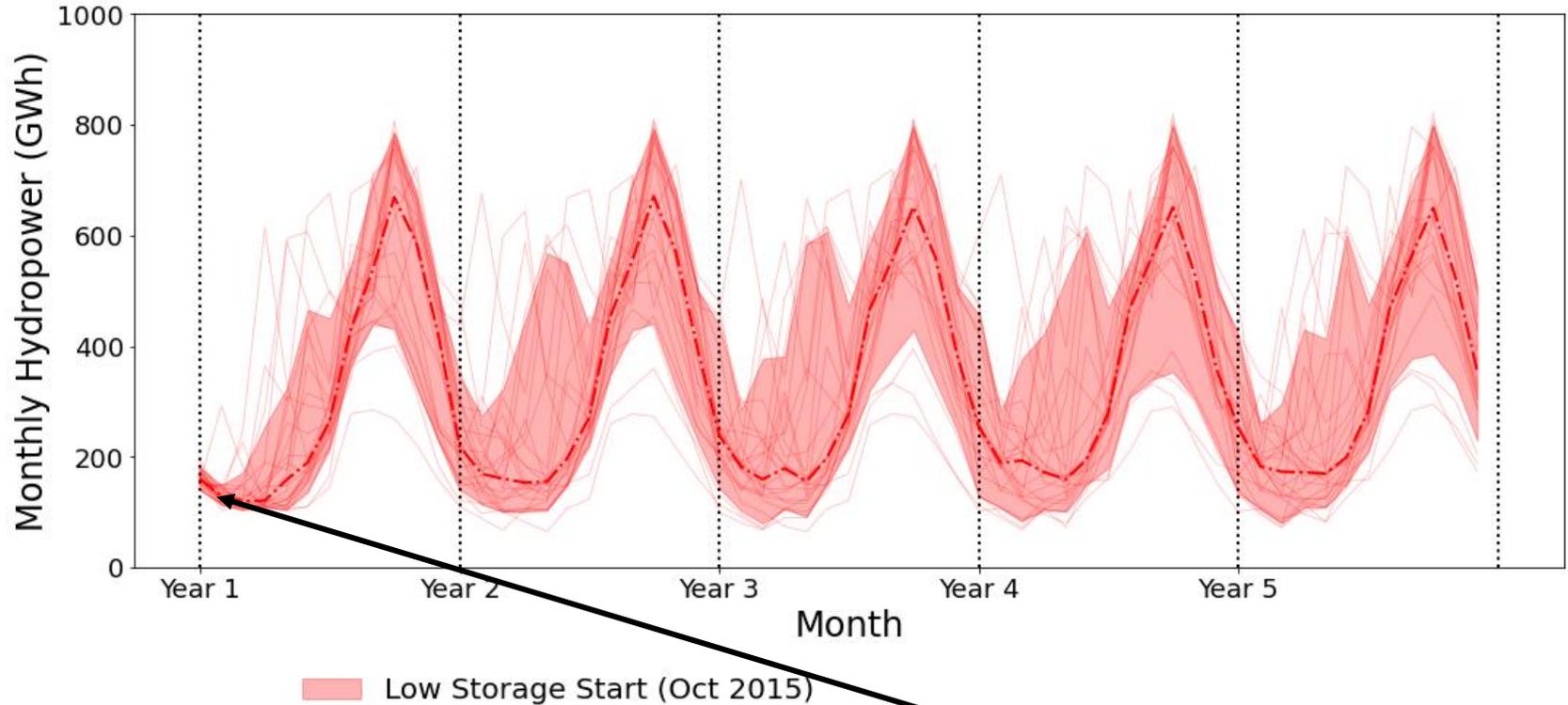
Initial Storage Levels & CVP hydropower



CALFEWS allows for the analysis of the climatology (all 5-yr inflow sequences) at any beginning storage level

Initial Storage Levels & CVP hydropower

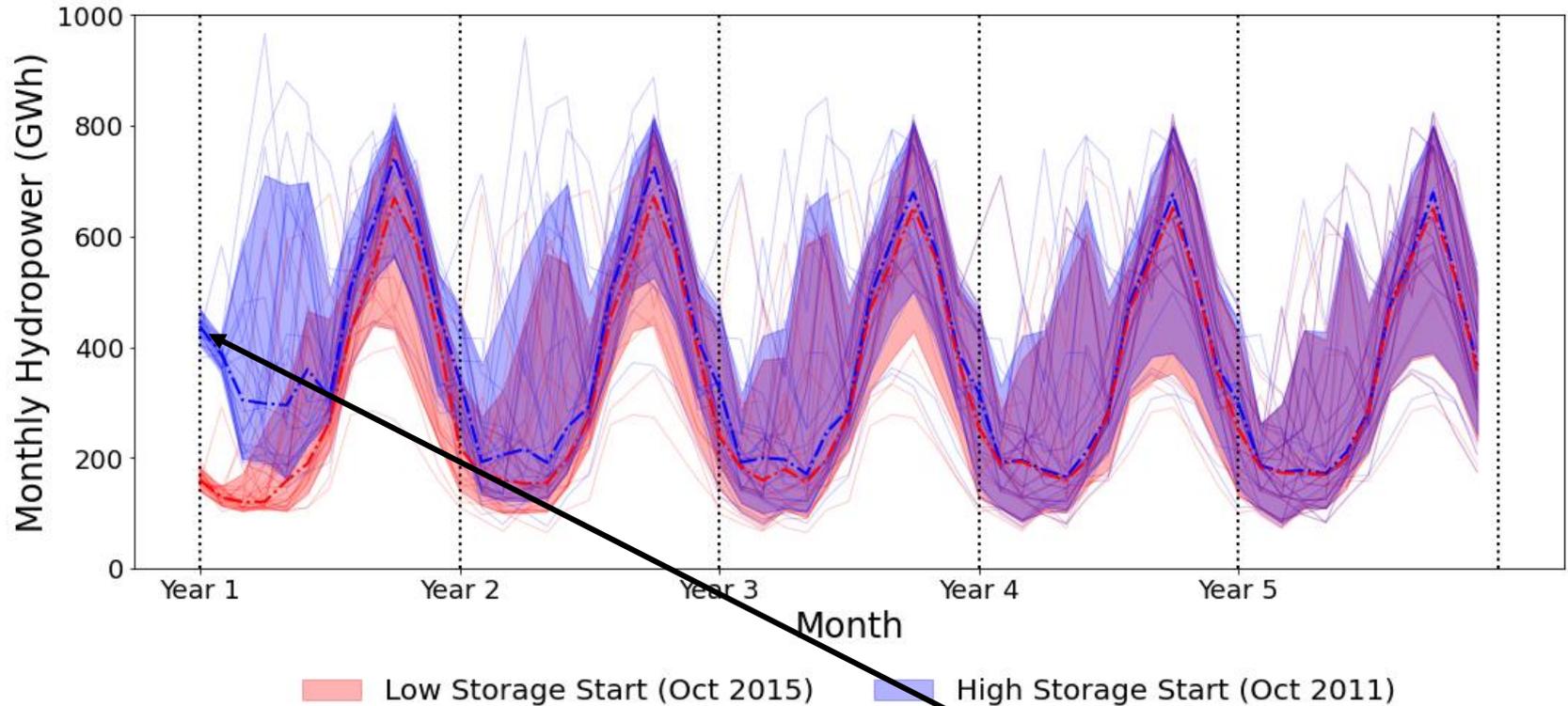
CVP Total Hydropower Generation (GWh)



Simulations with initial conditions (storage levels) as on Oct-1st 2015

Initial Storage Levels & CVP hydropower

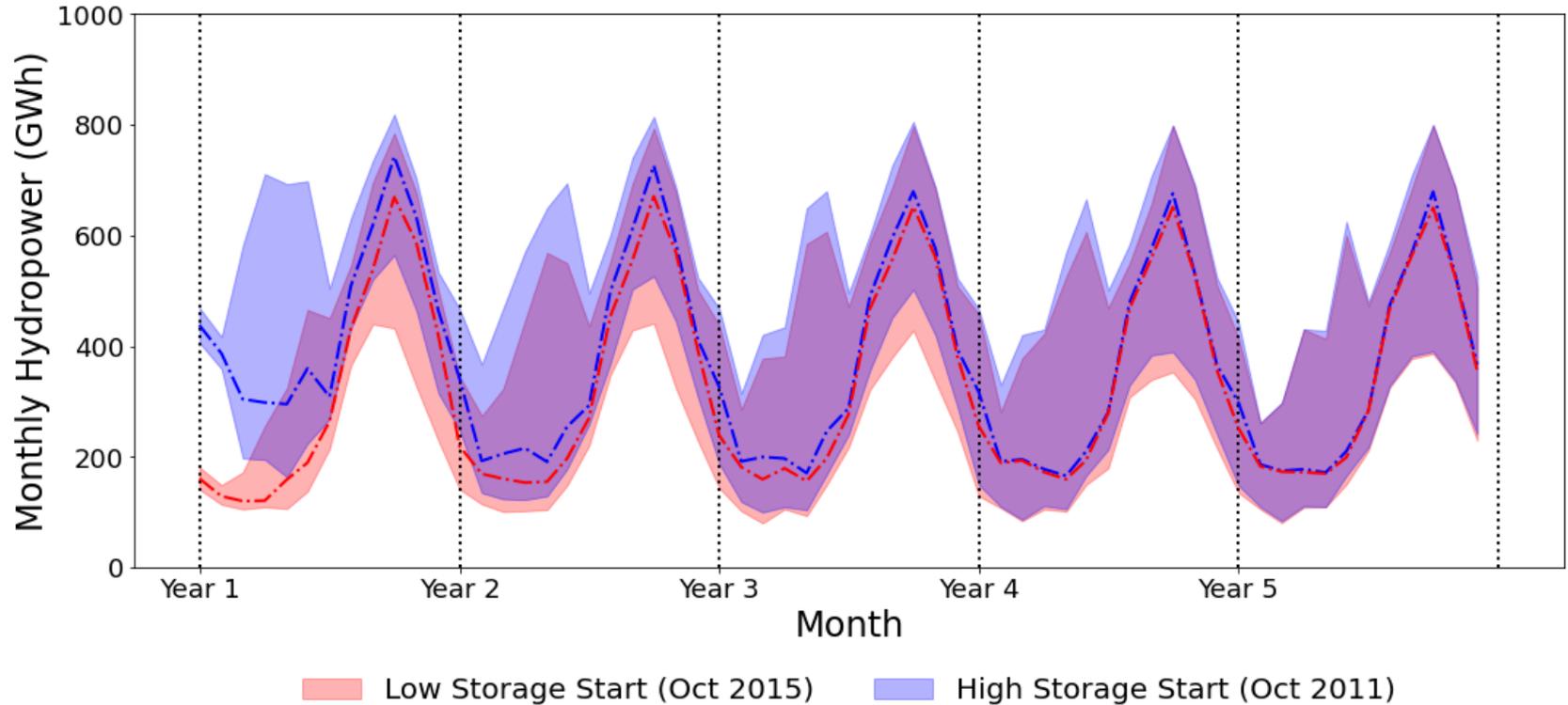
CVP Total Hydropower Generation (GWh)



Simulations with initial conditions (storage levels) as on Oct-1st 2011

Initial Storage Levels & CVP hydropower

CVP Total Hydropower Generation (GWh)



Conclusions

Thank you!

Support provided by:

U.S. DEPARTMENT OF
ENERGY | Office of ENERGY EFFICIENCY
& RENEWABLE ENERGY
WATER POWER TECHNOLOGIES OFFICE



UNC Institute for Risk Management and Insurance Innovation (IRMII)

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