Current Research Efforts

CBRFC Stakeholder Engagement Meeting

Wednesday, November 8

Outline

- Stakeholder driven initiatives
- NWS driven initiatives
- Office driven initiatives

- Work Group led by Southern Nevada Water Authority consisting of basin stakeholders, Reclamation, and the CBRFC

- *Advance scientific understanding* to improve the accuracy of hydrological forecasts *and projections*, to enhance the performance of predictive tools, and to *better understand* the uncertainty related to future supply and demand conditions in the Colorado River Basin

- Group has been invaluable in prioritizing research, leveraging funding opportunities, and working with partners to develop applied research projects

CBRFC Forecasts Using ASO Data - Method

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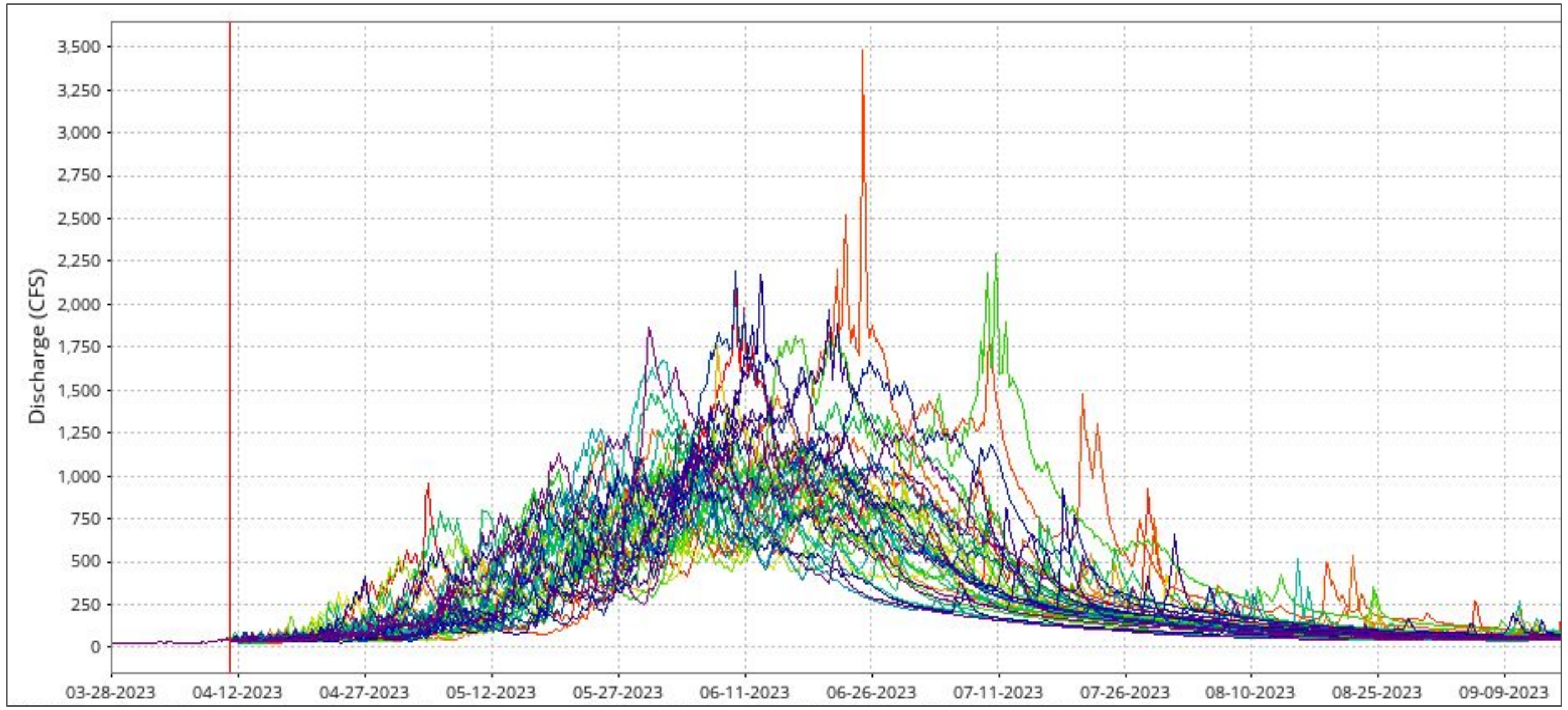
Convert 50m gridded ASO SWE product to mean areal SWE value
-for each catchment (elevation zone) in RFC hydrologic model

Replace operational snow model (SNOW-17) SWE with ASO SWE
-in an 'offline' version of model

Run Ensemble Streamflow Prediction (ESP) model
-with new (ASO) snow states
-uses 1991-2020 air temperature and precipitation
-produces 30 different hydrographs



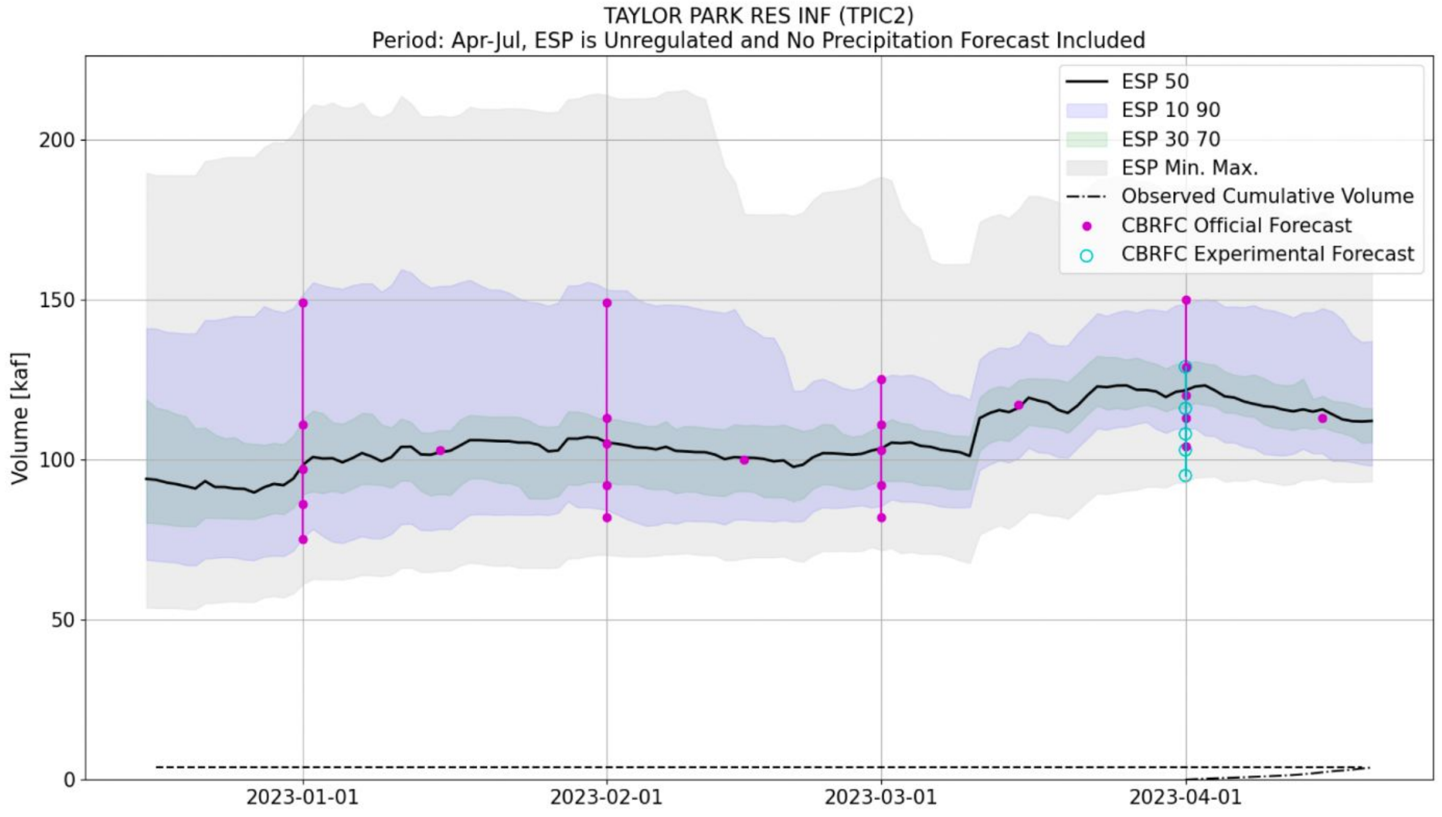
Create experimental forecast product.

Experimental Seasonal (Apr - Jul) CBRFC Forecast with direct insertion of estimated SWE from airborne lidar survey

Location: Taylor - Taylor Park Reservoir (TPIC2)

Date of Flight: April 1, 2023

This experimental forecast product is provided for information purposes only and is not intended as an official forecast product of the Colorado Basin River Forecast Center (CBRFC). The experimental forecast shown in blue on the figure and provided in the table is created by running the Ensemble Streamflow Prediction (ESP) model after direct insertion of basin average snow water equivalent (SWE) from Airborne Snow Observatory Inc. (ASO) into the CBRFC's operational, calibrated, and lumped parameter snow model (SNOW-17). Please contact the CBRFC with any questions regarding these numbers or figures.



Forecast / Exceedance Value	ESP90	ESP70	ESP50	ESP30	ESP10
CBRFC Experimental Forecast 4/1/2023	95	103	108	116	129
CBRFC Official Forecast 4/1/2023	104	113	120	129	150

Probabilistic forecast volumes in thousands of acre-feet (kaf). Columns indicate exceedance values.

CBRFC Experimental Forecast Example - Granby Reservoir Inflow (2022)

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Experimental Seasonal (Apr - Jul) CBRFC Forecast with direct insertion of estimated SWE from airborne lidar survey

Location: Colorado - Lake Granby, Granby, Nr (GBYC2)

Date of Flight: April 18, 2022

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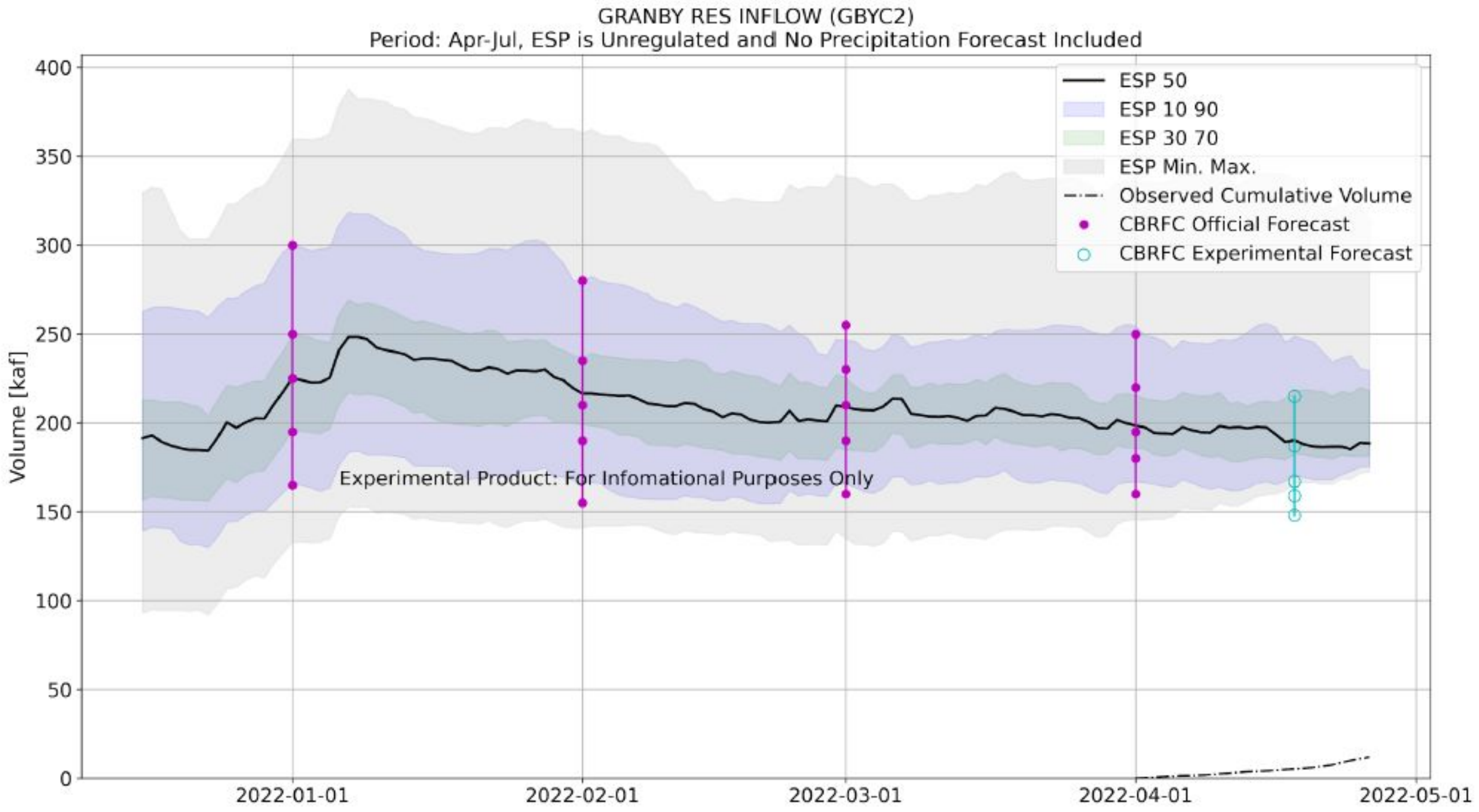


Forecast / Exceedance Value	ESP90	ESP70	ESP50	ESP30	ESP10
CBRFC Experimental Forecast 4/18/2022	148	159	167	187	215
CBRFC ESP Model Guidance 4/18/2022	171	182	190	218	249

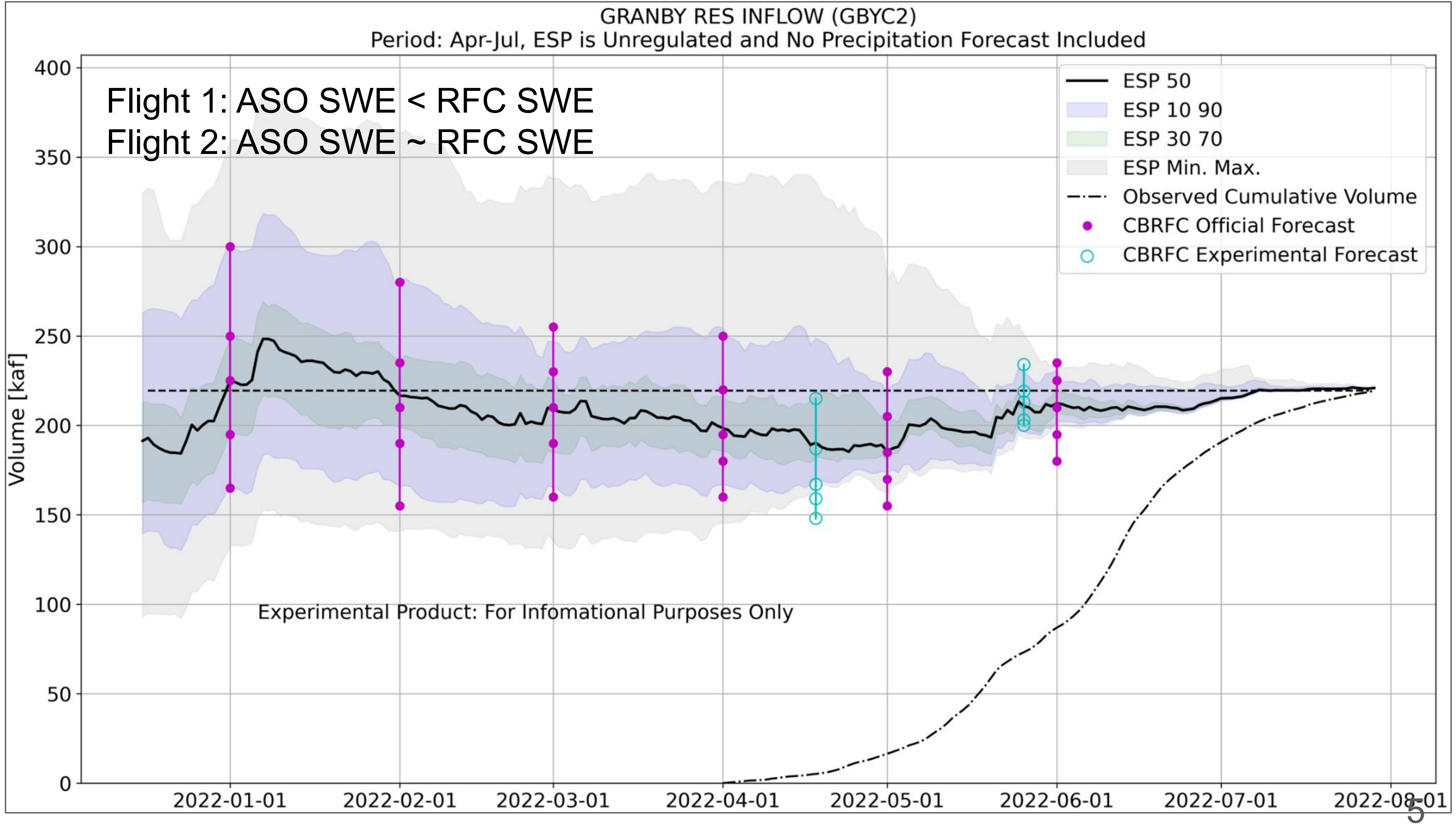
Probabilistic forecast volumes in thousands of acre-feet (kaf). Columns indicate exceedance values.

Contact: cbrfc.operations@noaa.gov - https://www.cbrfc.noaa.gov/us/us.php

<-Middle of season experimental forecast product

April-July Forecast Period

End of season graphic - multiple ASO flights/verification



Other Potential Datasets

- Other Snow datasets
  - University of Colorado
  - SWANN and other gridded, data-assimilation products
  - SNODAS
  - Snow data is the priority for evaluation in CBRFC's upcoming "landing strip"

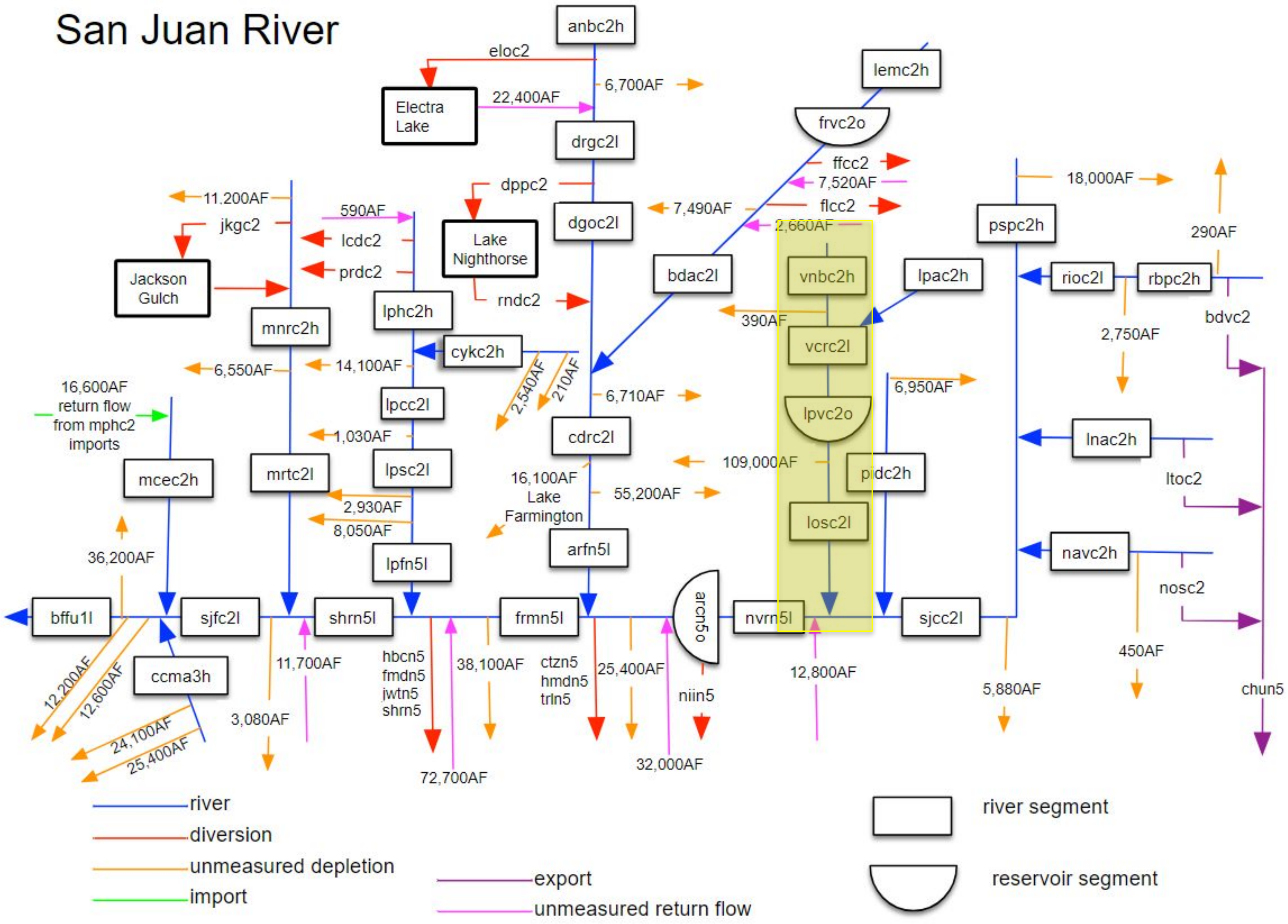
- Soil Moisture datasets
  - Ohio State University
  - New and augmented networks

- Evapotranspiration
  - Open ET
  - Dynamic ET

Importantly, we would like historical data when possible. This helps us make decisions about how effective information is at improving our forecasts - we want to make sure model is skillful and reliable over the long run

Modeling Unmeasured Depletions

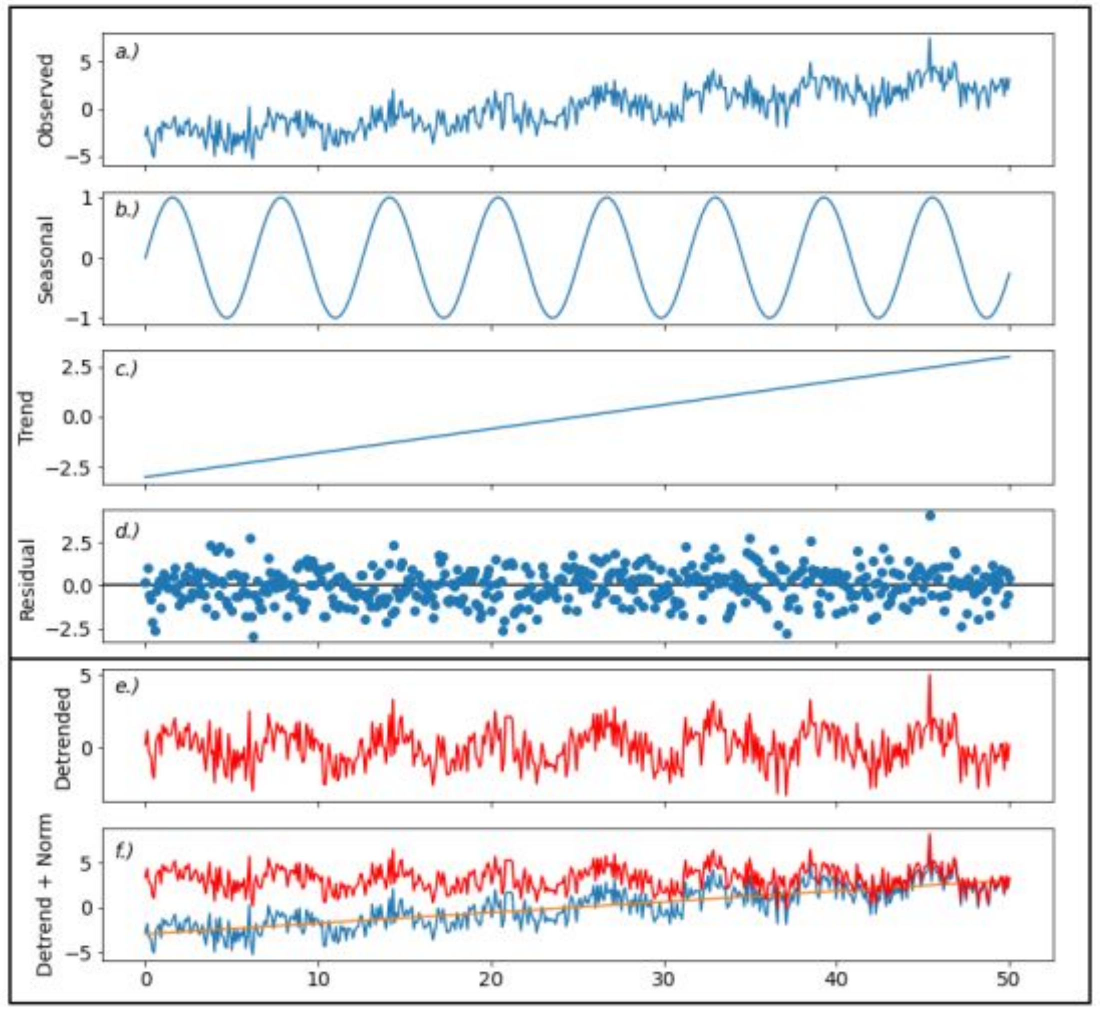
- Worked with RTI to develop a new method for estimating unmeasured depletions in Colorado
  - Leveraged expansive water use dataset maintained by the State of Colorado
  - Utilizes Penman-Monteith method (as opposed to legacy Blaney Criddle)
- Operationally implemented over Los Pinos River Basin
  - Big step! Research to Operations (R2O) can be tricky at times
  - CBRFC did some extensive prep work to get this in
- Continued evaluation necessary



Detrended Temperature Analysis

Worked with RTI to examine the impact of detrended temperature data

- Part of larger project that is also looking at the impact of incorporating dynamic ET (in process)
- Temperature alone impacts timing of runoff more than magnitude
- Dashboard available



Raw numbers (example):

year	mon	period	forcings	0.5	site	obs_thru_july
1991	4	1991 - 2020	2001 - 2020	205.85	WBRW4	253.08
1991	4	1991 - 2020	1981 - 2010	228.92	WBRW4	253.08
1991	4	1991 - 2020	1991 - 2020	224.29	WBRW4	253.08
1991	4	1991 - 2020	1981 - 2020	221.43	WBRW4	253.08

year	mon	period	forcings	0.5	site	obs_thru_july	
1991	4	1991 - 2020	2001 - 2020	207.15	WBRW4	253.08	
1991	4	1991 - 2020	1981 - 2010	233.08	WBRW4	253.08	
1991	4	1991 - 2020	1991 - 2020	224.43	WBRW4	253.08	
1991	4	1991 - 2020	1981 - 2020	226.83	WBRW4	253.08	Research

Reclamation-Funded Research Projects

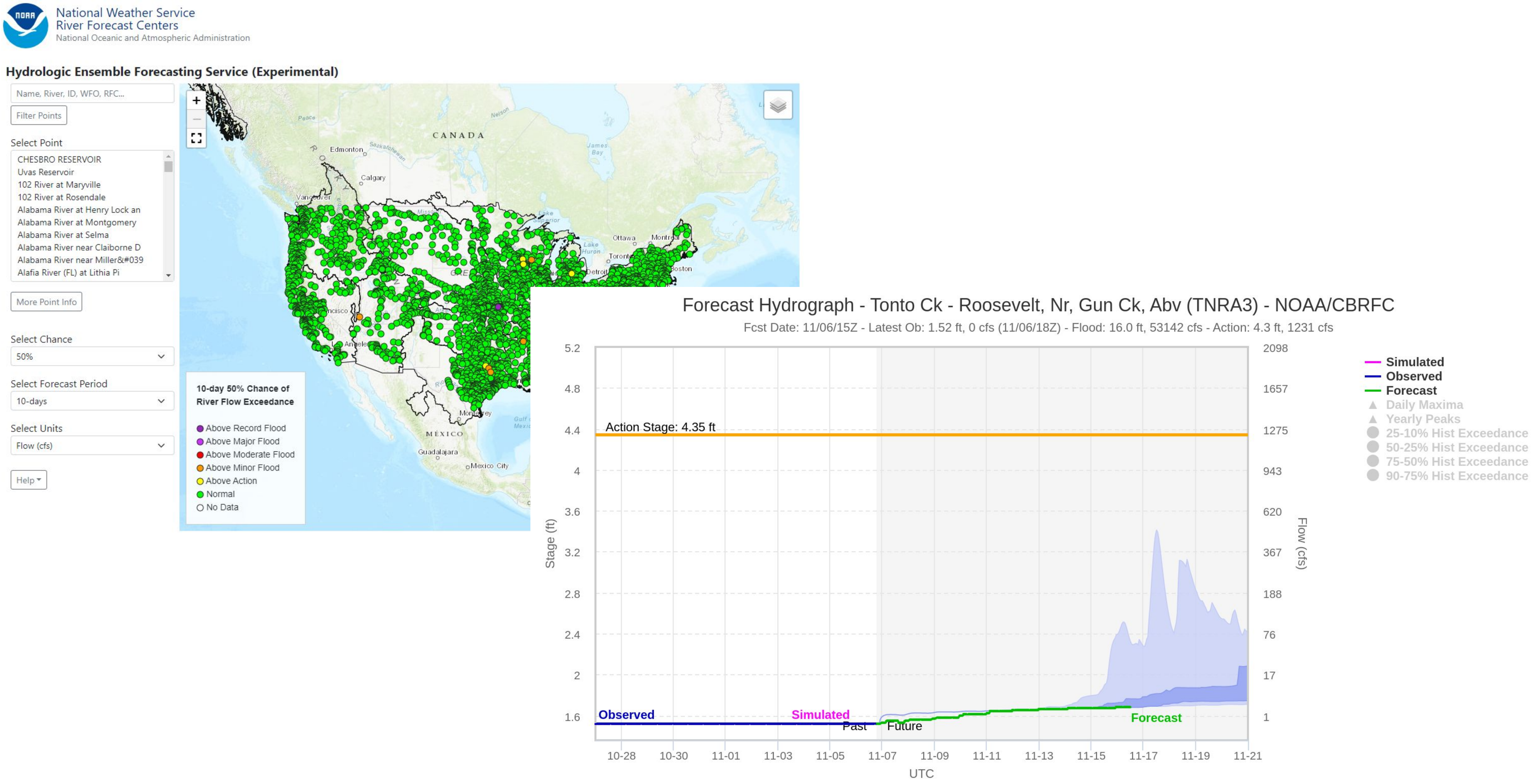
- RTI
  - Development of a SWE dataset that utilizes data assimilation and machine learning techniques
  - Dataset is developed specifically for use in RFC models
  - Advancement of distributed modeling capabilities
- University of Utah
  - Further advancement of the iSNOBAL model
- Boise State University
  - Development of a CBRFC "landing strip"
  - Evaluation of new snow products
- SNOFO Projects
  - Additional ASO flights
  - New data collection
  - New datasets developed
- Reclamation-funded position stationed at the CBRFC

Why use Hydrologic Ensemble Forecasts?

Goal: improve NWS hydrologic services

Feature	ESP	HEFS
Forecast time horizon	Weeks to seasons	Hours to years, depending on the input forecasts
Input forecasts ("forcing")	Historical climate data (i.e. weather observations) with some variations between RFCs	Short-, medium- and long-range weather forecasts
Uncertainty modeling	Climate-based. No accounting for hydrologic uncertainty or bias. Suitable for long-range forecasting only	The plan is to capture uncertainty in weather forecast and corrects for biases in forcing and flow at all forecast lead times - Goal is to capture model uncertainty as well
Products	Limited number of graphical products at the national level.	A wide array of data and user-tailored products are *planned*, including standard verification

Output - CBRFC Demo web page



Observed Unregulated Streamflow Volume
Percent Change From 1991-2020

Weather Forecast Office

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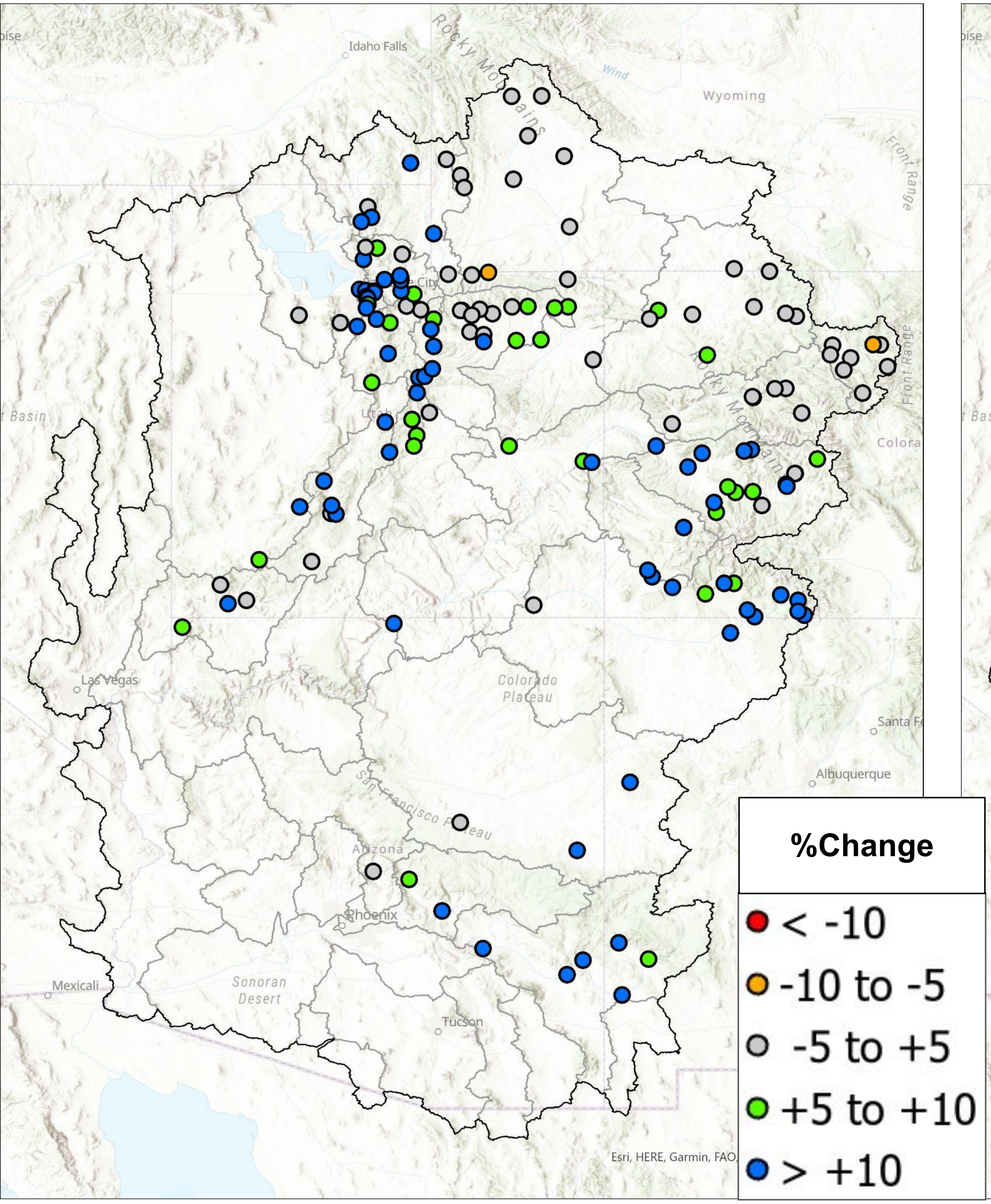
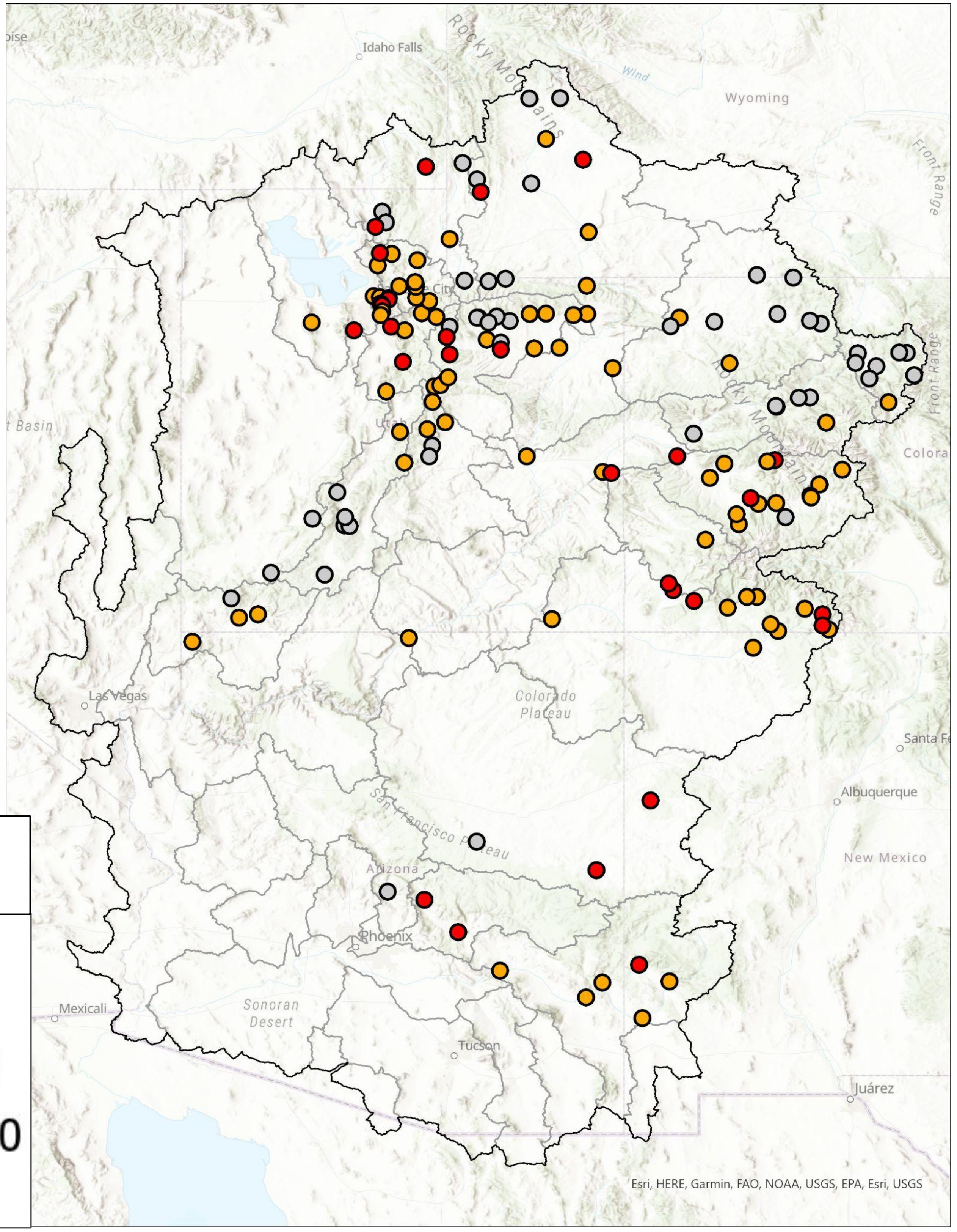
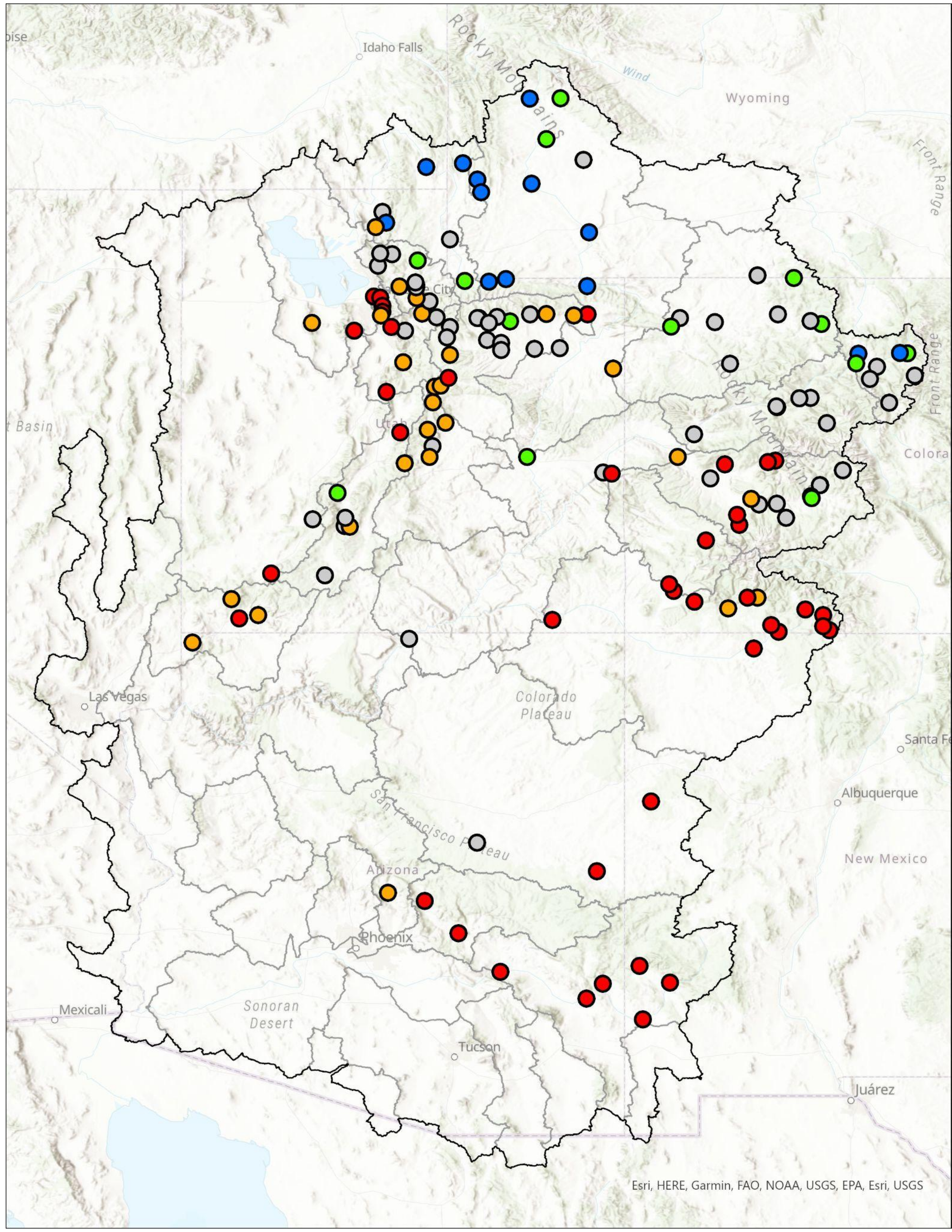
1981-2010



2001-2020



2011-2020

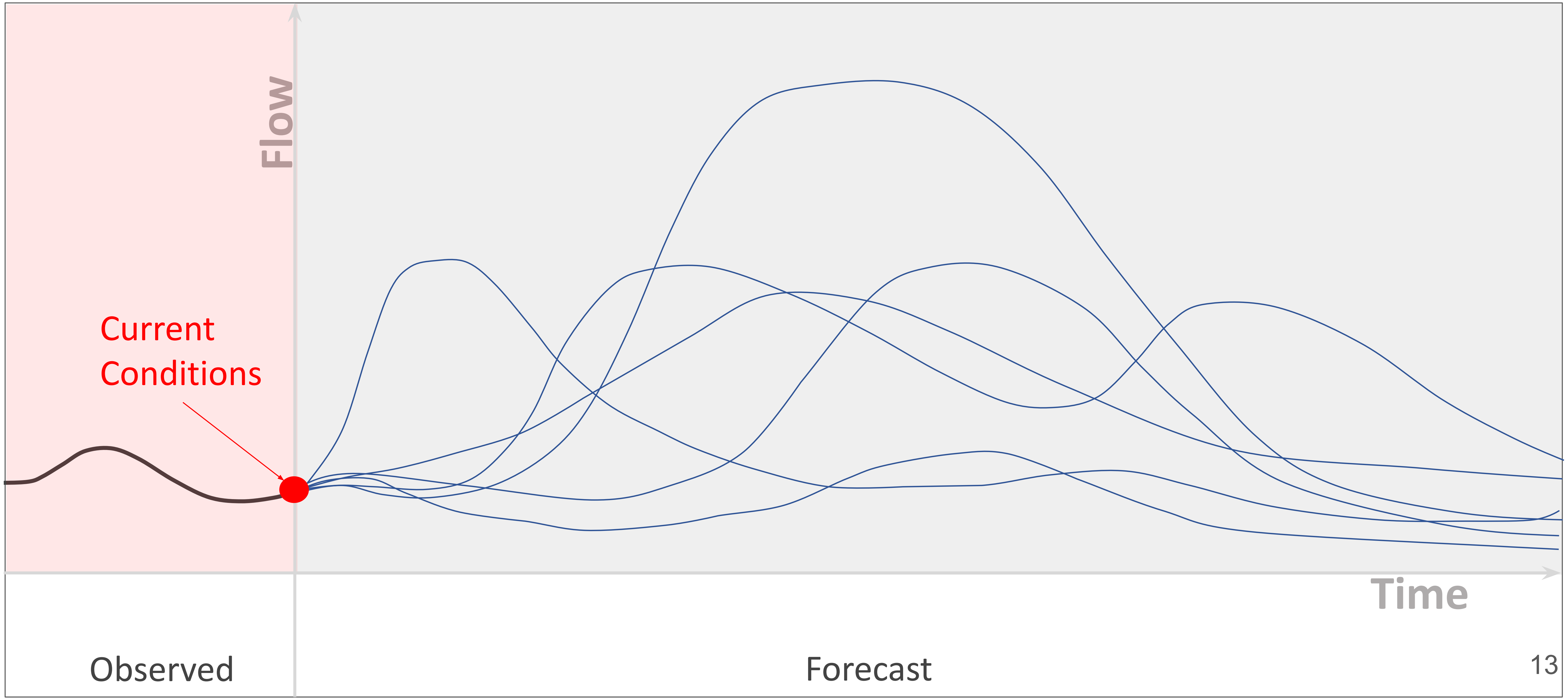


Ensemble Streamflow Prediction (ESP)

- Start with current model conditions of snowpack, soil moisture and simulated flow
  - *These are the saved model states from the daily operational run*
- Apply precipitation and temperature from historical years (aka Forcings)
  - A hydrograph, or trace, is generated for each year

Current conditions from daily model run

- Simulated Flow
- Soil Moisture
- Snowpack



Forcings

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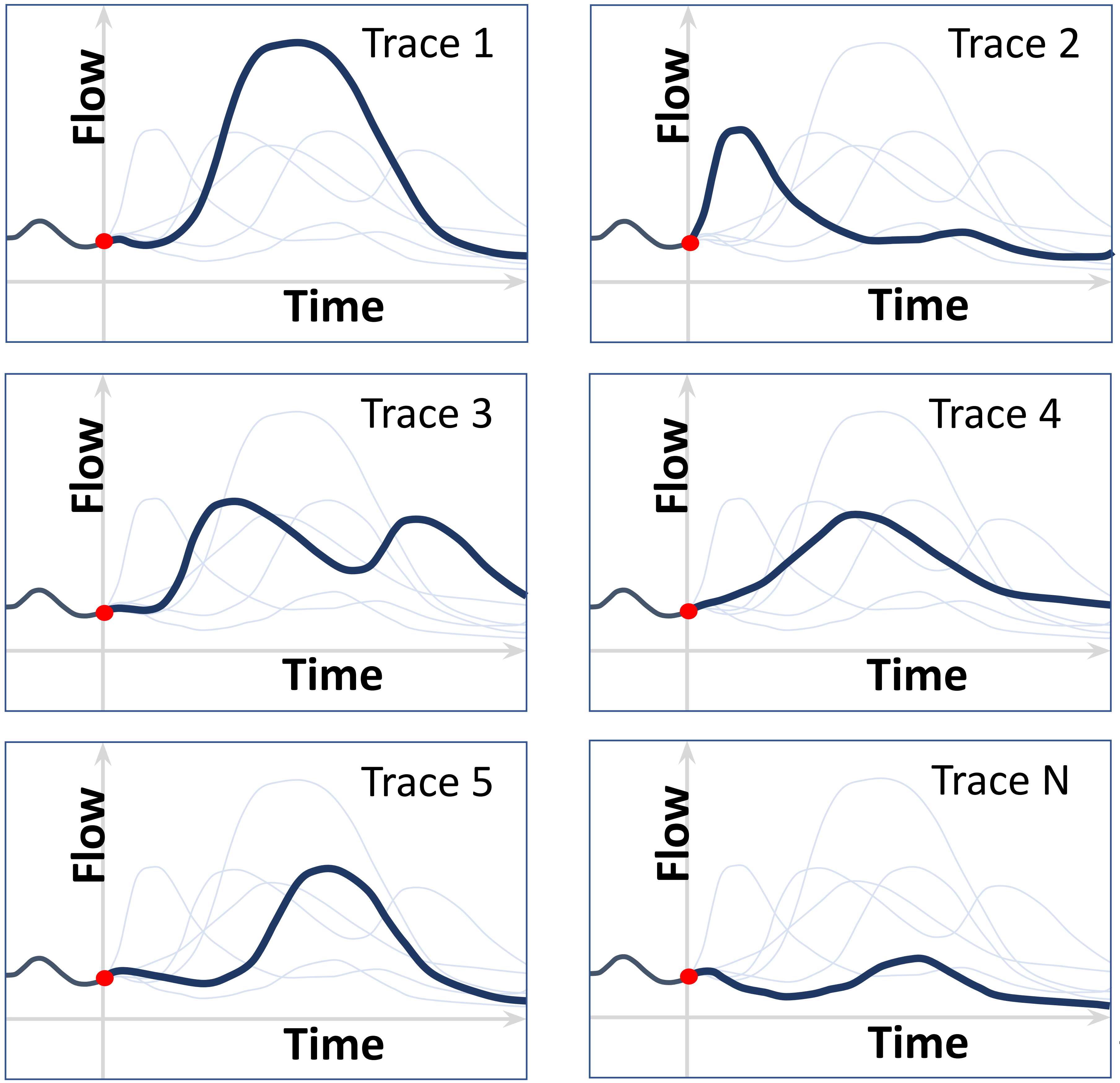
Do different forcing periods perform better?

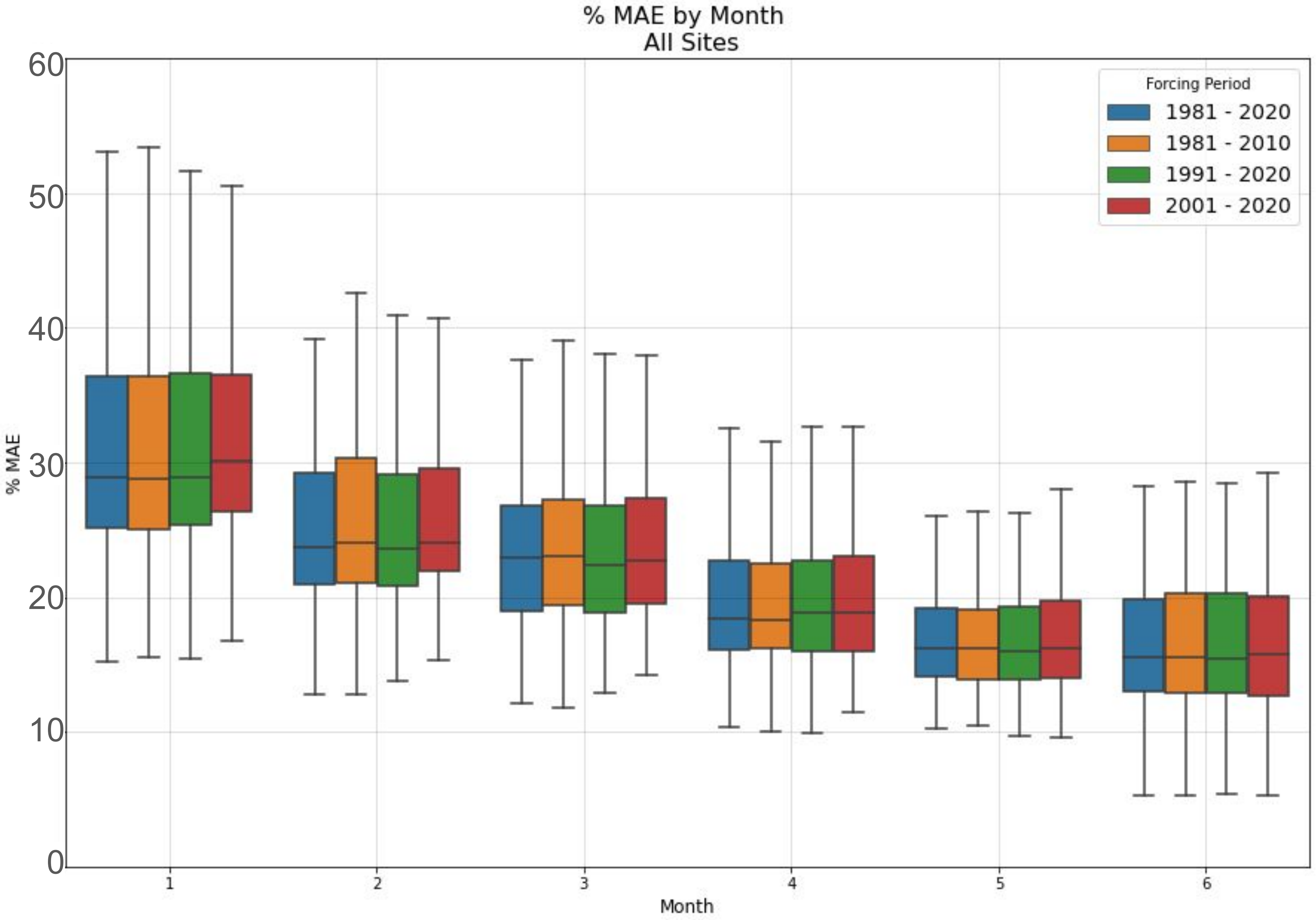
Forcing periods compared:

- 1981 - 2020 (40 traces)
- 1981 - 2010 (30 traces)
- 1991 - 2020 (30 traces)
- 2001 - 2020 (20 traces)

Each of these are compared using the same verification period (1991 - 2020)



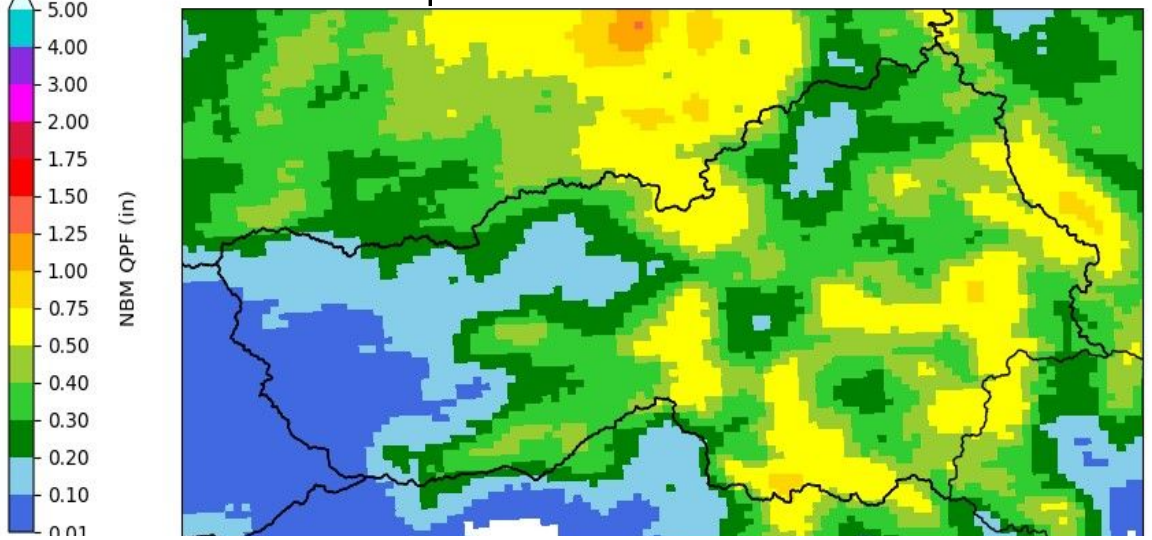
% MAE



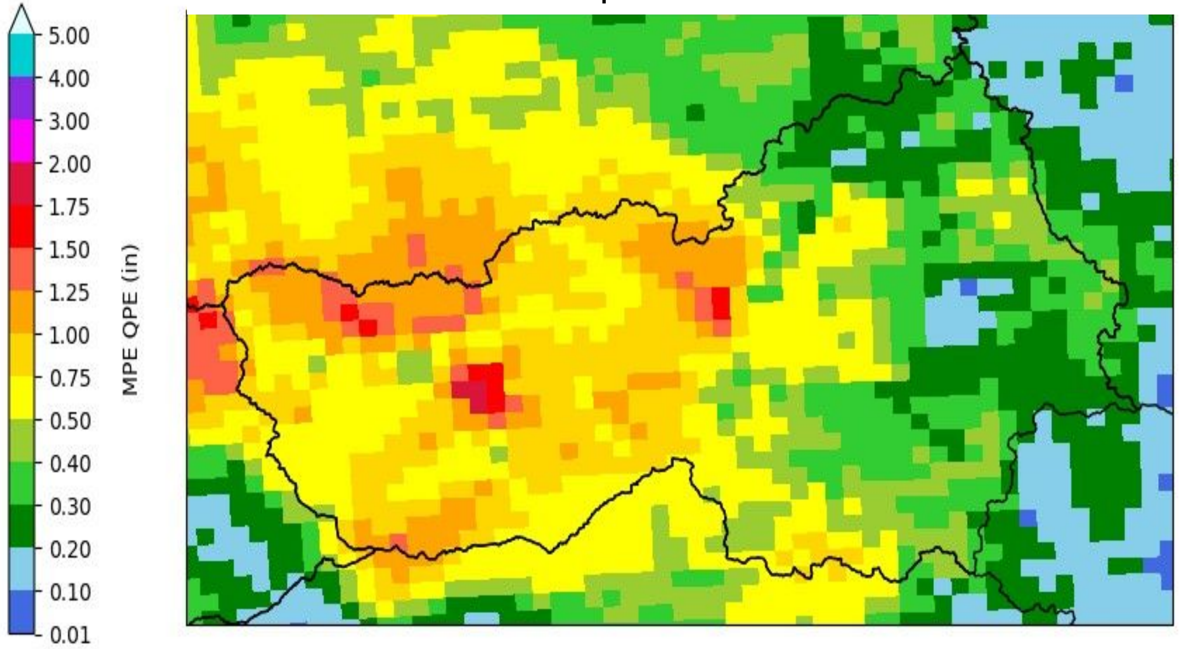
N = 125	Median % Mean Absolute Error					
Forcing	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**
1981 - 2010	29%	24%	23%	18%	16%	16%
1981 - 2020	29%	24%	23%	18%	16%	16%
1991 - 2020	29%	24%	22%	19%	16%	16%
2001 - 2020	30%	24%	23%	19%	16%	16%

CPC S2S

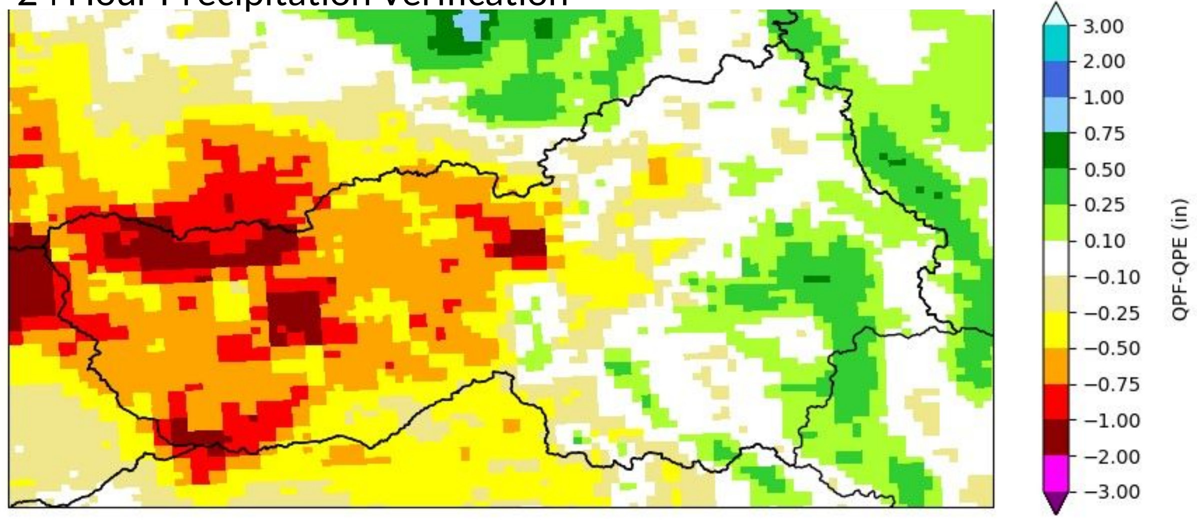
24 Hour Precipitation Forecast: Colorado Mainstem



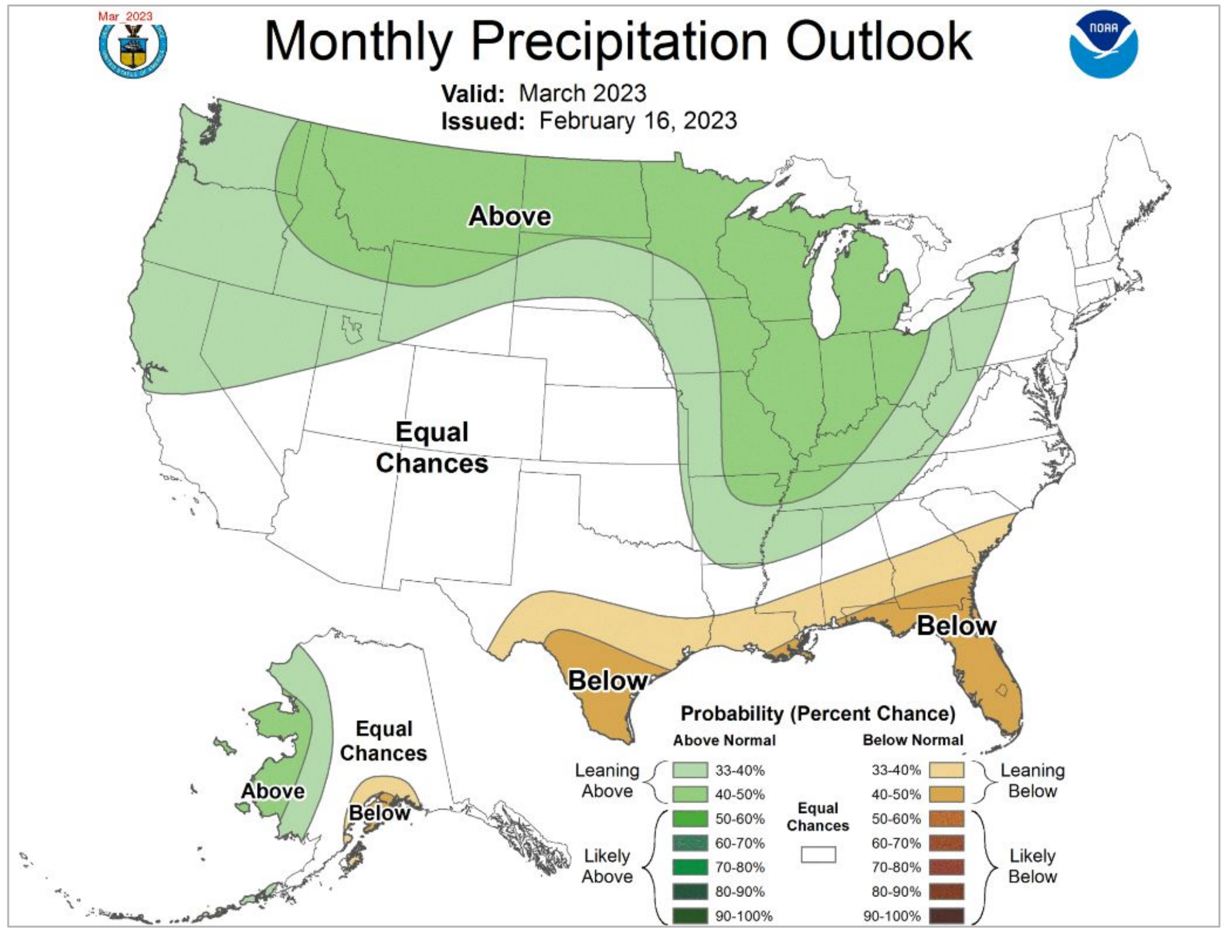
24 Hour Observed Precipitation: Colorado Mainstem

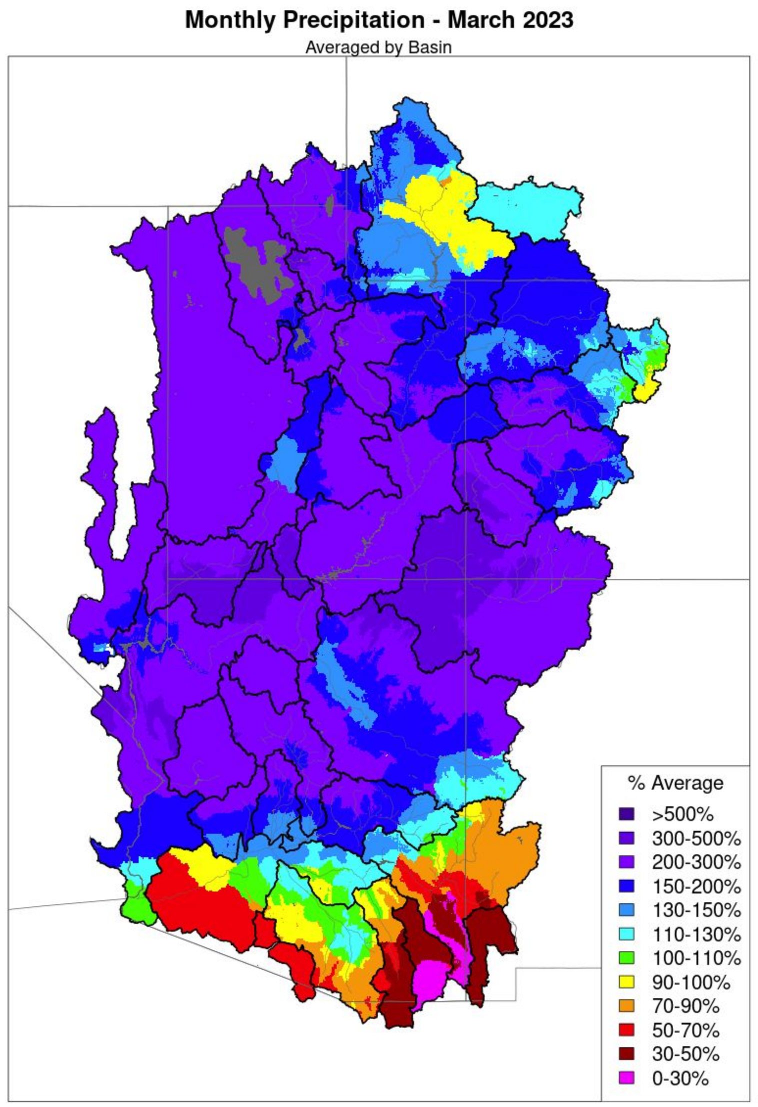


24 Hour Precipitation Verification



Monthly Forecast March 2023



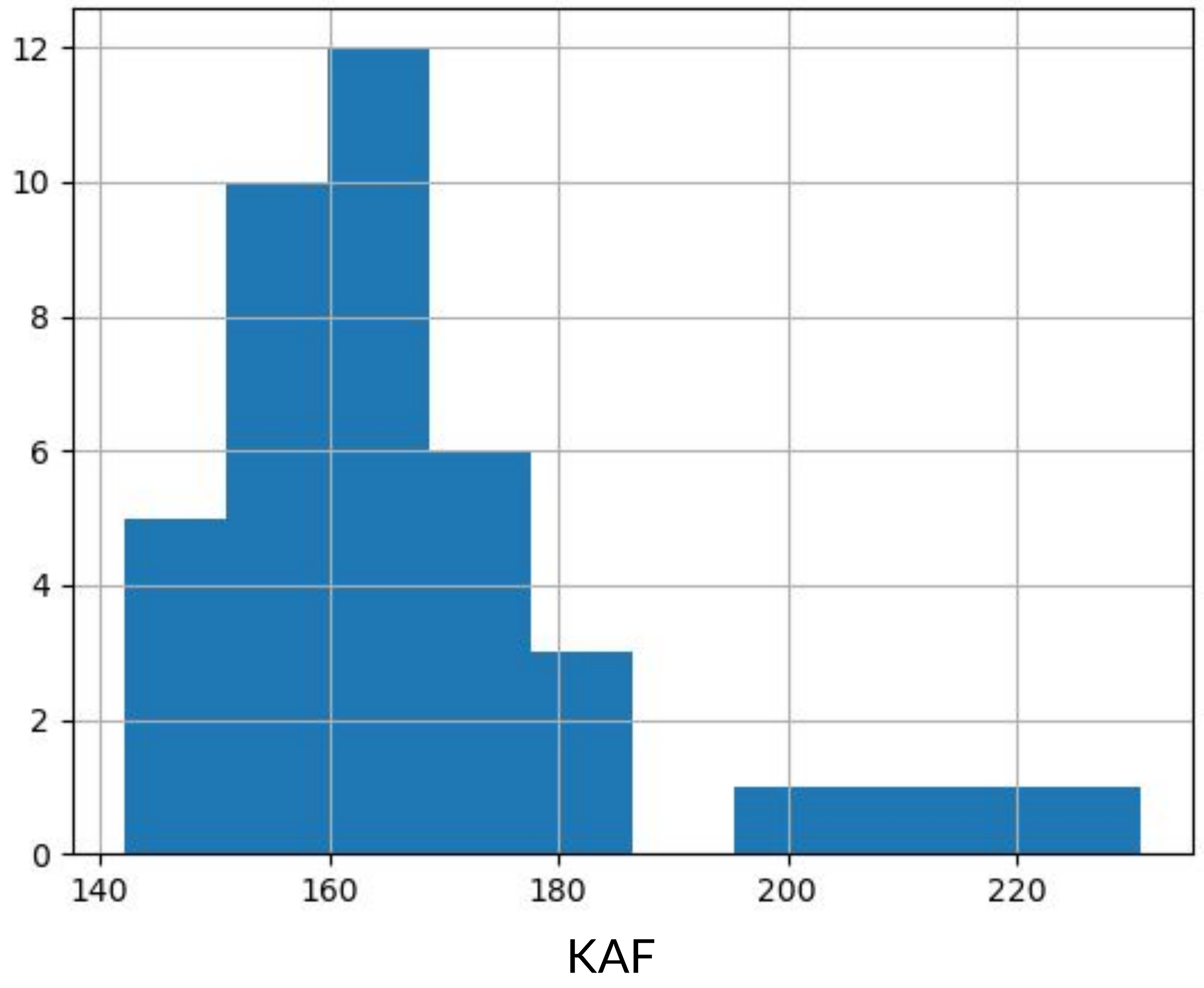


• Developed a method of combining...

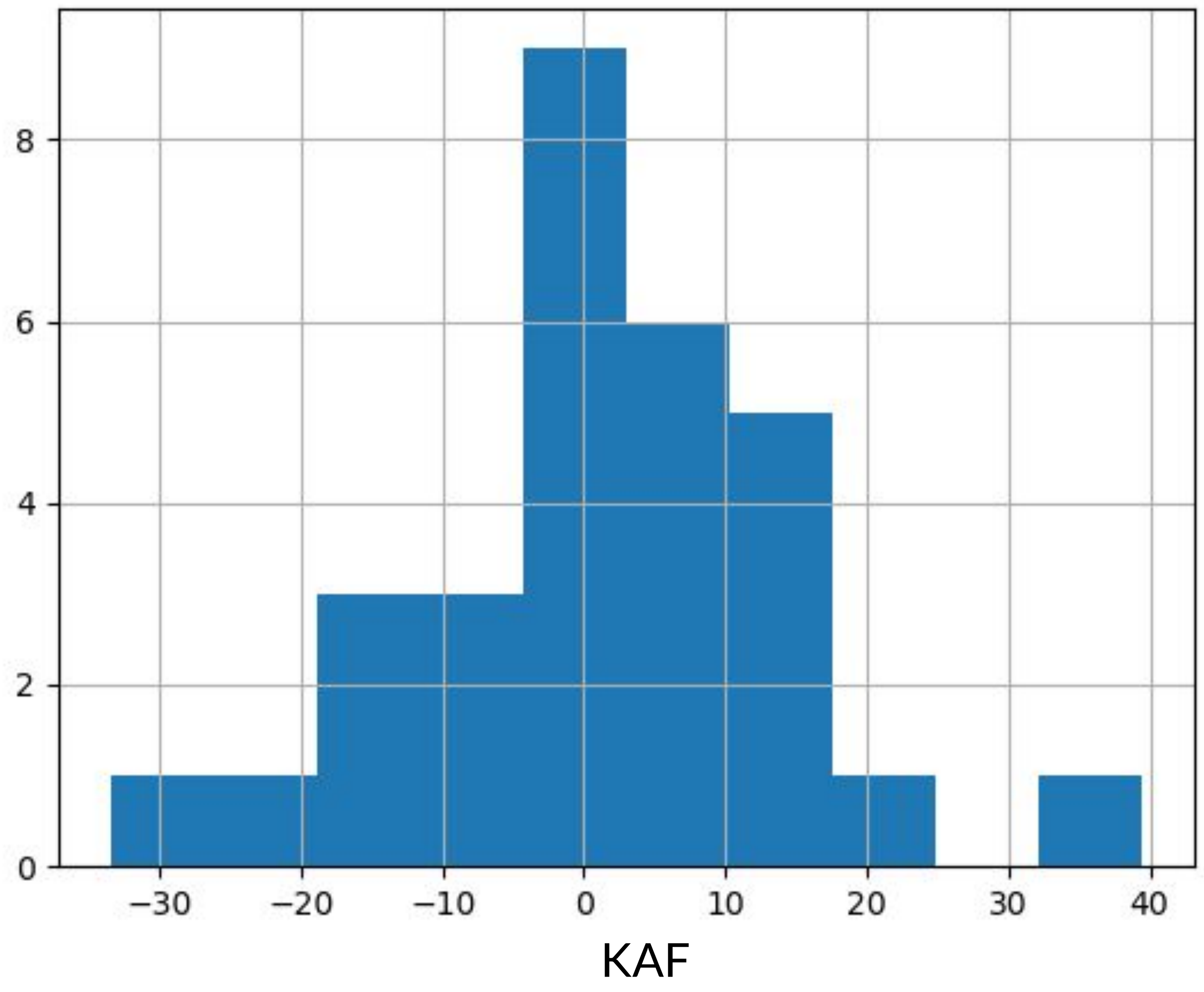
a. Future Weather Uncertainty from ESP with...

b. Model Error from the Calibration Record

a. Volumes from ESP



b. Errors from Calibration Record



Addressing Model Error in Water Supply Forecasts

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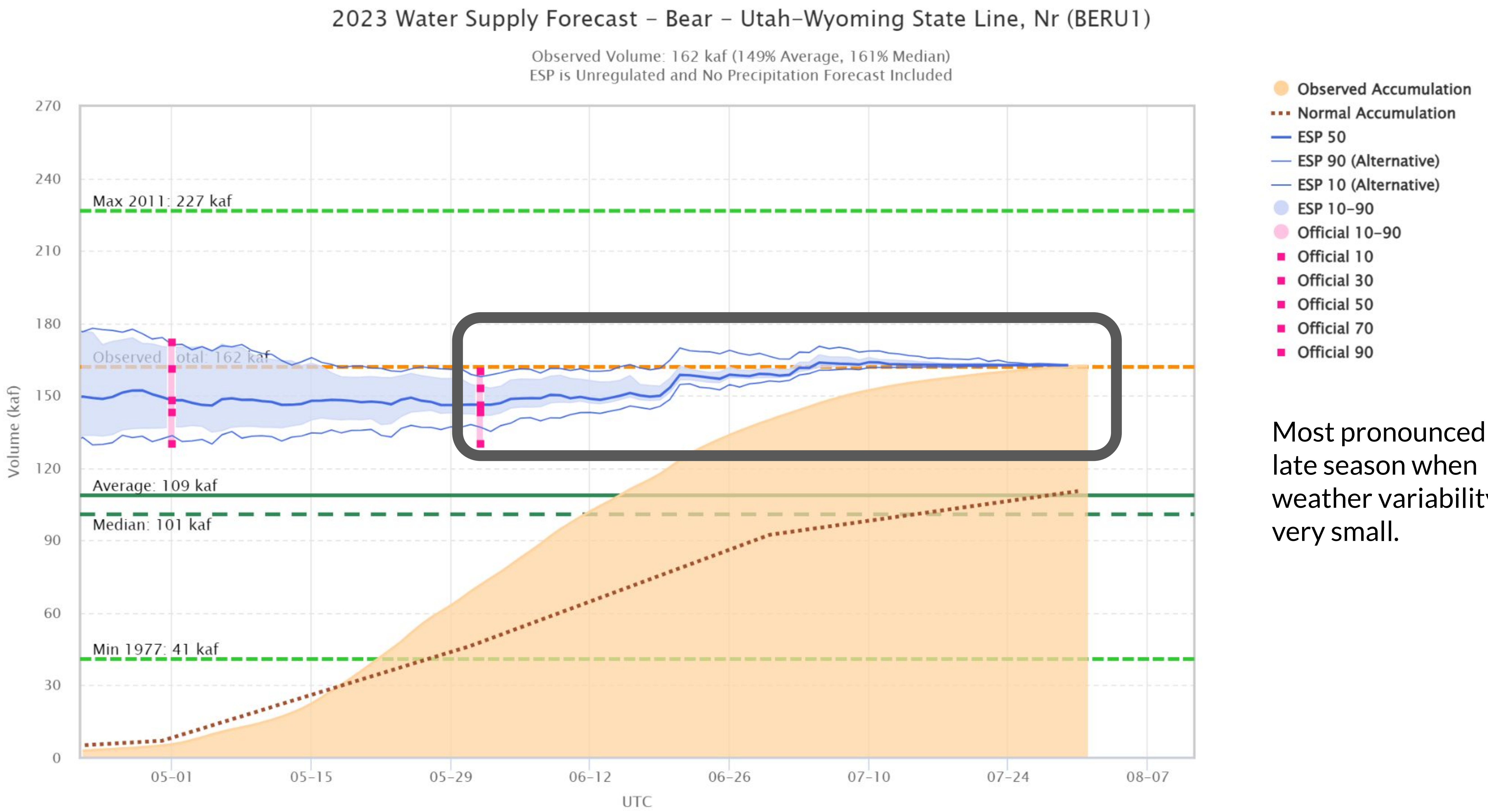


Most pronounced in late season when weather variability is very small.

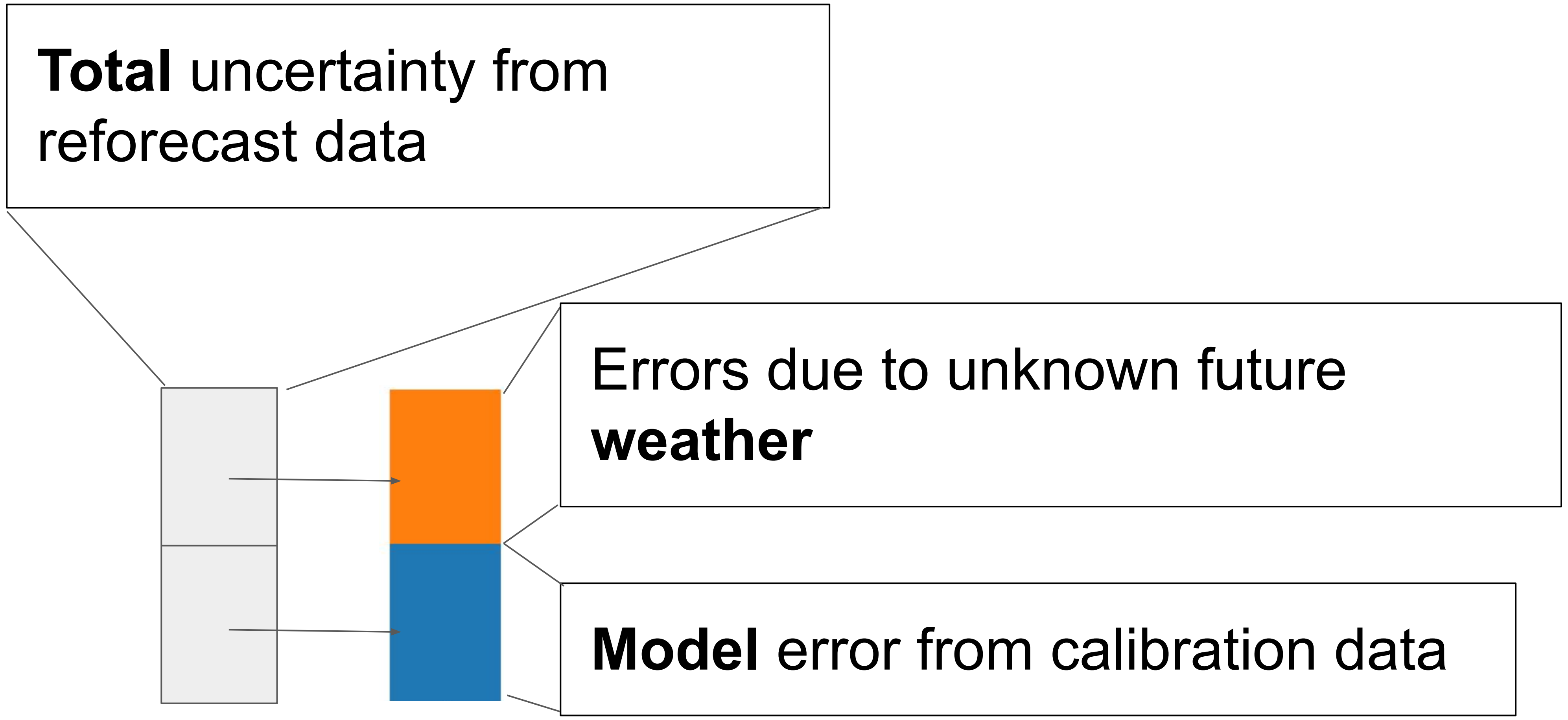
Water Supply Forecast Errors

- Uncertainty in water supply forecasts are a combination of model errors and unknown future weather (mostly April - July precipitation).
- We can quantify the total error in water supply forecasts by looking at 35 years of reforecast data.

Total uncertainty due to:
1. Unknown future precipitation
2. Model Errors

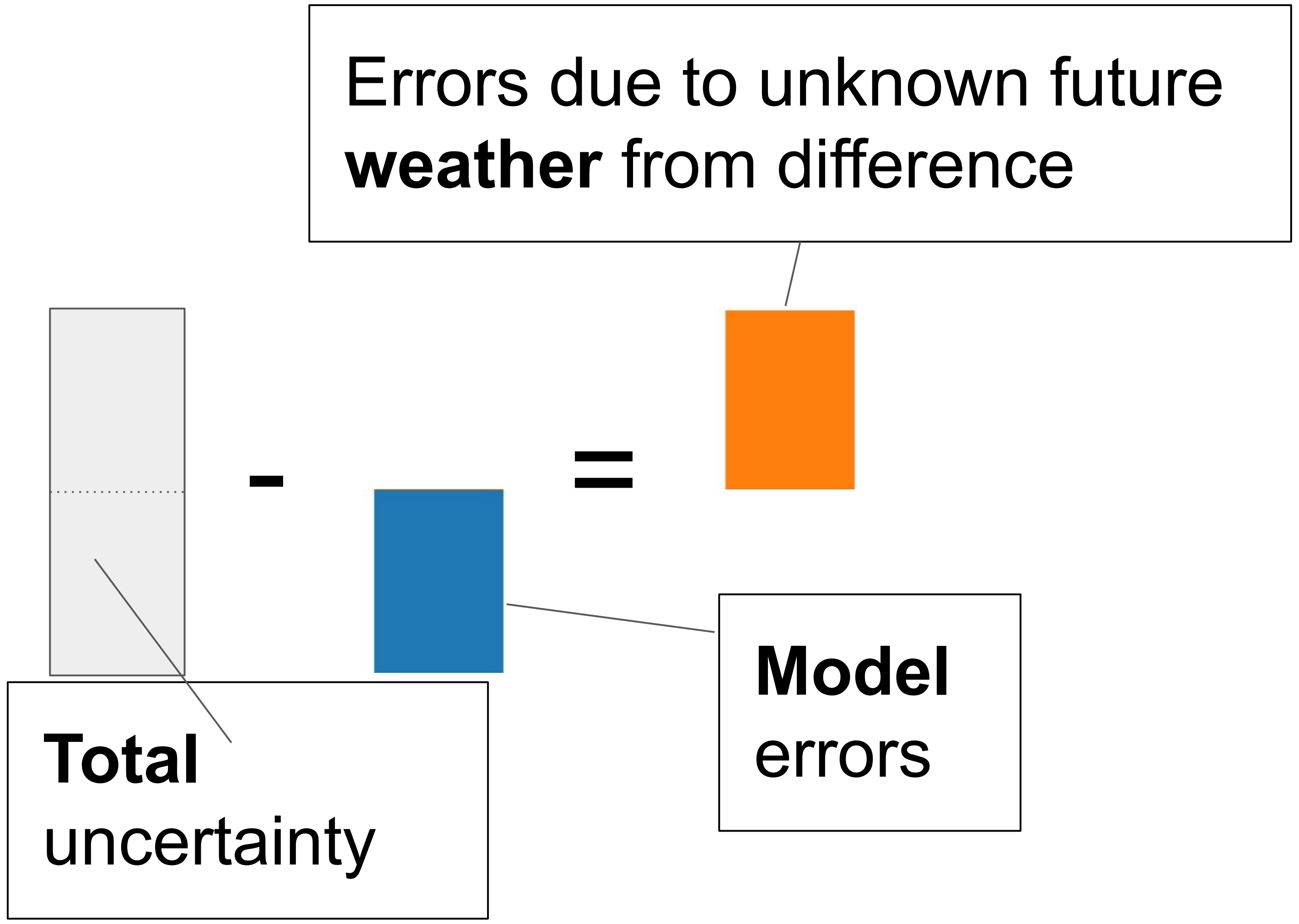
Water Supply Forecast Errors

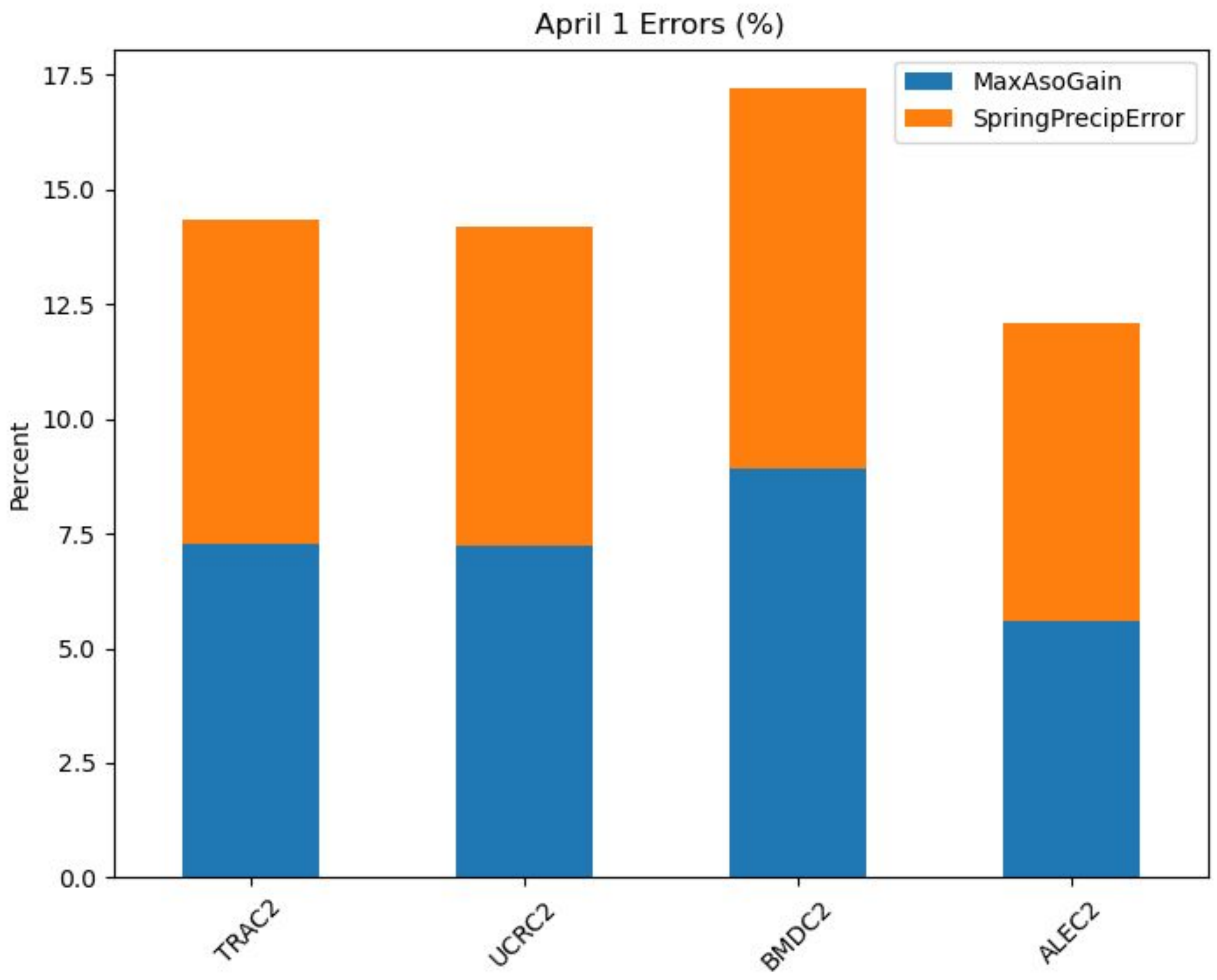
- Model errors can be attributed to...
  - Errors in model soil moisture
  - Errors in model snow pack
  - Errors in model parameters
  - Errors in model structure
  - Etc.
- We can quantify total model errors by looking at 30 years of our latest calibration data.



Water Supply Forecast Errors

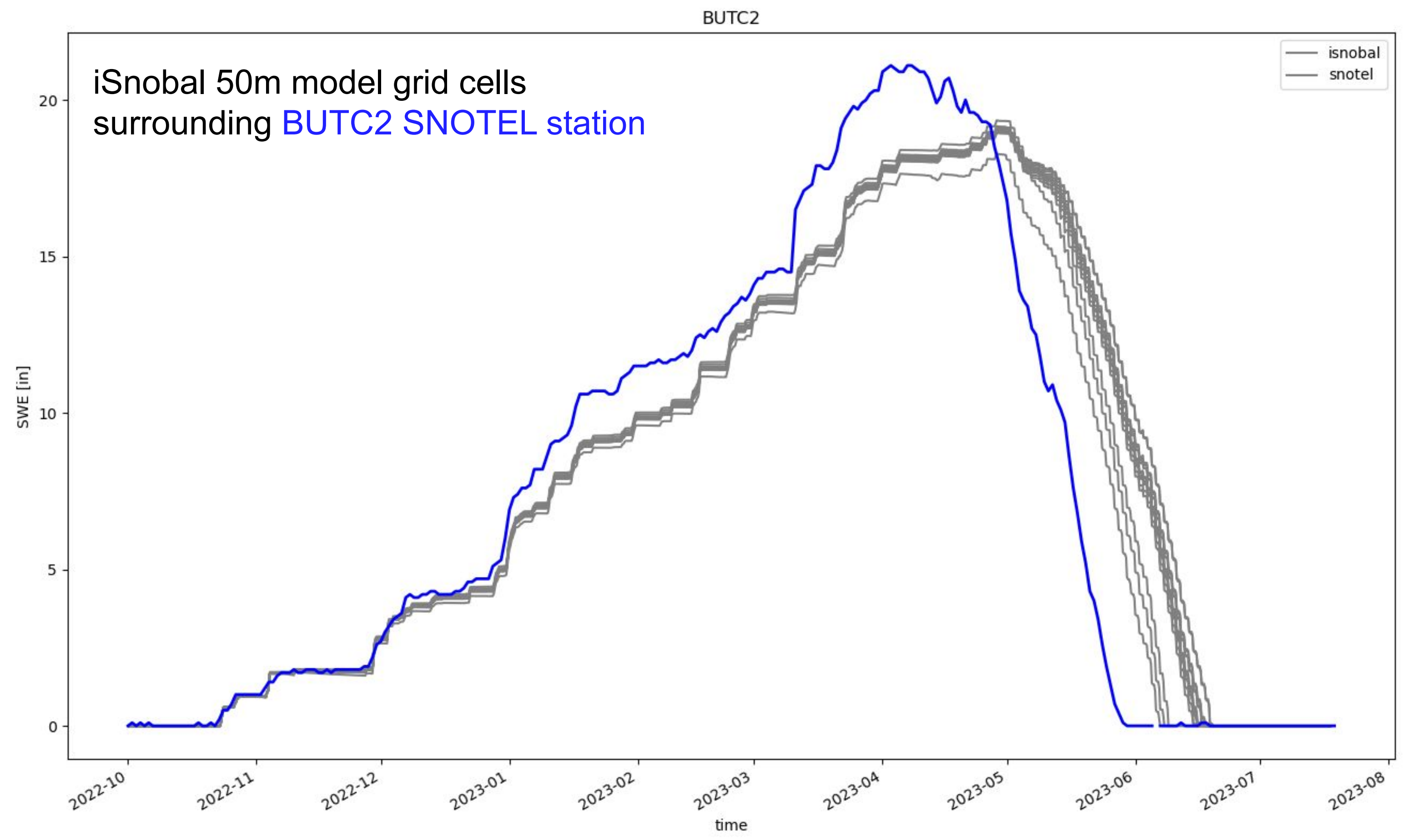
- Uncertainty due to unknown future precipitation is obtained by differencing.
- On average, roughly half of the volume error in an April 1 Water Supply forecast is attributed to the unknown spring precipitation amount.
- The other half is due to model errors

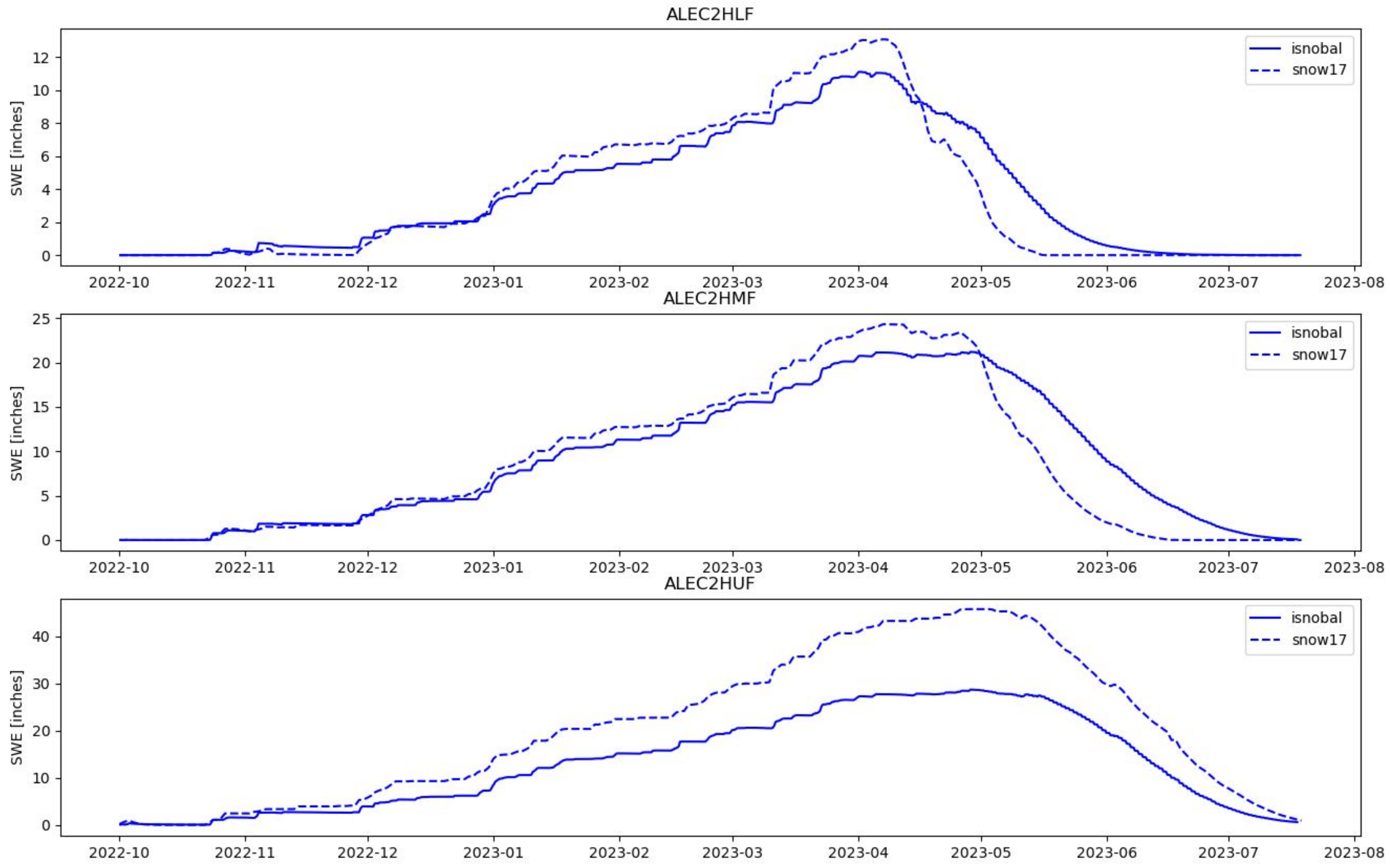




Distributed Modeling - Quick Update

- **Physically Based Distributed Snow Modeling**
  - ALEC2 and DIRC2 automated and SWE / RAIM visible in CHPS
  - Evaluation tools for SWE compare at points and zones complete





Distributed Modeling - Quick Update

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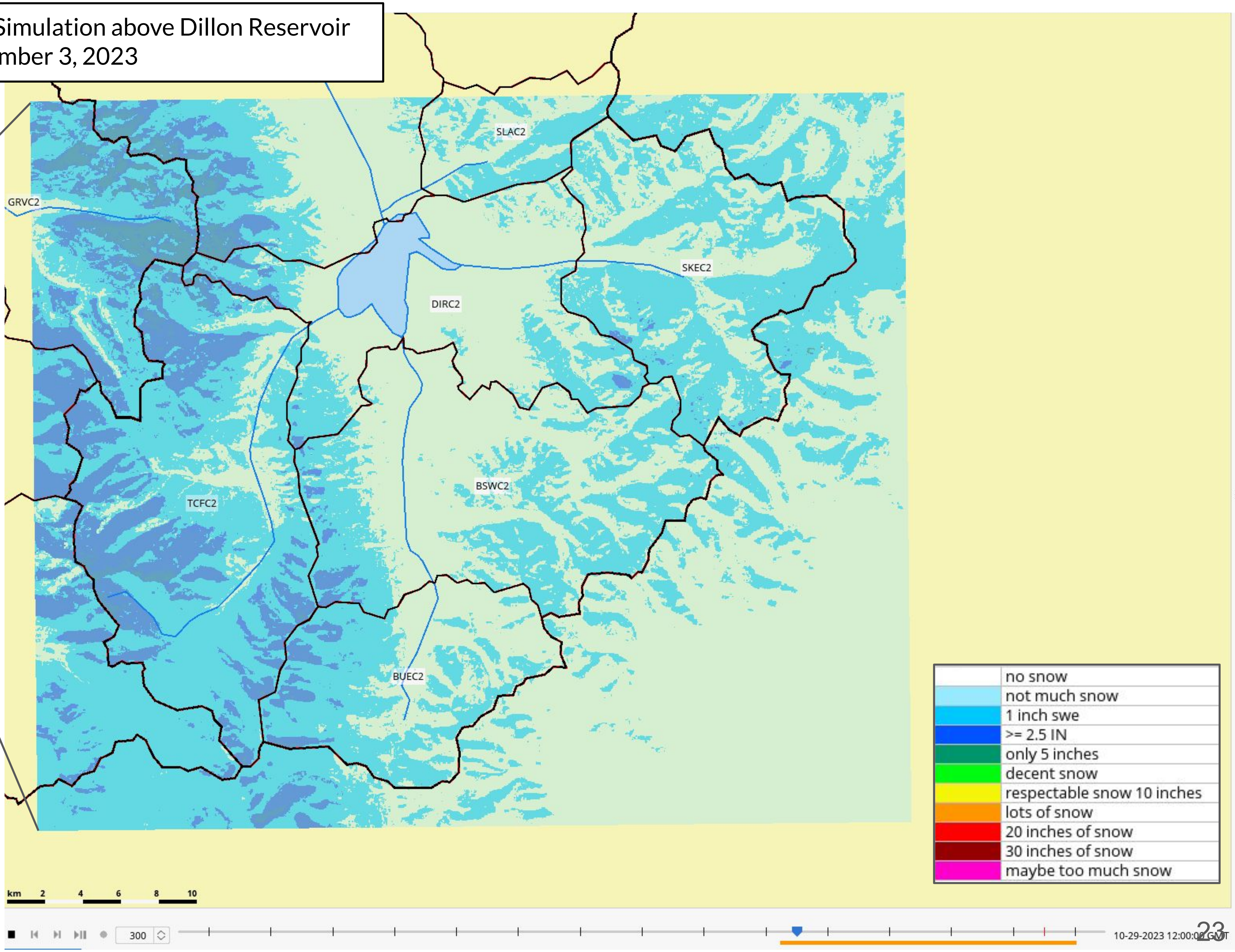
iSnobal 50m SWE Simulation above Dillon Reservoir
October 29 - November 3, 2023



Distributed Modeling - Quick Update

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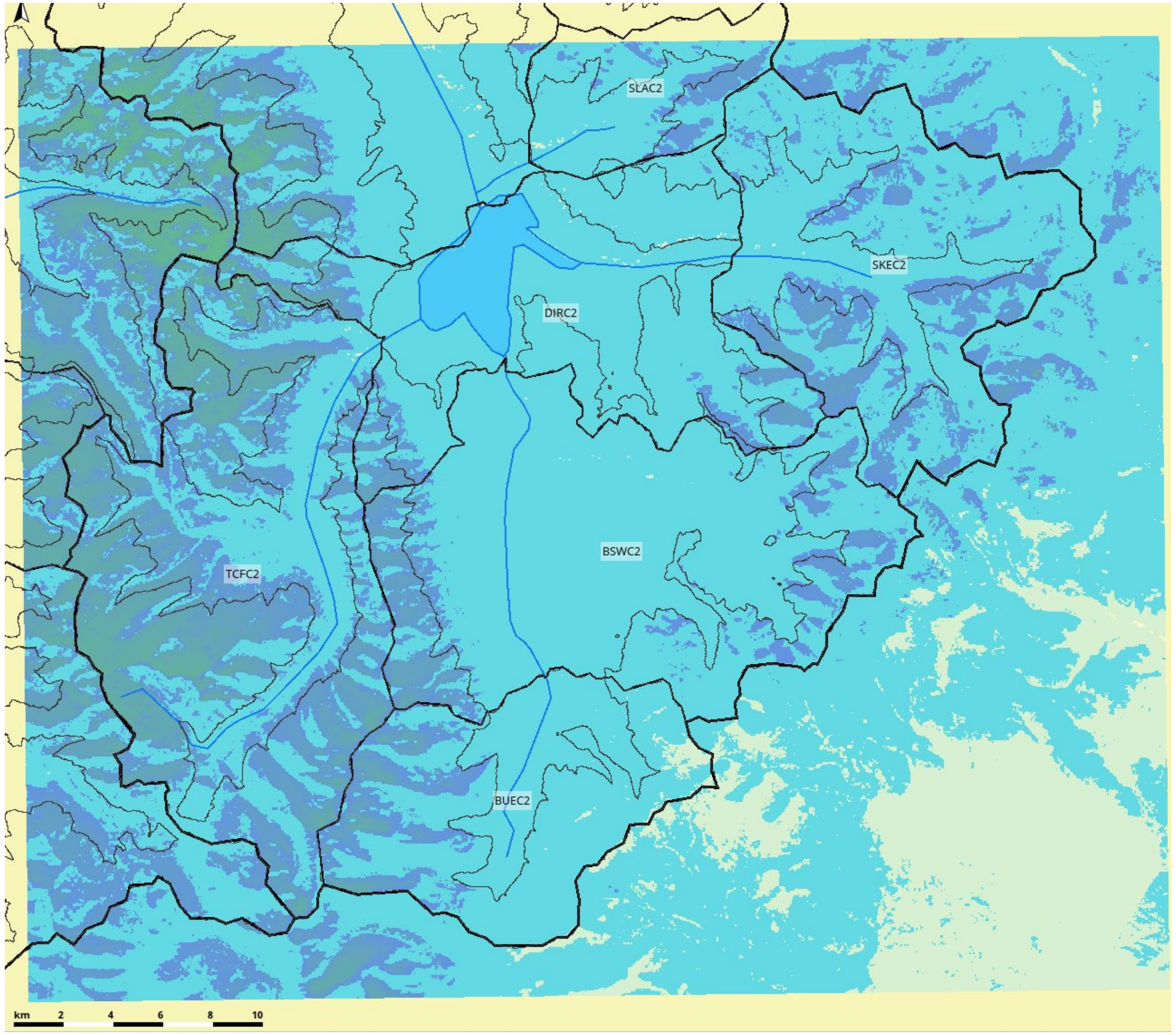
Model Resolution Comparison

CBRFC Elevation Zones vs. 50m iSnobal



Distributed Modeling - Quick Update

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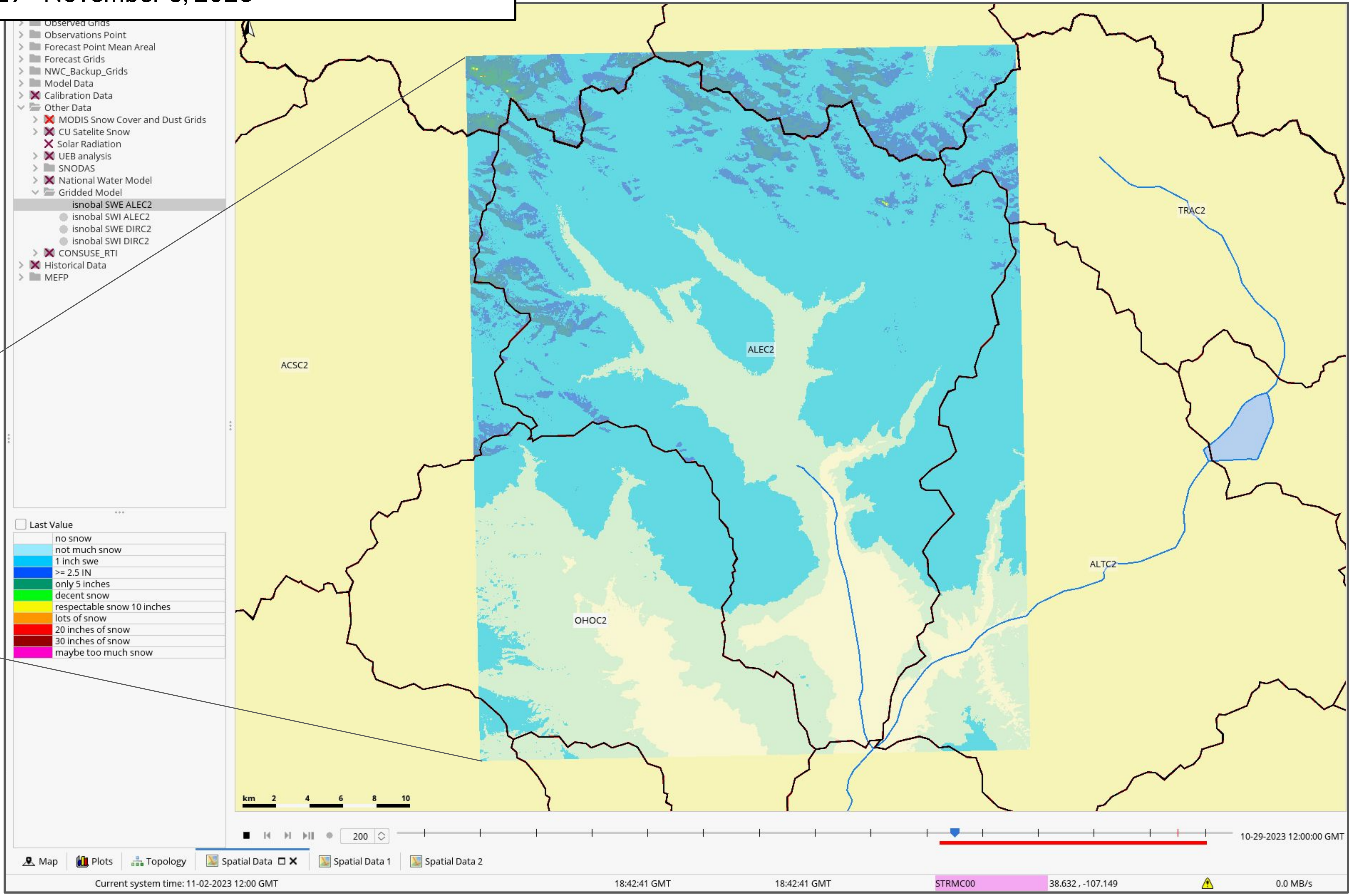
iSnobal 50m SWE Simulation: East River - Almont
October 29 - November 3, 2023



Questions?