WRF-Hydro/ASO Ensemble Seasonal Water Supply Forecasting for California, Colorado and Utah: WY 2024

Airborne Snow Observatories, Inc.

June 3, 2024

Outline & Acknowledgements:

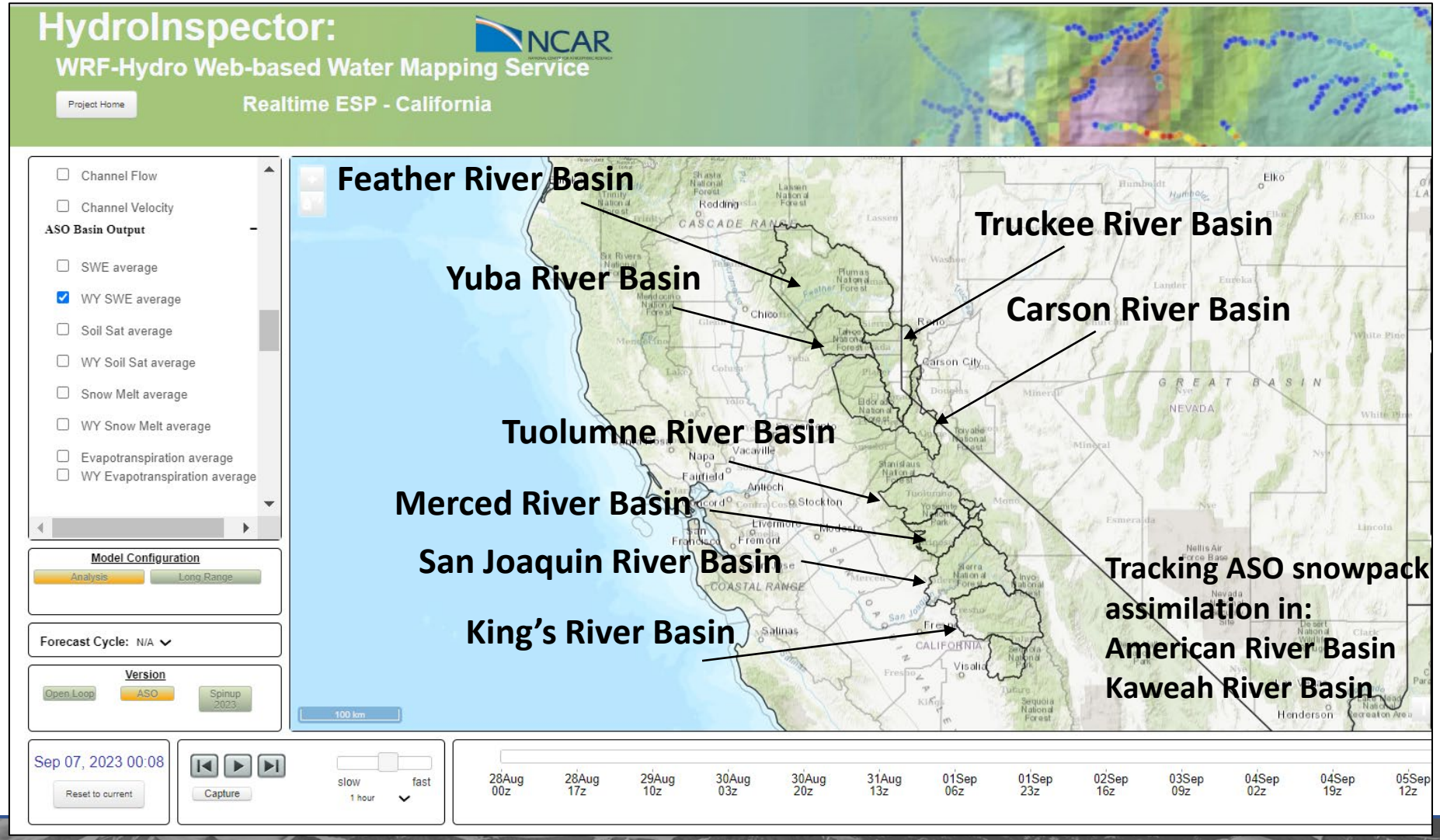
- Overview of forecasting domains
- Forecasting Process using NoaMP/WRF-Hydro
- Sample results for 2024 to date…

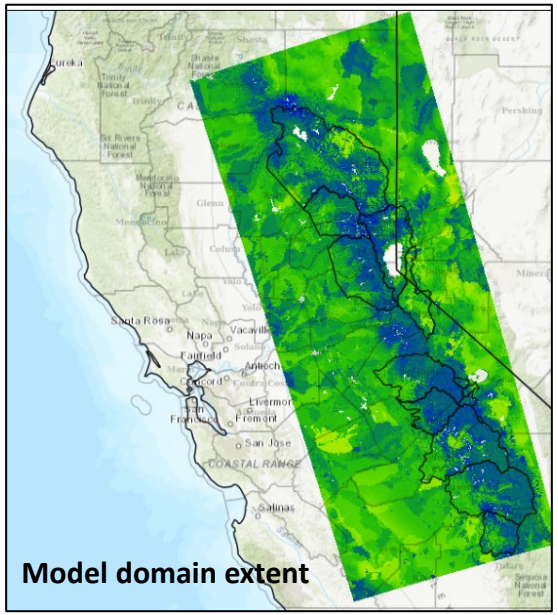
- ASO Hydrologic Prediction/Modeling Team:
  - Logan Karsten
  - Dave Gochis
  - Broader ASO team for snow products…

- WRF-Hydro team at NCAR:

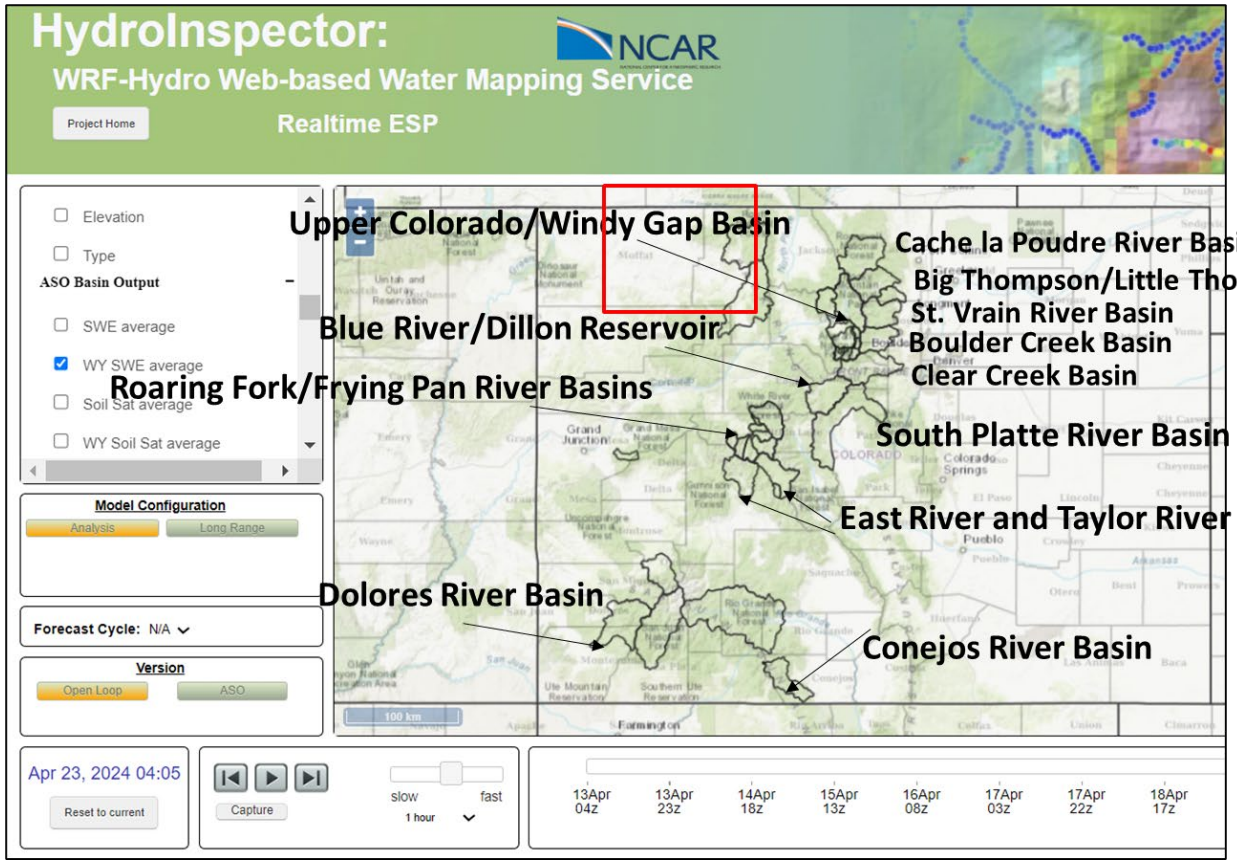
Y. Zhang, M. Casali, J. Grim, A. Gaydos, R. Rozenswieg-Abolafia, A. Dugger, K. Sampson

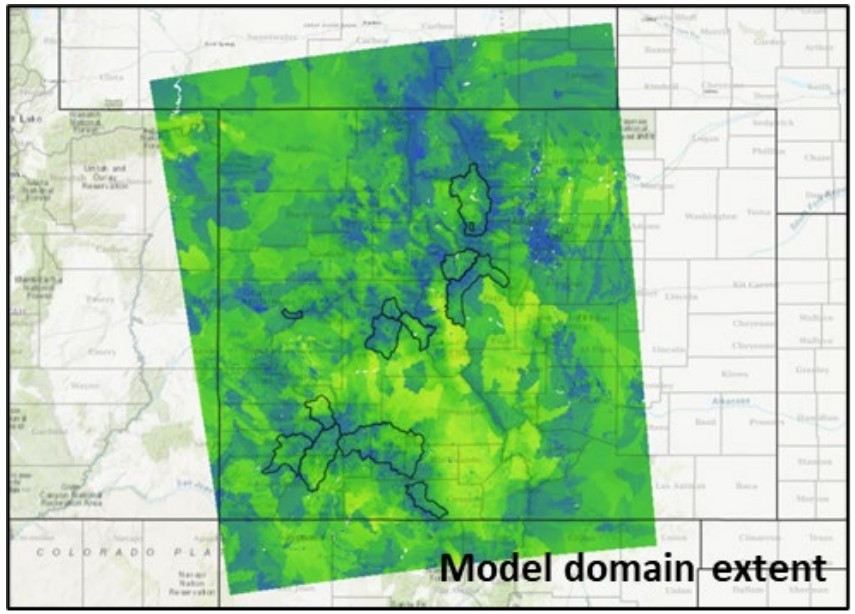
WY2024 Supported WRF-Hydro Forecast Basins



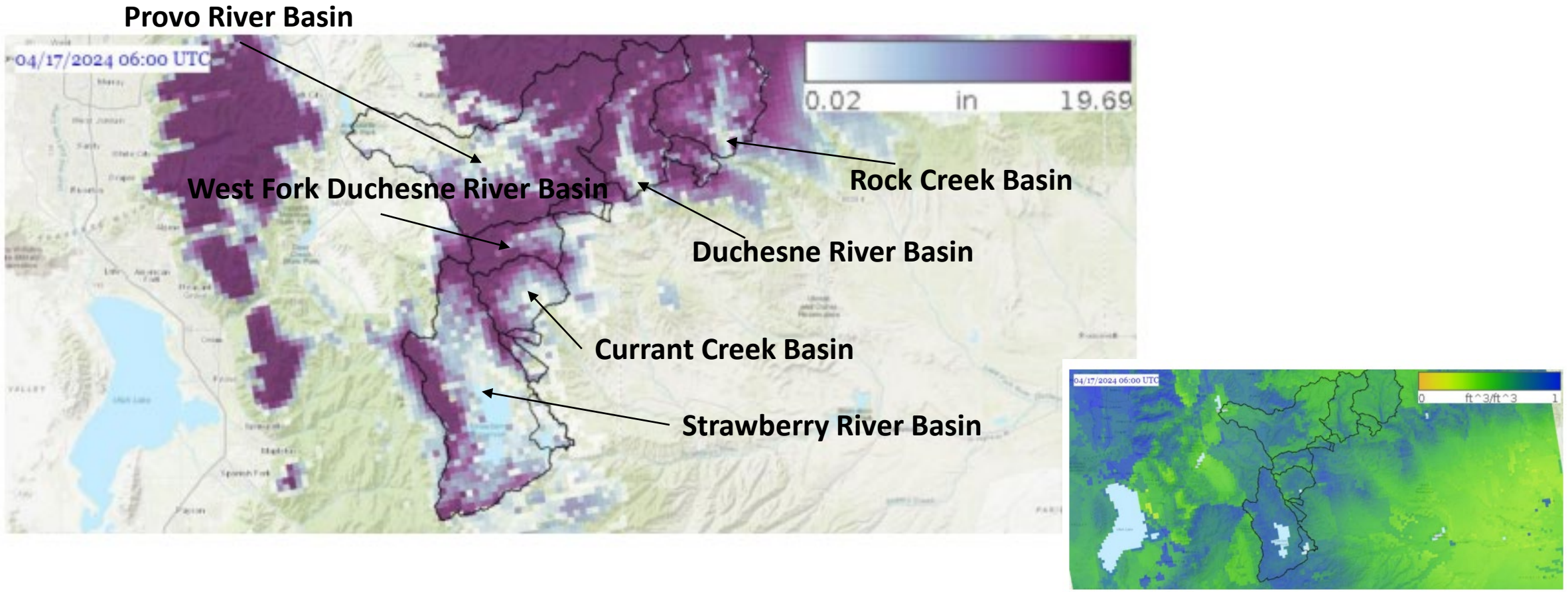


WRF-Hydro Colorado ESP: WY2024 Seasonal Water Supply Forecasts

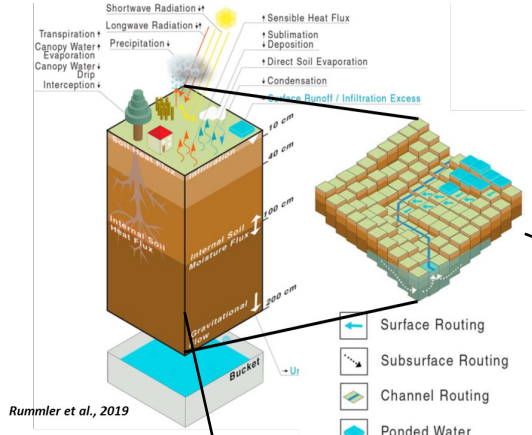




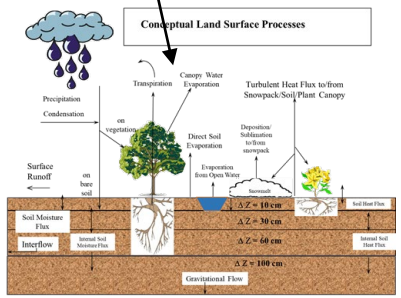
WY2024 Supported WRF-Hydro Forecast Basins

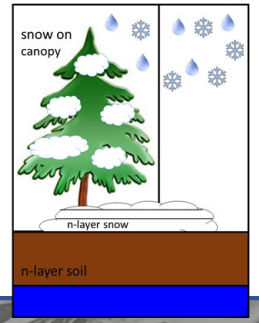


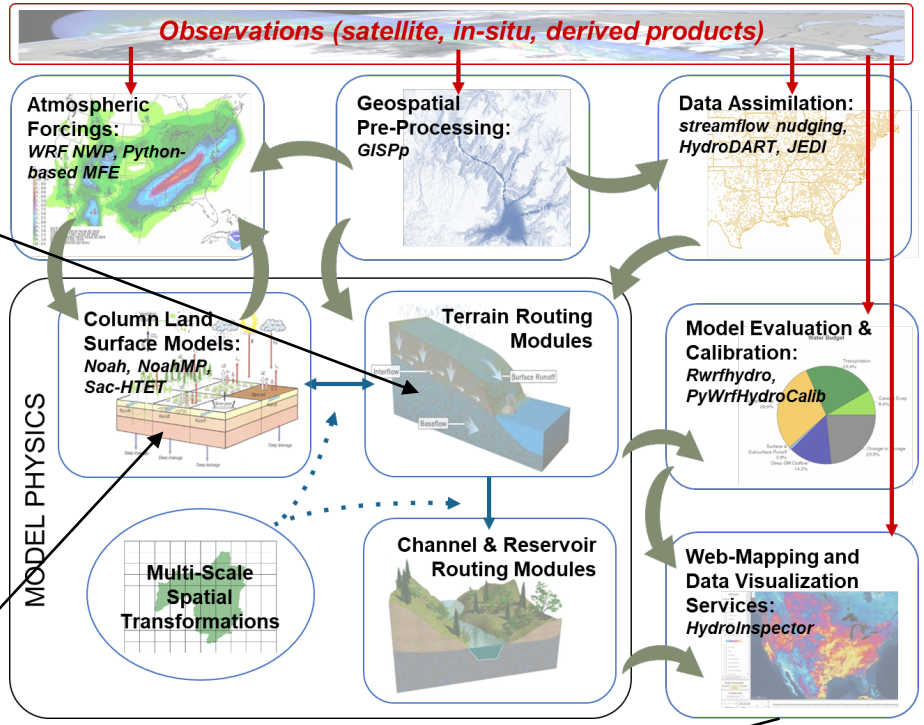
WRF-Hydro based forecast process:

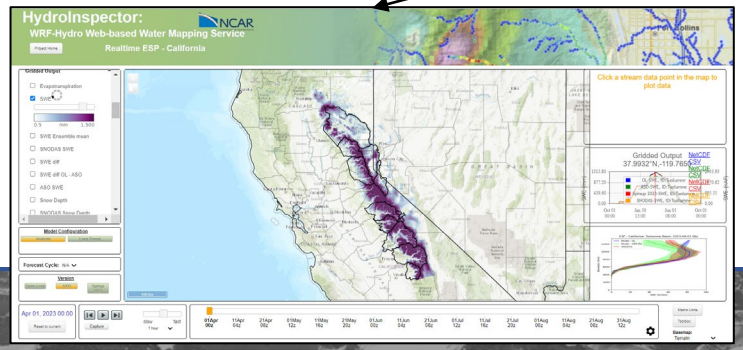


Rummler et al., 2019









Assimilation-Prediction Workflow:

1. Downscale and bias correct long-term meteorological data records (hourly downscaled observed analyses of meteorological data)

2. Calibrate model to hourly streamflow/inflow at over ***unregulated*** stations across CO/CA headwater basins

3. Regionalize model parameters from calibration basins to rest of CA/CO domains

4. Execute long-term retrospective run for spin-up and for statistical referencing (homegrown optimal-blend analysis forcings)

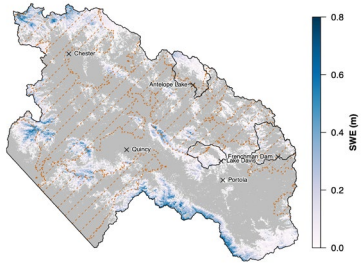
5. Assimilate ASO-observed snowpack (past: direct insertion, next: AEnKF-like)

6. Execute operational and research ensemble water supply forecasts and products (enhanced ensemble generation and weighting)

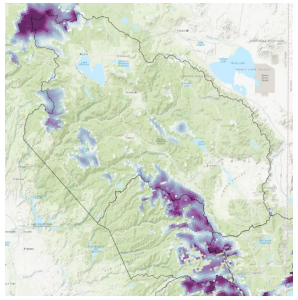
WRF-Hydro-ASO Data Assimilation: California Example

1. Direct Insertion Process:

1. 50m ASO SWE&depth



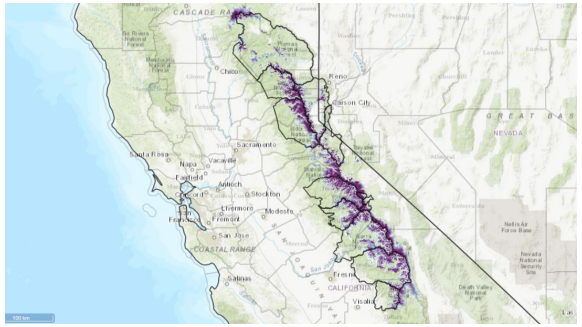
2. 1km SWE & depth



3. Insert and re-initializte WRF-Hydro/NoahMP snow States into "cold-start" version

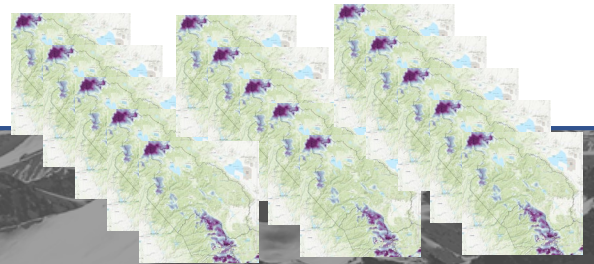
- Init: depth & SWE
- Derive density
- Re-derive layers
- Re-initialize temperature

4. Insert updated states into full regional forecast domain



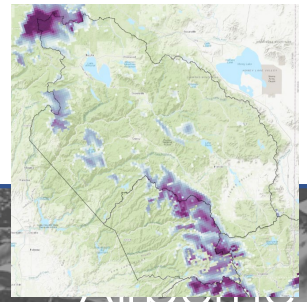
- **Pros:** Simple, fast, computationally-lean, preserves ASO survey values
- **Cons:** Model likely not fully equilibrated, can have large mass-discontinuities across assimilation
- Will do additional manual DA when large assimilation increments are present…
- **Moving to an ensemble DA process…**

2. Ensemble DA Process: *(see also Lahmers et al., 2021, Tuolumne)*



Robust ensemble: parameters, forcings, physics

LIS-based AEn-KF
DART-based AEn-KF



Optimal analysis from ensemble

Blend into full domain with other Basins…

WY2024 WRF-Hydro Forecast Reports

ASO Hydrologic Forecast Report

Yuba River Basin, CA

Forecast Date: Apr. 23, 2024

Airborne Snow Observatories, Inc. is a public benefit corporation with a mission to provide high-quality, timely, and accurate snow measurement, modeling, and runoff forecasts to empower the world's water managers to make the best possible use of our planet's precious water.

Historical data and reports can be found at:
data.airbornesnowobservatories.com

TUOLUMNE RIVER BASIN
FEB. 6, 2024 HYDROLOGIC FORECAST

Snowpack Status:

2.a.

Figure 2. Spatial map of SWE difference between WRF-Hydro ASO-assimilated values and OpenLoop values (inches). Valid: Feb. 6, 2024

2.b.

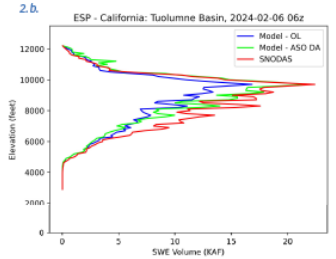


Figure 3. Elevation distribution of SWE between WRF-Hydro OpenLoop, ASO-assimilated and SNODAS (kac-ft). Valid: Feb. 6, 2024

Table 1.

Basin	Estimated SWE volume (kac-ft)
SNODAS	582.340
ASO-assimilated	509.308
OpenLoop	419.663

Figure 4. Basin-avg SWE from WRF-Hydro OpenLoop, ASO-assimilated and SNODAS (kac-ft)

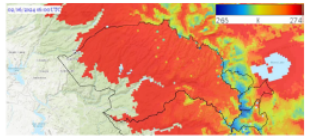


Figure 5. WRF-Hydro/OpenLoop integrated snowpack temperature (deg C). Valid: Feb. 6, 2024

TUOLUMNE RIVER BASIN
FEB. 6, 2024 HYDROLOGIC FORECAST

Modeled Evapotranspiration:

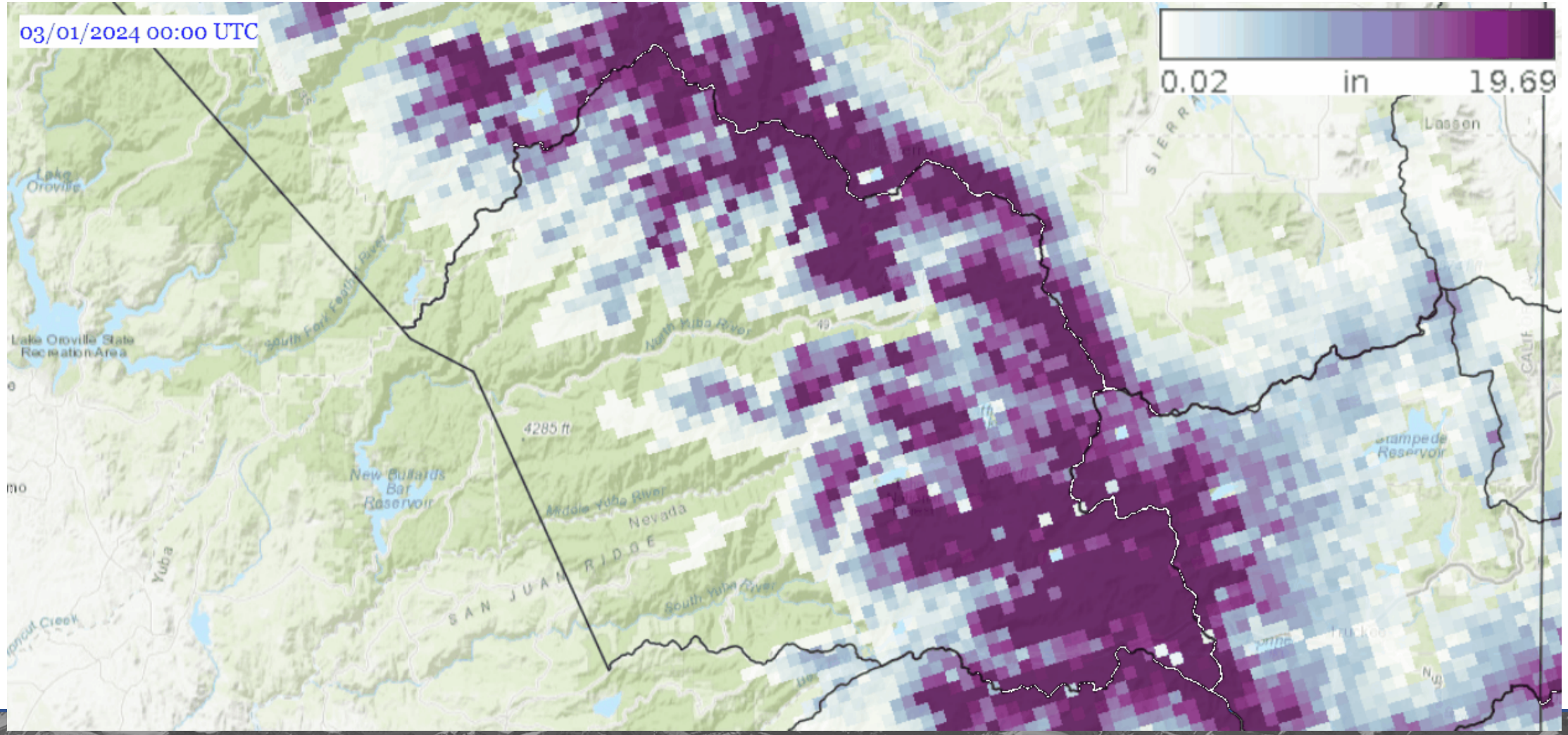
Summary of Evapotranspiration Consumption:
**PLACEHOLDER ...narrative.... narrative...

Figure 15. WRF-Hydro/OpenLoop analyzed, vertically-integrated soil saturation. (%-saturation). Valid: Feb. 6, 2024

Basin	Forecasted Evapotranspiration (kac-ft)
ASO - 02/06 00z	1017.898
OL - 02/06 00z	1017.386

Figure 16. WRF-Hydro forecasted evapotranspiration (kac-ft) from the OpenLoop and ASO-assimilated model analyses. Valid: Feb. 6, 2024

Snowpack Analyses: Yuba River Basin…



Snowpack Analyses: Yuba River Basin

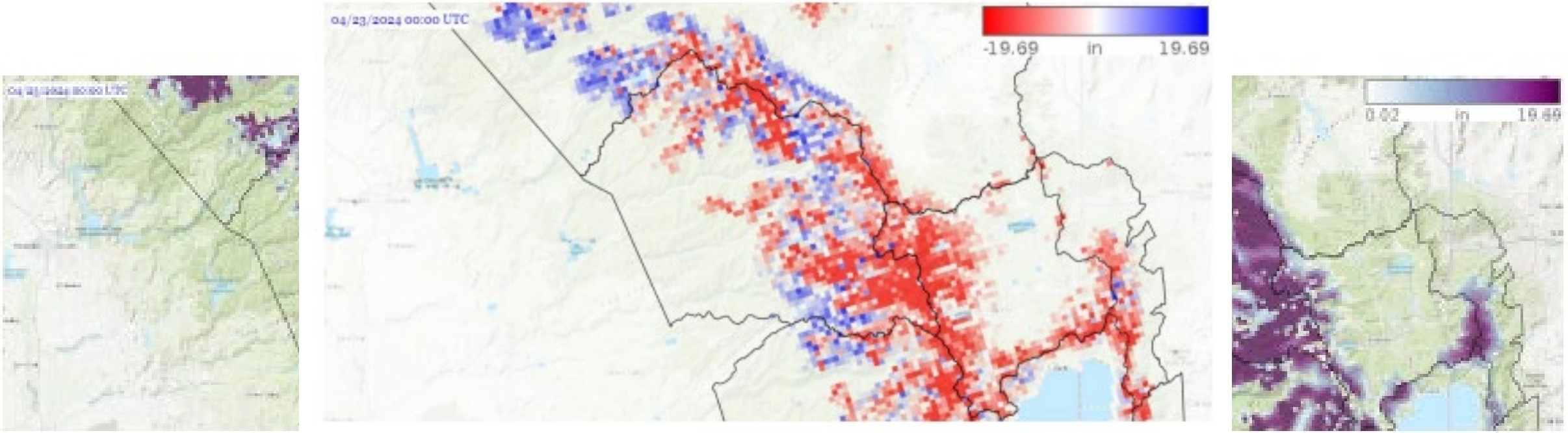


Figure 1. *Left: WRF-Hydro/ASO-assimilated, Right: OpenLoop 1km gridded Snow Water Equivalent (SWE - inches).*
Valid: Apr. 23, 2024

Snowpack Analyses: Yuba River Basin

Basin-integrated SWE: **ASO Surveys…**

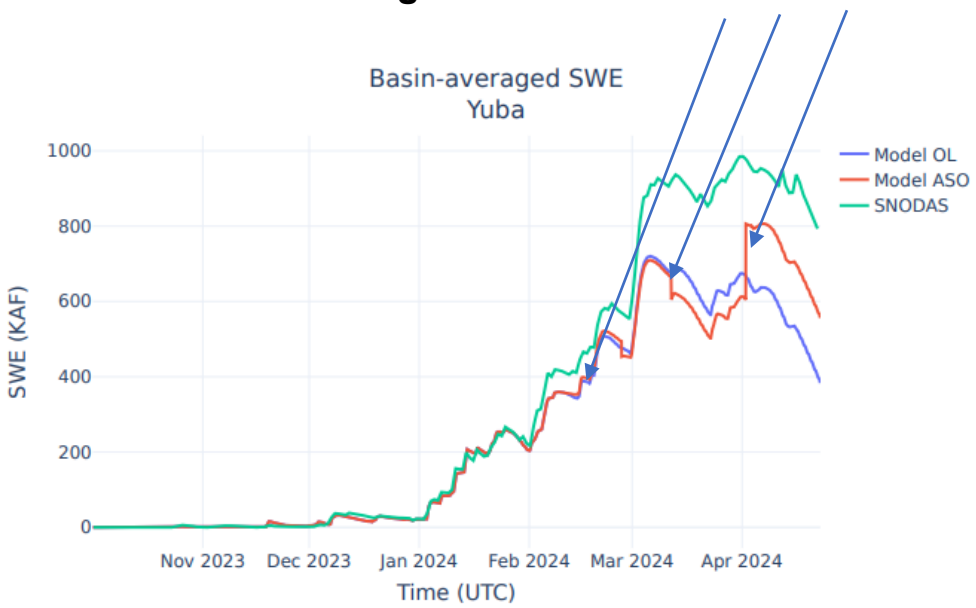


Figure 4. Basin-avg SWE from WRF-Hydro OpenLoop, ASO-assimilated and SNODAS (kac-ft)

Basin-integrated SWE Forecast:

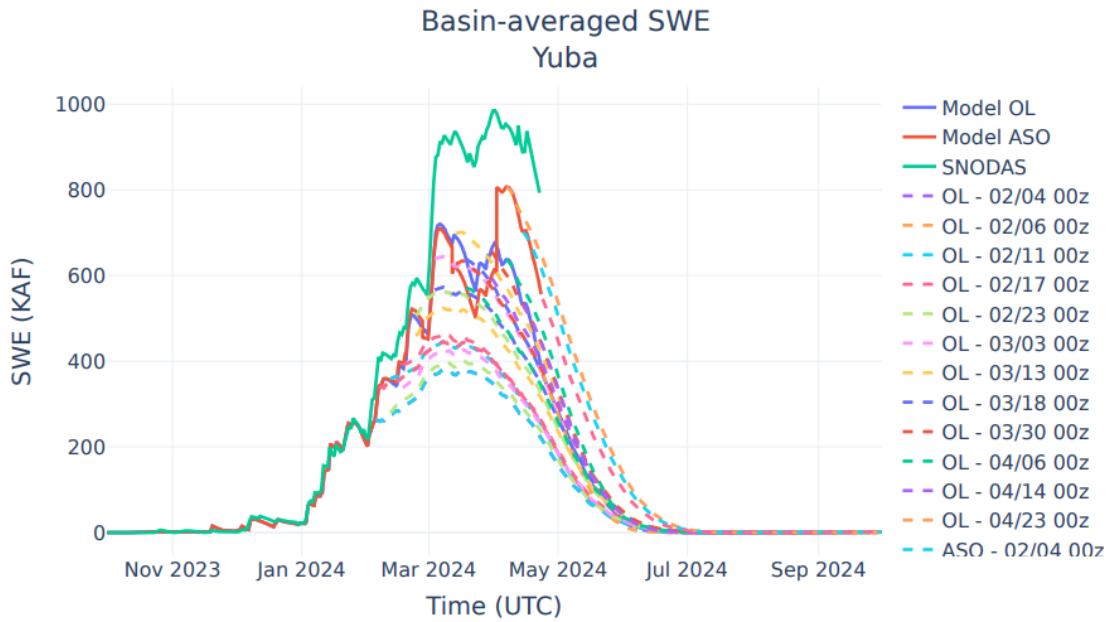


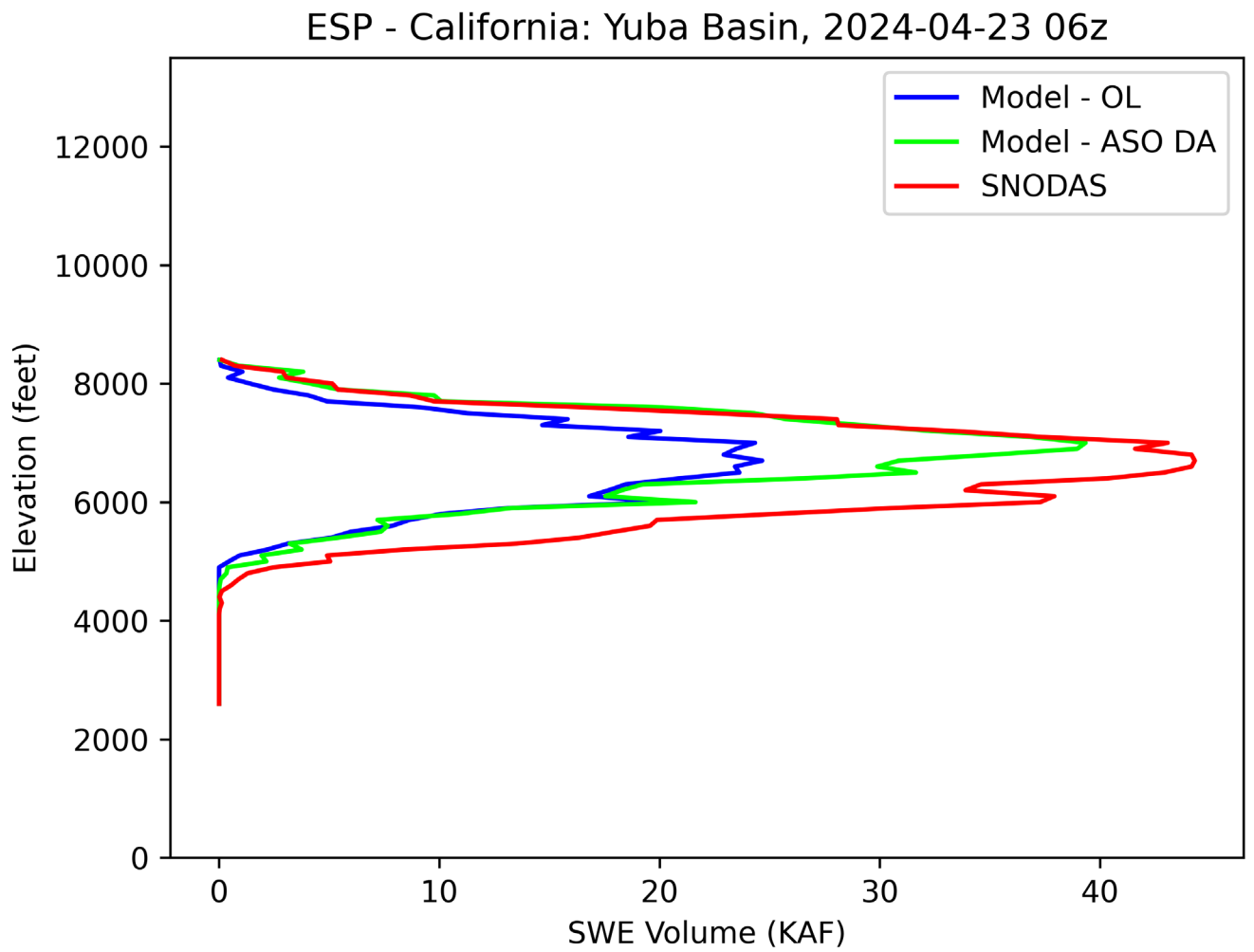
Figure 6. WRF-Hydro model analyzed and ensemble mean forecasted SWE. Valid: Apr. 23, 2024

Table 1. Apr. 23, 2024

Basin	Estimated SWE volume (kac-ft)
SNODAS	766.163
ASO-assimilated	554.154
OpenLoop	379.611

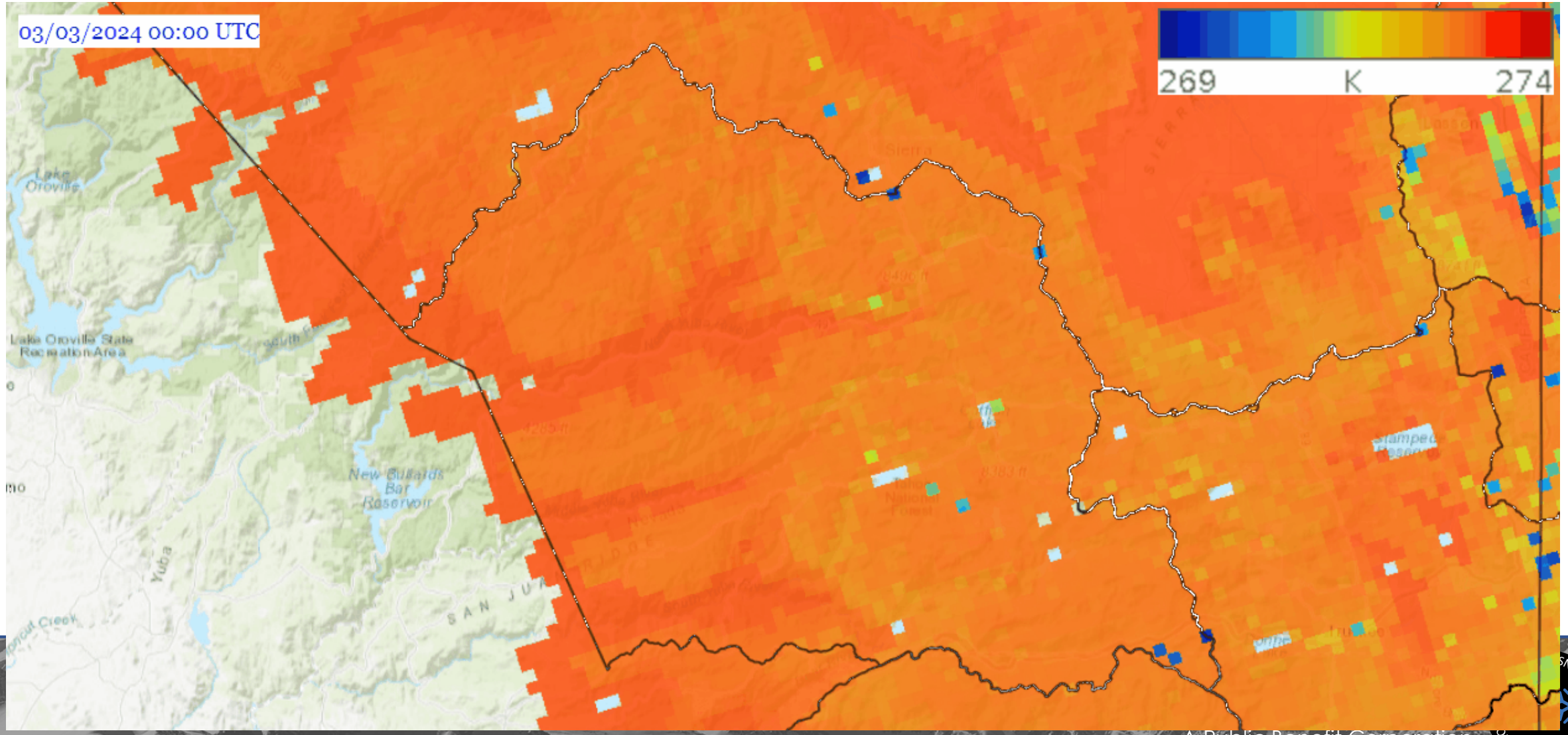
Snowpack Analyses: Yuba River Basin…

Springtime Elevation Evolution…



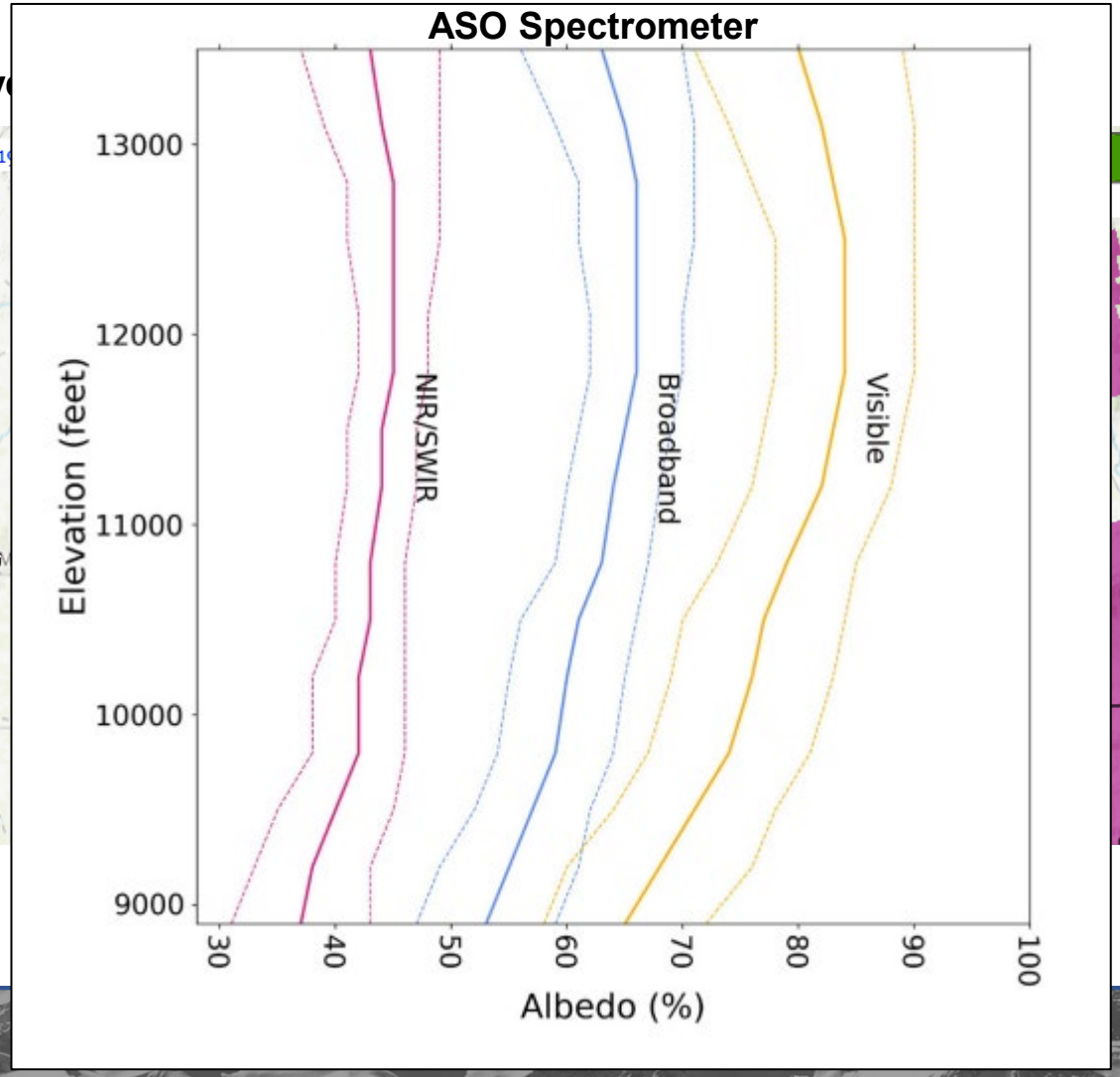
Snowpack Thermal analysis: Yuba River…

Snowpack Temperature Animation

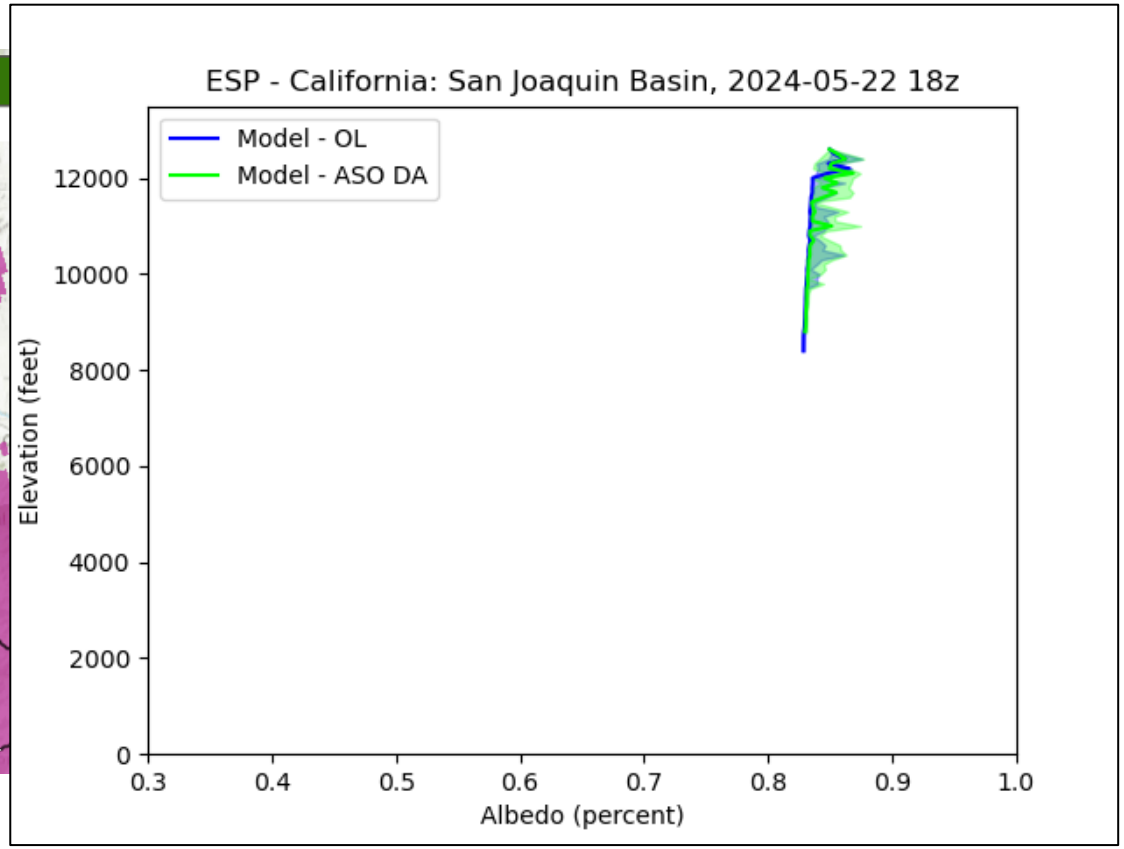


Snow Albedo (VIZ): San Joaquin Basin

WRF-Hy



WRF-Hydro model



Snowpack Analyses: Yuba River Basin…

Snowmelt forecasts….

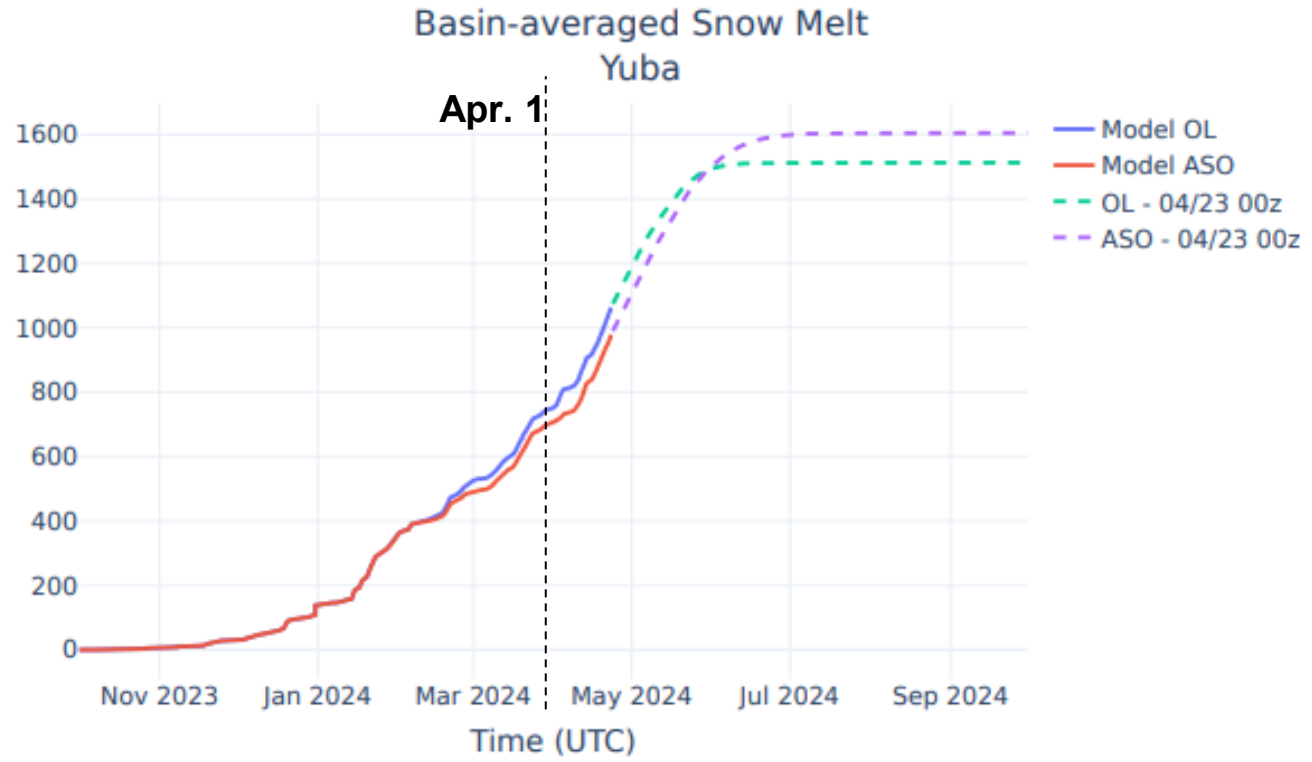
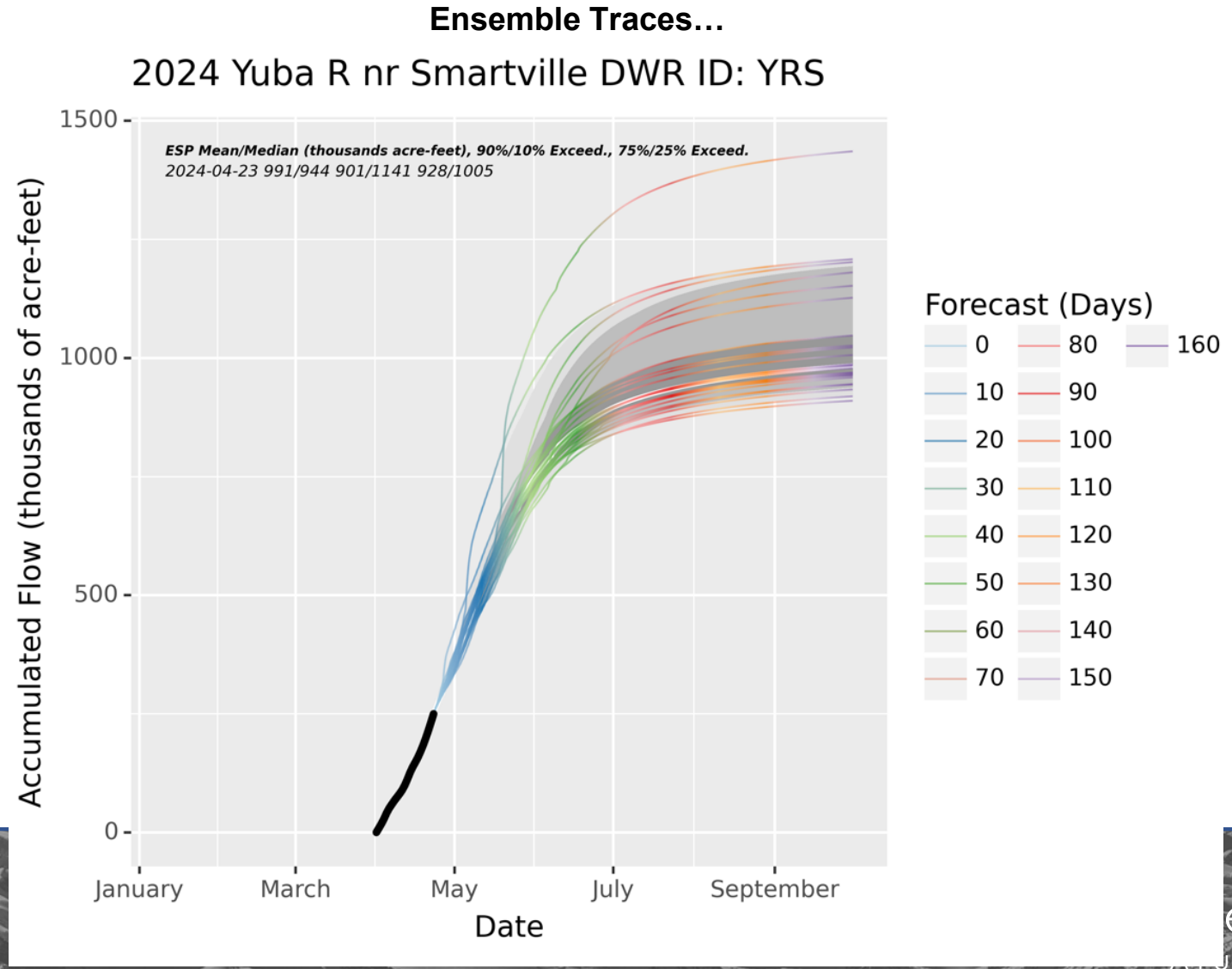


Figure 7. *WRF-Hydro model forecasted basin-integrated ensemble mean accumulated snowmelt (inches) from OpenLoop and ASO-assimilated version.*

ASO WRF-Hydro Ensemble Seasonal Runoff Forecasts:



ASO WRF-Hydro Ensemble Seasonal Runoff Forecasts:

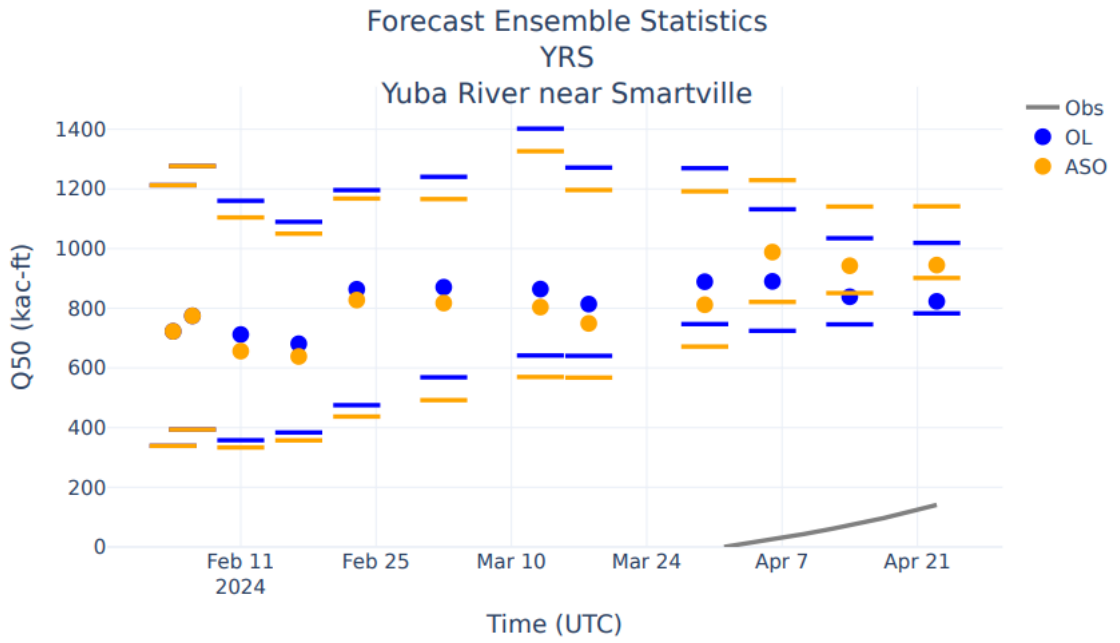
Runoff/Inflow Forecast Information…

Forecast Tables…

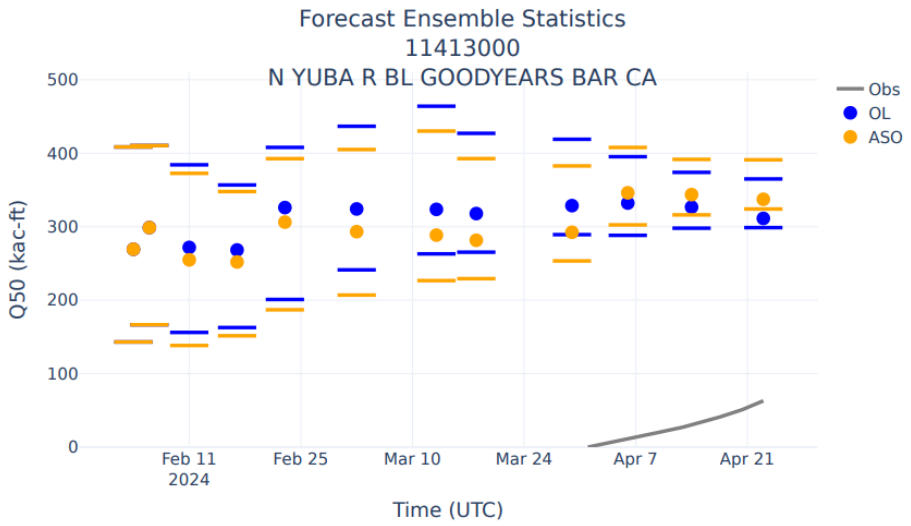
YRS (Yuba River near Smartville)
Volumes (kac-ft)

Forecast Date	Mean	Q90	Q75	Q50	Q25	Q10
Apr 06, 2024 (OL)	915.654	724.438	809.062	890.272	1032.979	1131.911
Apr 06, 2024 (ASO)	1012.647	821.302	908.147	988.378	1132.619	1229.371
Apr 14, 2024 (OL)	868.537	746.133	780.232	838.608	924.083	1034.854
Apr 14, 2024 (ASO)	973.616	850.998	881.866	942.575	1030.029	1140.814
Apr 23, 2024 (OL)	870.642	782.928	805.880	823.221	883.838	1019.130
Apr 23, 2024 (ASO)	991.234	901.591	928.188	944.817	1005.707	1141.692

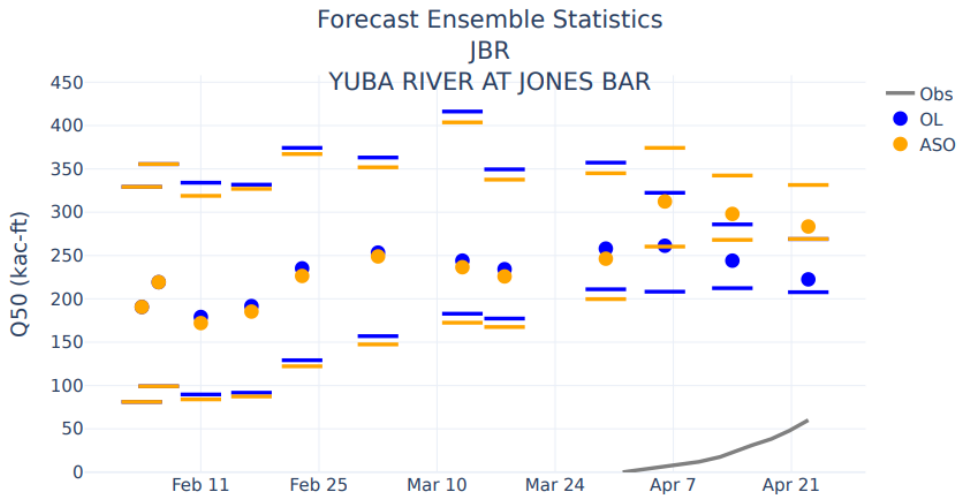
Dot plots…

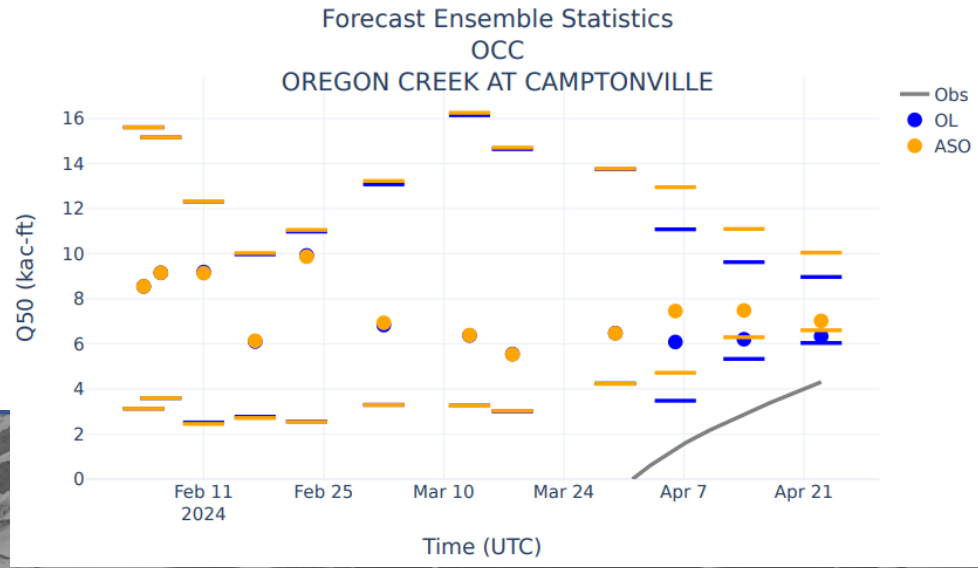


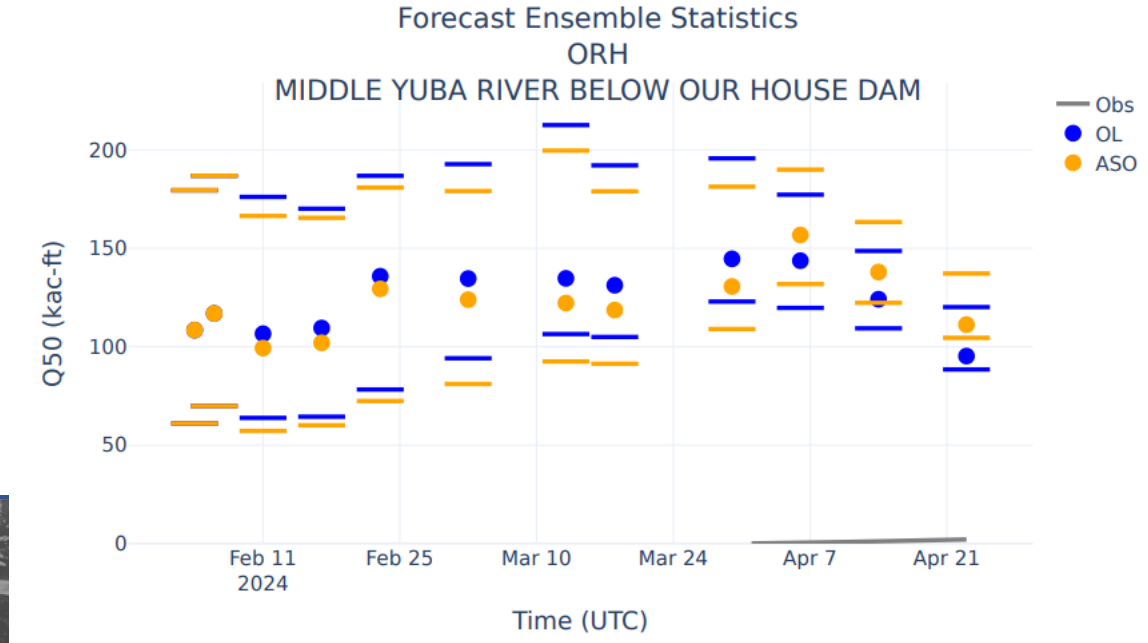
ASO WRF-Hydro Ensemble Seasonal Runoff Forecasts:



More Dot plots…

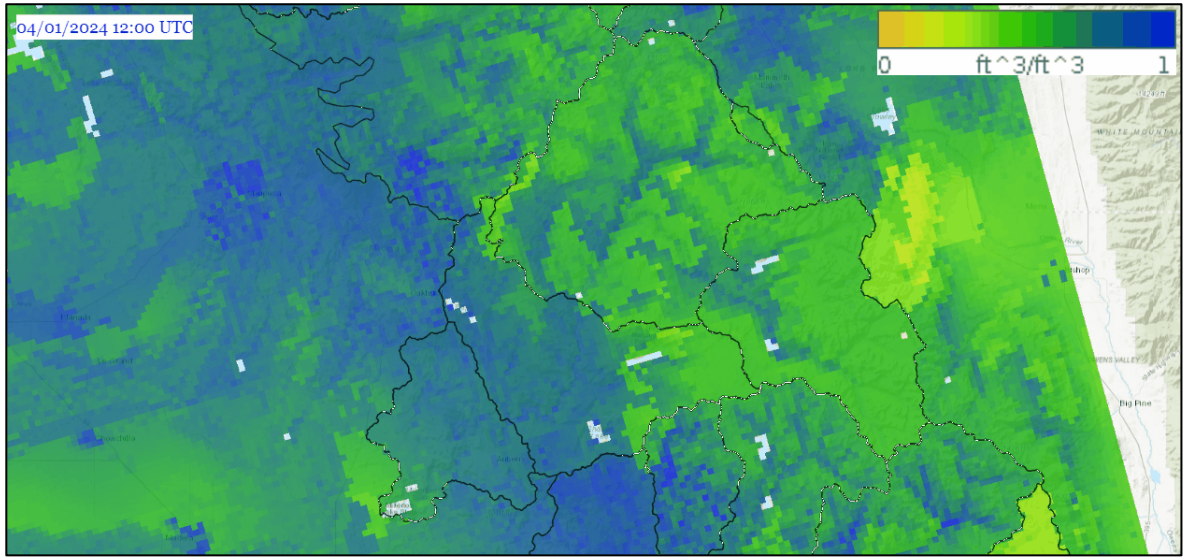


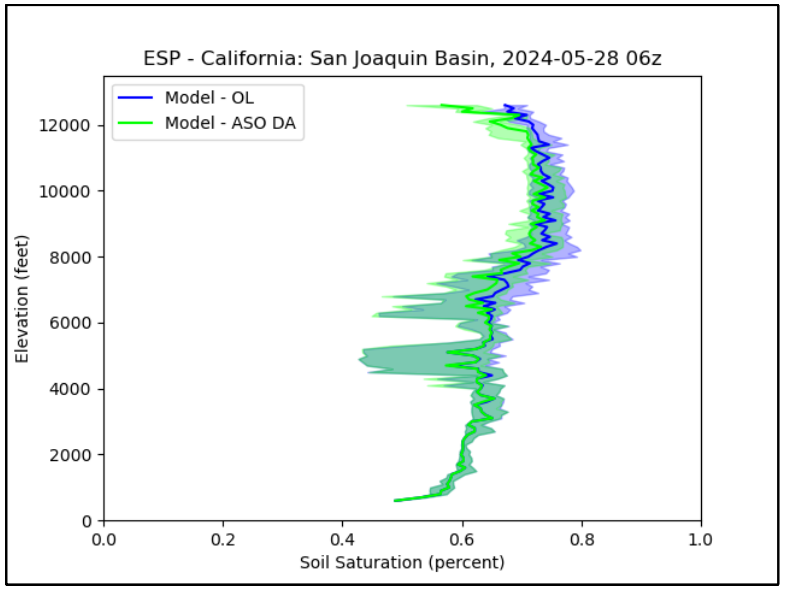


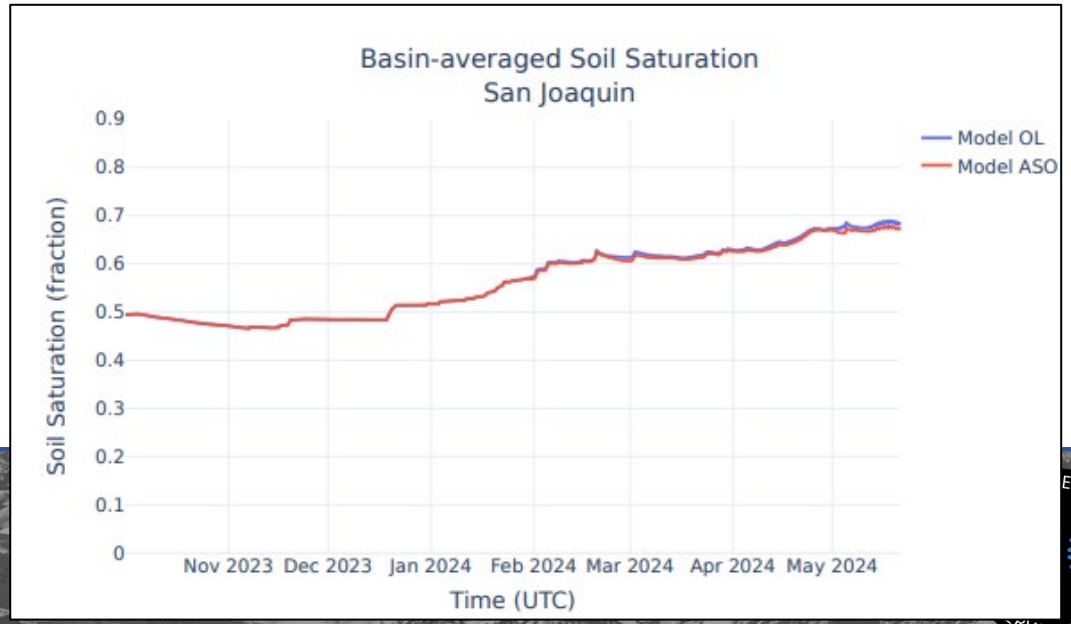


Soil Moisture Analyses: San Joaquin Basin

WRF-Hydro Soil Saturation Apr. 1 – May 28, 2024

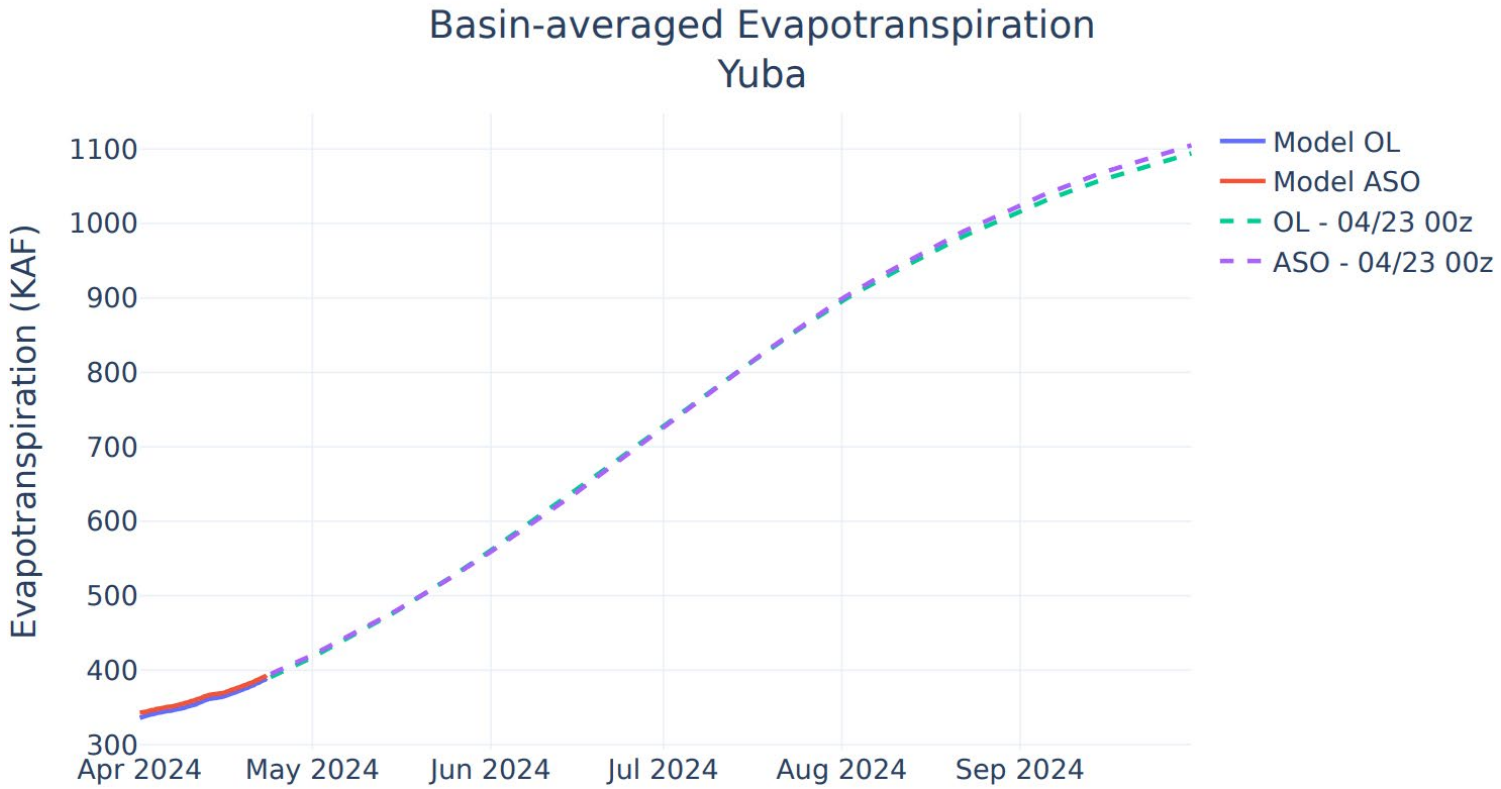


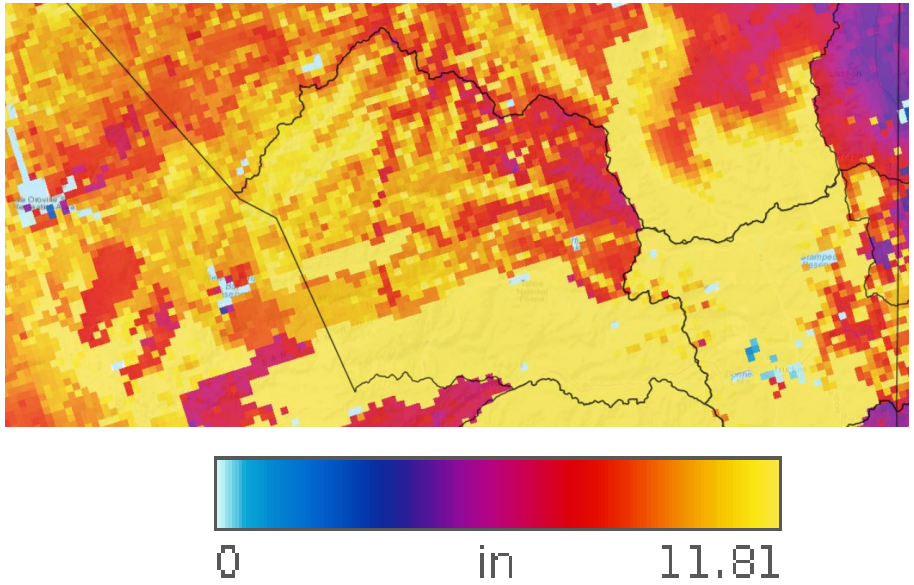




ASO WRF-Hydro Projected Seasonal ET:

WRF-Hydro ET Forecast ending Jul 31, 2024:





Thank you

D. Gochis

Head of Prediction Services, ASO, Inc.

david.gochis@airbornesnowobservatories.com

WY2024 WRF-Hydro Forecast Report: San Joaquin Basin

ASO Hydrologic Forecast Report

San Joaquin River Basin, CA

Forecast Date: May 28, 2024

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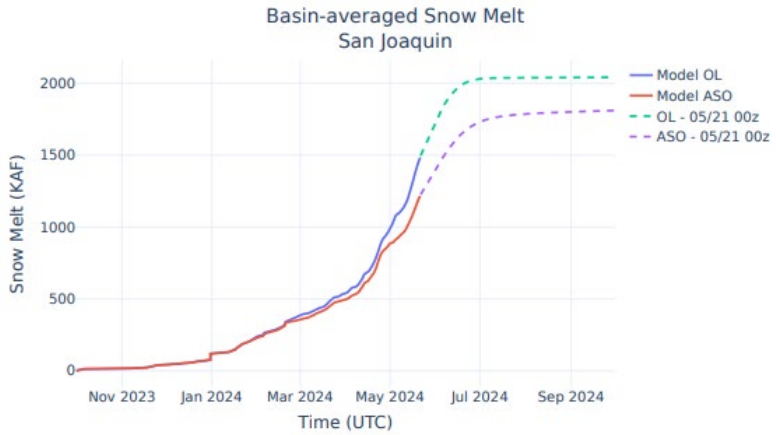


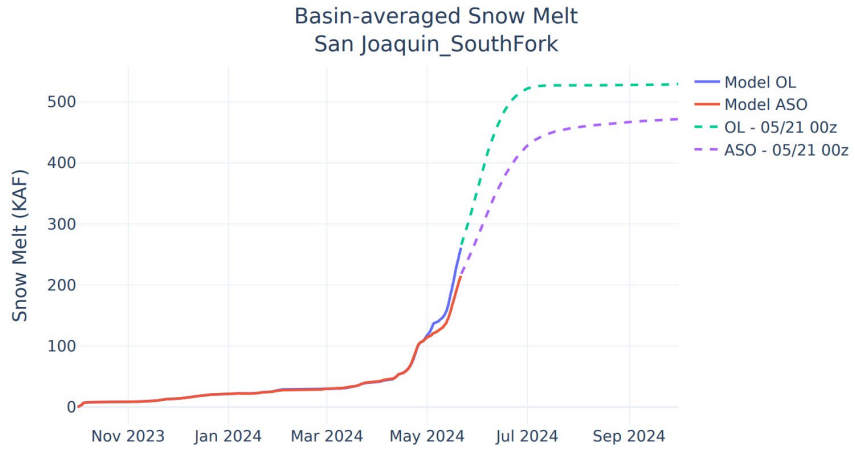
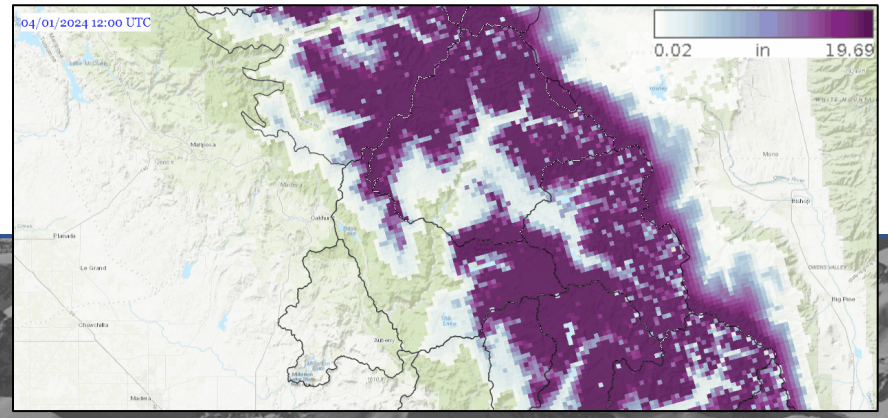
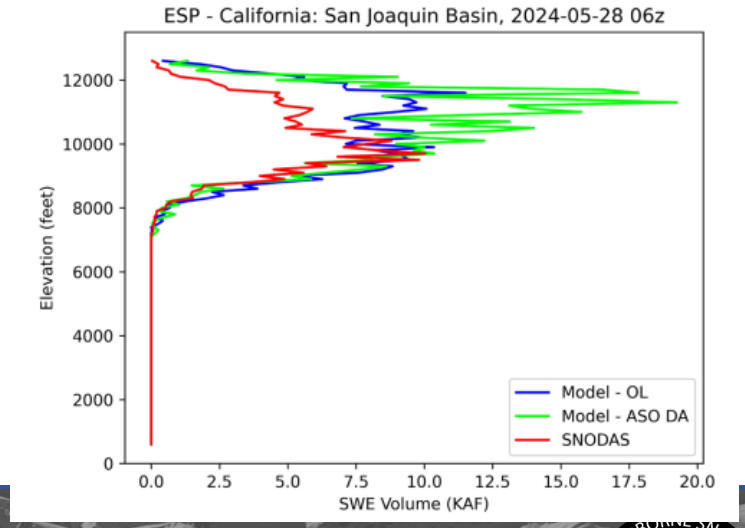


Table 1. Valid: May 28. 2024

Basin	Estimated SWE volume (kac-ft)
SNODAS	206.887
ASO-assimilated	376.144
OpenLoop	327.640

Snow Water Equivalent (Apr 1 – May 28)





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