# WRF-Hydro/Airborne Snow Observatory Assimilated Hydrologic Forecasts: Colorado

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[Updated for all basins each new forecast that becomes available]

**Provided by: NCAR WRF-Hydro Modeling Team**

D. Gochis, Y. Zhang, A. Gaydos, J. Grim, M. Casali, K. Sampson

## Overview:

This report summarizes WRF-Hydro forecast results for selected major river basin forecast points across the state of Colorado. Included in each report are the following:

- Spatial maps of analyzed ASO-assimilated SWE from WRF-Hydro
- Time-series plots of basin-averaged analyzed and forecasted SWE from the WRF-Hydro OpenLoop model, WRF-Hydro ASO-assimilated model and SNODAS products
- Plots of elevation bin-averaged SWE vs. elevation from WRF-Hydro OpenLoop and ASO-Assimilated analyses and SNODAS
- Tabulations of Apr. 1 – Jul. 31 and/or Apr. 1 – Sep. 30 ensemble seasonal water supply forecasts

## WRF-Hydro Forecasts for the Colorado Airborne Snow Measurement (CASM)

The WRF-Hydro modeling system has been employed in various seasonal water supply forecasting activities in the State of Colorado since 2015. Starting first in the Rio Grande/Conejos River basin regions new forecast basins/locations have steadily been added over time as interest in the system has grown. Currently a single model domain has been established over all of the mountain headwater regions of the state to enable snowpack and runoff predictions from key water resource generation areas. While the model integrates over all of these areas, preparation and optimization of *reliable* forecasts at particular locations is limited to areas where funded efforts have been made to engage in data assimilation, model evaluation and model optimization. Prior forecast domains have included the Rio/Conejos system, East/Taylor system, the Dolores basin, Blue River/Dillon Reservoir system and the Upper Colorado/Fraser/Willow Creek/Windy Gap system. The CASM mission has recently (past 2 years) contributed to this data assimilation and model optimization effort by coordinating and support Airborne Snow Observatory, Inc. surveys of snowpack and model forecasting activities. This year new forecast basins include the Roaring Fork/Frying Pan System, the Upper South Platte System and Poudre/ Big Thompson/St. Vrain/Boulder/Clear Creek Front Range systems. Implementation of these new areas along with enhanced optimization of prior domains initiated in April 2023 at the start of the new contract to

fund WRF-Hydro forecasting. As such, forecast development for new basins added this year are still a work in progress and forecast results will be shared as they become available.

This report is organized by river basin which each basin area containing the following information:

- Spatial analyses of ASO-assimilated (where available) snow water equivalent (SWE)
- Basin-averaged analyses and ensemble mean forecast plots of SWE
- Elevation distributions of SWE
- Spatial maps and basin-averaged analyses of modeled soil moisture
- Sub-seasonal (April-July) and seasonal (April-Sept.) values of ensemble accumulated runoff or reservoir inflow

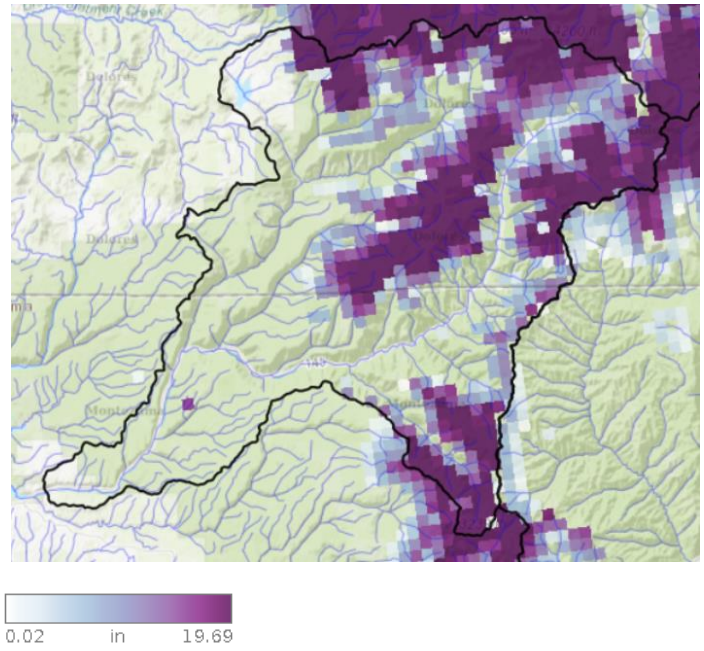
Additional model outputs are being prepared and will be added to future reports as they become available. Additionally, as noted above, several forecast locations are new or are having issues addressed that relate to the availability of timely and quality unregulated flow information for model calibration and forecast preparation. As such, not all locations have forecast information available at this time but will be added as work proceeds.

**IMPORTANT:** All flow accumulation forecasts from this specific configuration of the WRF-Hydro model are "natural" flow values with no accounting for reservoir storage/release, diversions, transfers or managed return flows. As such, these forecast numbers should be compared against analogous naturalized flow measurements or estimates.

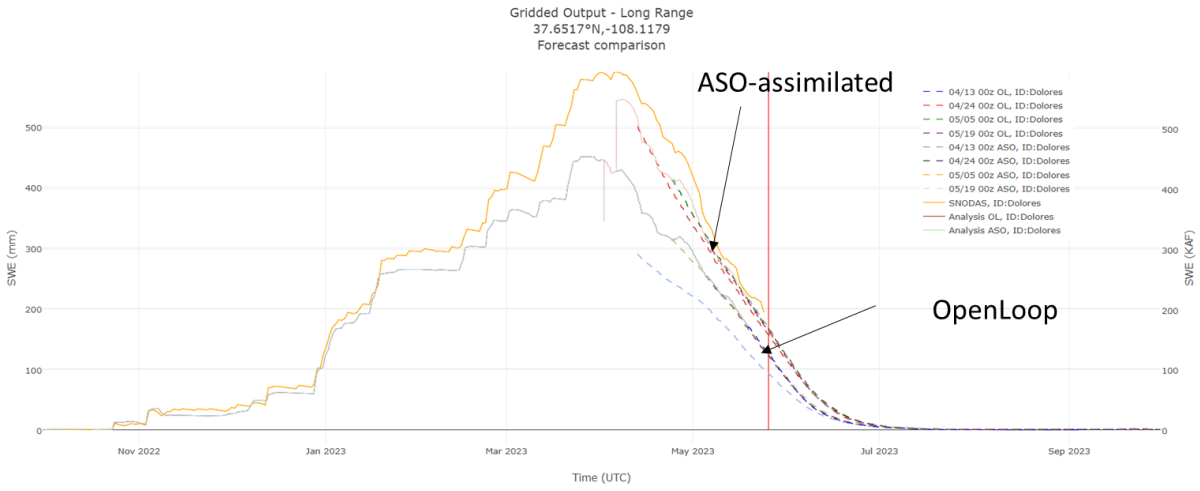
## Dolores River Basin:

As of May 20 the ASO-assimilated snowpack from the WRF-Hydro model was approximately 218 kac-ft and dropping quickly. Snowpack ablation forecasts have tracked subsequent analyses quite well. Nearly all snowpack resided above 9,000 ft. Basin-averaged soil saturation fraction remained around 75% indicating very wet conditions.

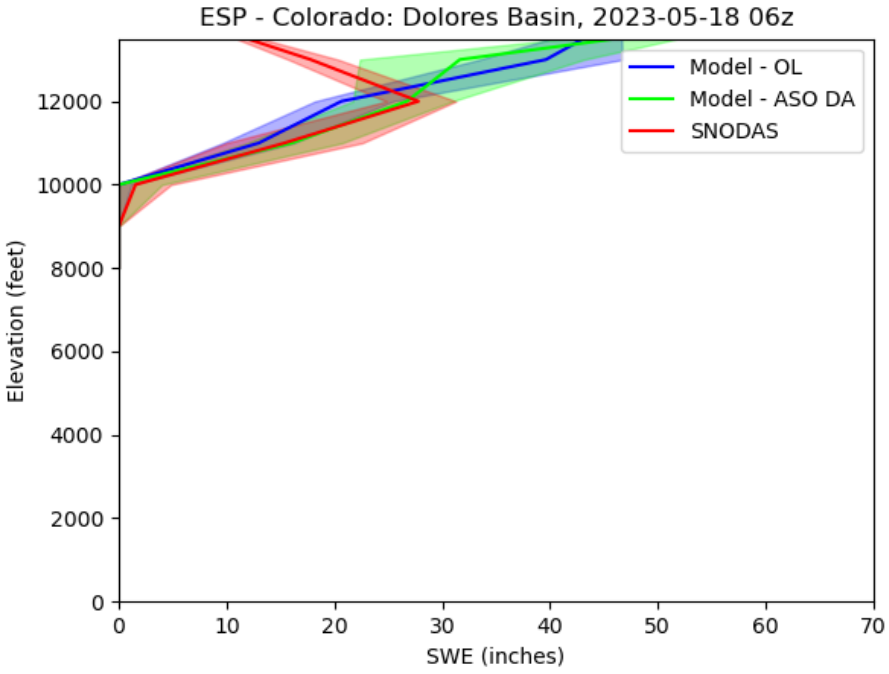
*Spatial map of ASO-assimilated SWE:*



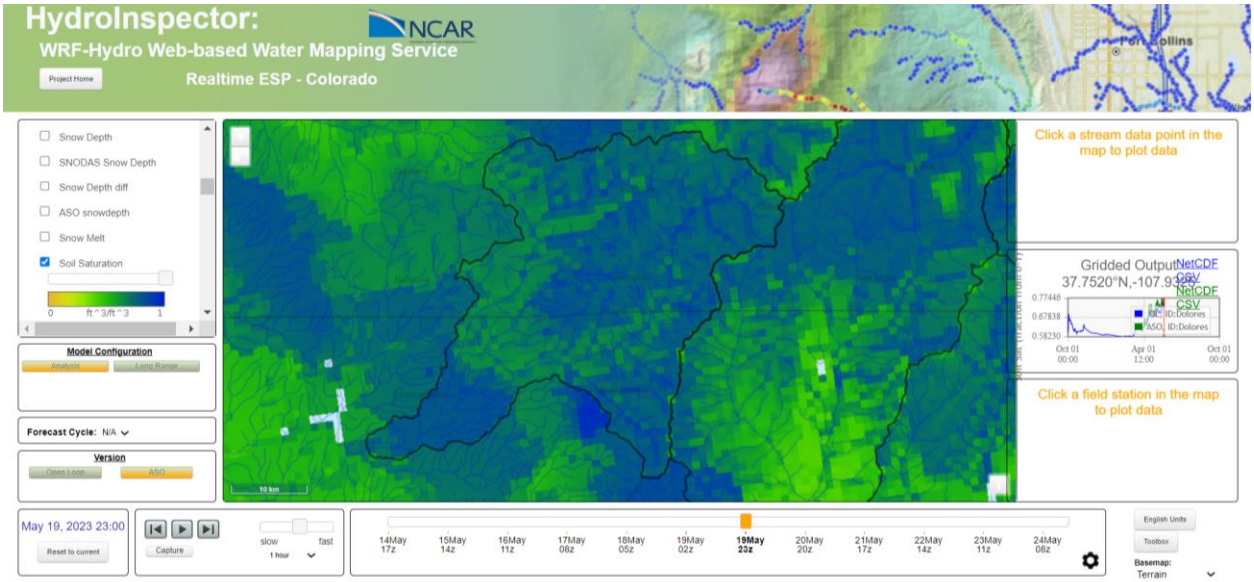

*Basin-averaged analyses and forecasts of ASO-assimilated SWE:*



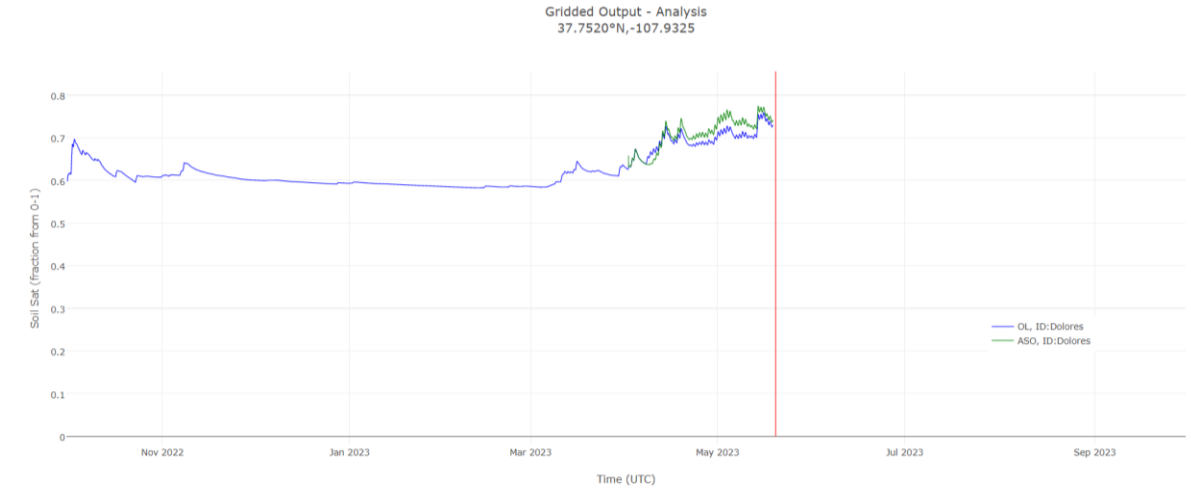
*Elevation profile of SWE for SNODAS (red), ASO-assimilated snowpack (green) and WRF-Hydro OpenLoop (blue)*




*Spatial map of WRF-Hydro modelled soil saturation:*



*Basin-averaged soil saturation values:*




*Dolores R. at Dolores, CO, median (Q50) runoff forecast (initialized on 5/20/2023):*

Apr-Jul: 438 kac-ft *(Noted major diversion upstream to Groundhog Res.: 16 kac-ft and climbing)

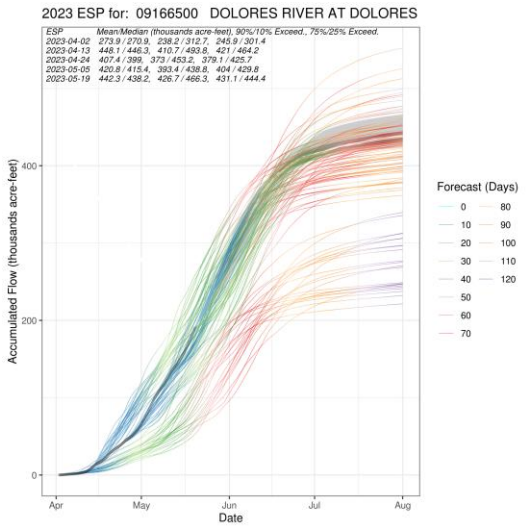
Apr-Sep: 465 kac-ft *(Noted major diversion upstream to Groundhog Res.: 16 kac-ft and climbing)

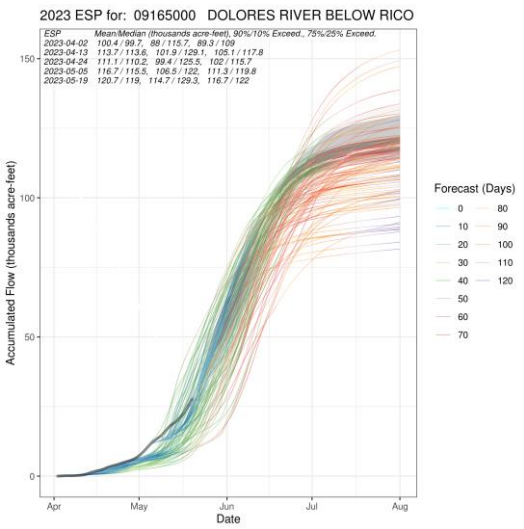
*Dolores R. blw Rico, CO, median (Q50) runoff forecast (initialized on 5/20/2023):*

Apr-Jul: 118 kac-ft

Apr-Sep: 128 kac-ft

*Sample plots for Apr-Jul ESP forecasts (ignore forecasts before 4/24):*

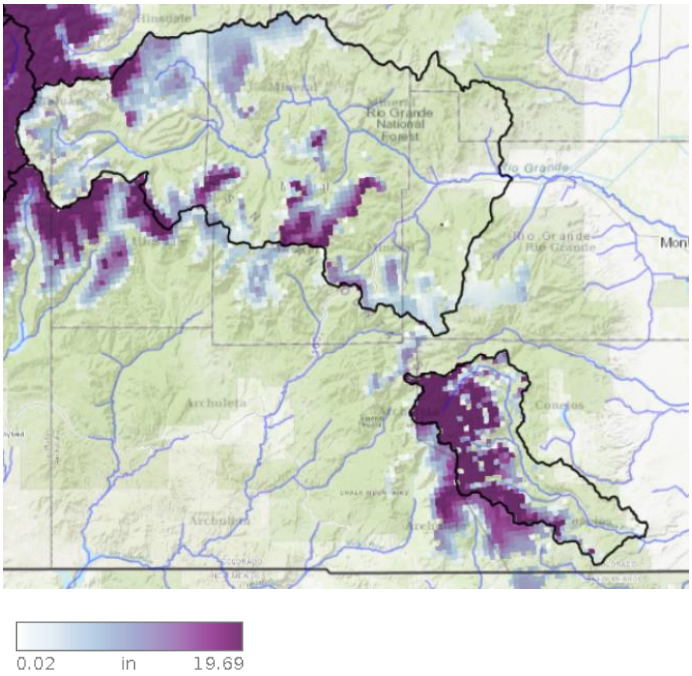


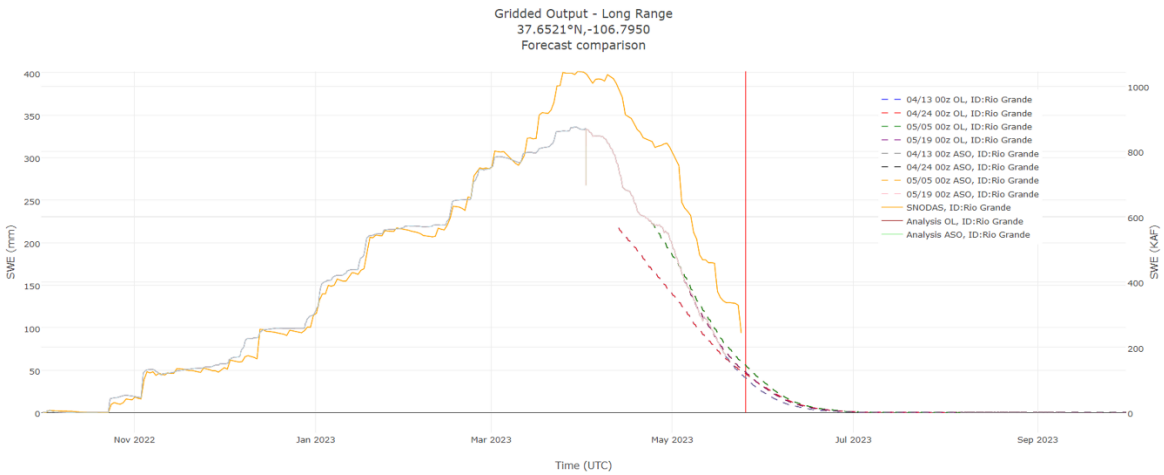
## Rio Grande/Conejos System:

As of May 20 the ASO-assimilated snowpack from the WRF-Hydro model was approximately 173 kac-ft for the Rio Grande above del Norte and 200 kac-ft for the Conejos basin above Mogote. Nearly all snowpack in both basins resided above 10,000 ft. Basin averaged soil saturation fractions for both basins were around 70% or above.

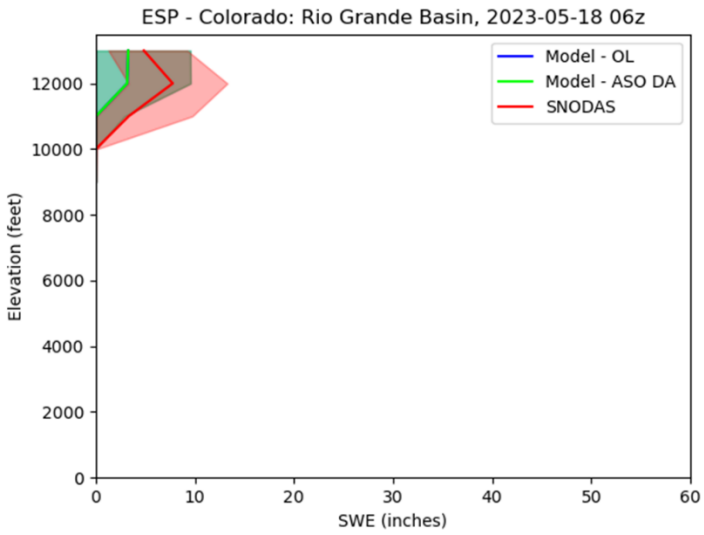
*Spatial map of ASO-assimilated SWE:*



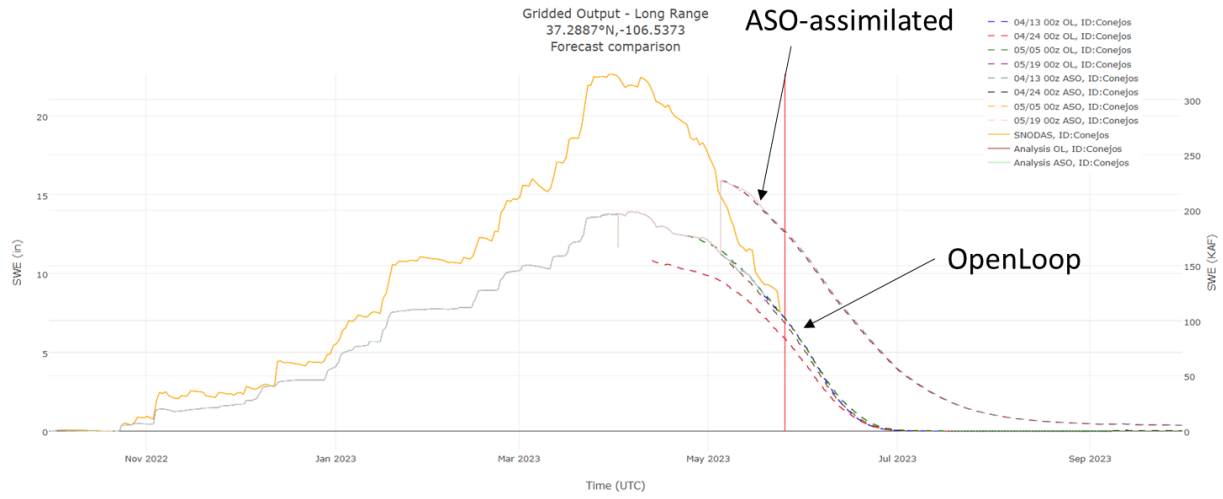

*Rio Grande basin-averaged analyses and forecasts of ASO-assimilated SWE: (OpenLoop only)*



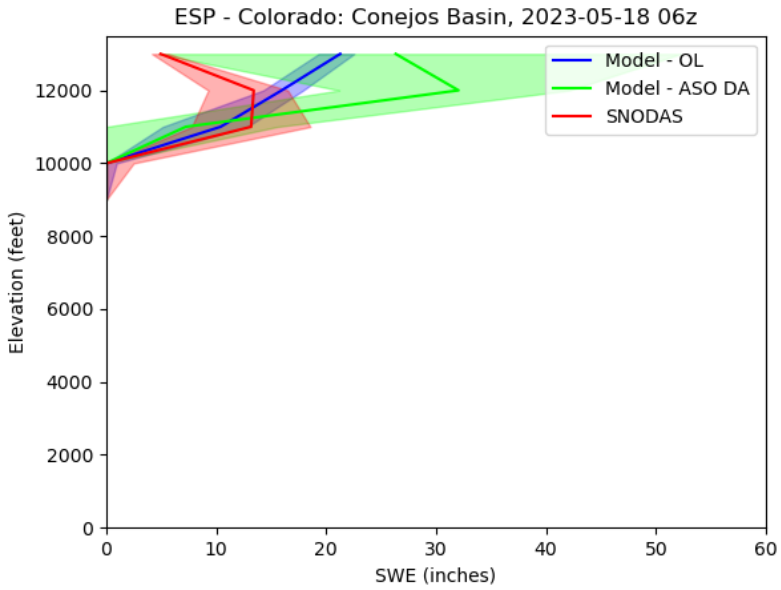
*Elevation profile of SWE for SNODAS (red), ASO-assimilated snowpack (green) and WRF-Hydro OpenLoop (blue)*



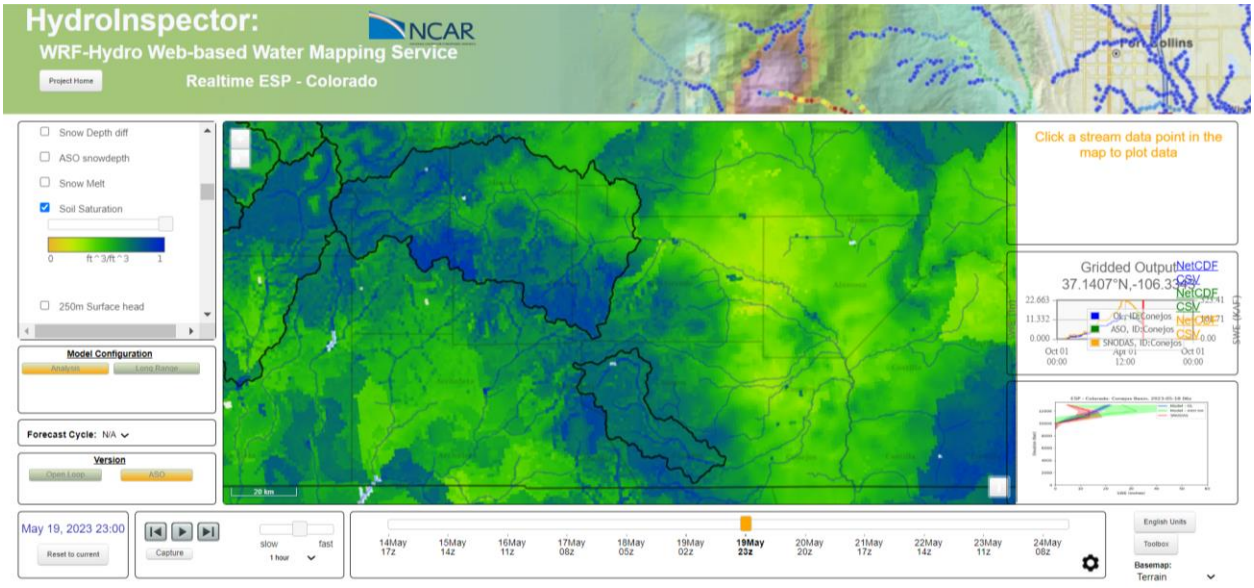

*Conejos basin-averaged analyses and forecasts of ASO-assimilated SWE:*



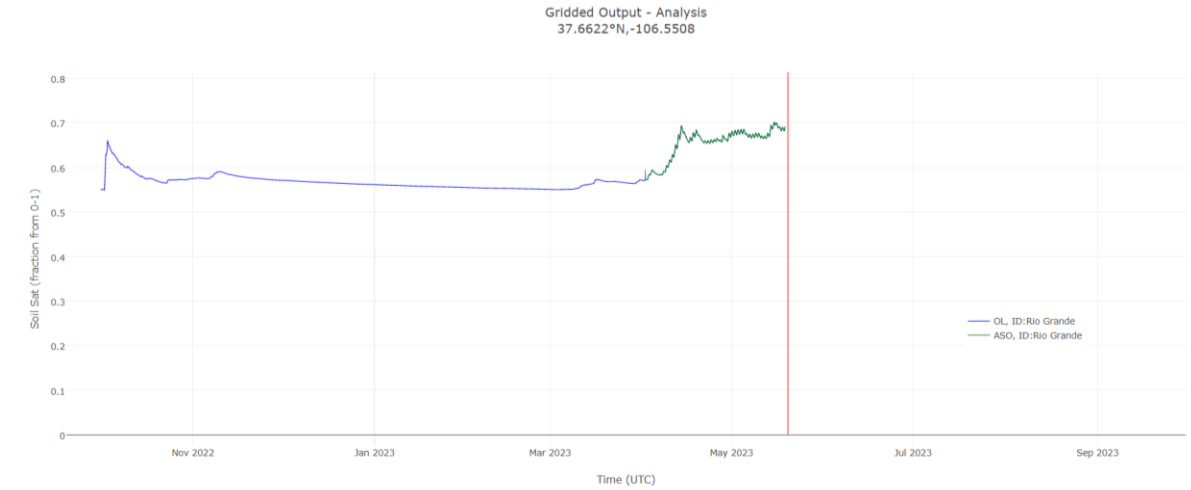
*Elevation profile of SWE for SNODAS (red), ASO-assimilated snowpack (green) and WRF-Hydro OpenLoop (blue)*

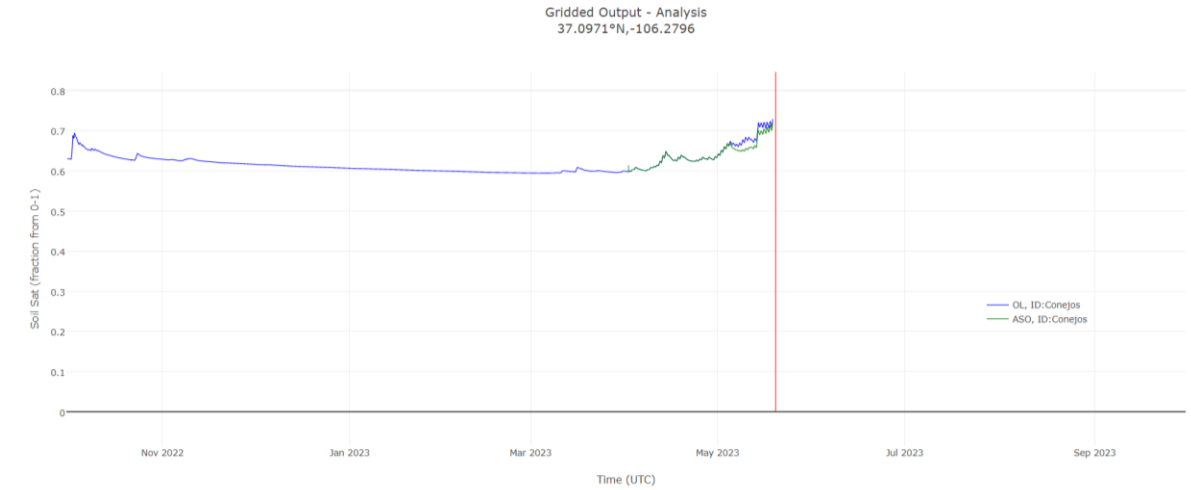



*Spatial map of WRF-Hydro modelled soil saturation:*



*Basin-averaged soil saturation values:*




*Rio Grande and Conejos April-Sep Median (Q50) Accumulated Runoff/Inflow (initialized on 5/20/2023):*

Rio at del Norte: WRF-Hydro/OL: 514 kac-ft (Apr-Jul): 548 kac-ft (Apr-Sep)

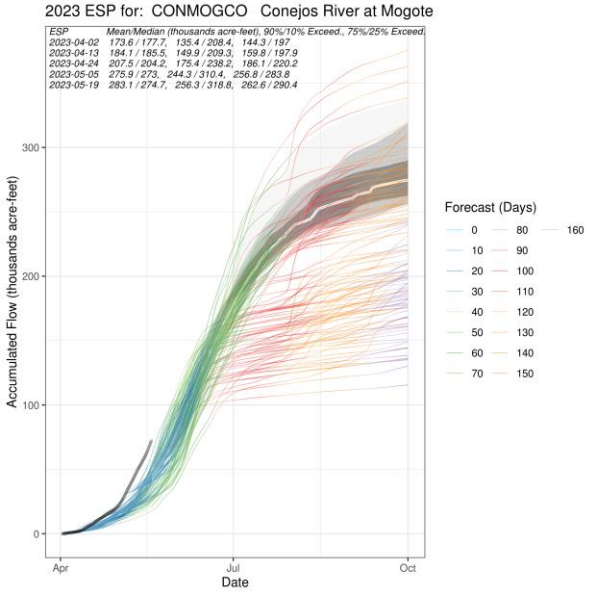
Conejos System: WRF-Hydro/ASO: 343 kac-ft (Apr-Jul): 392 kac-ft (Apr-Sep)

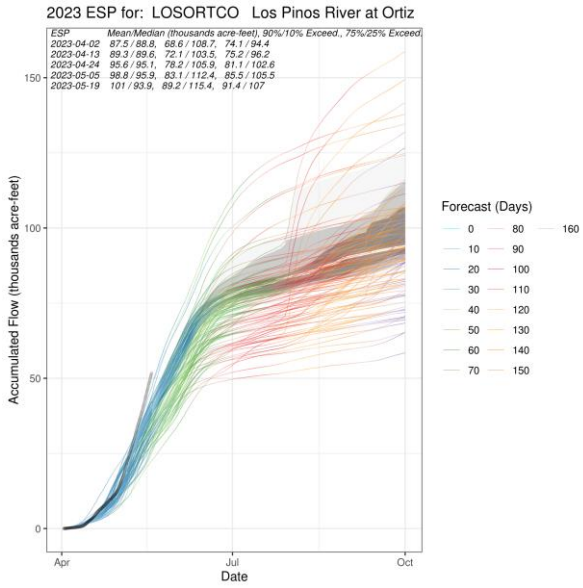
Conejos at Mogote: WRF-Hydro/ASO: 238 kac-ft (Apr-Jul): 275 kac-ft (Apr-Sep)

San Antonio @ Ortiz: WRF-Hydro/ASO: 21.3 kac-ft (Apr-Jul): 23 kac-ft (Apr-Sep)

Los Pinos @ Ortiz: WRF-Hydro/ASO: 83.7 kac-ft (Apr-Jul) 94 kac-ft (Apr-Sep)

*Sample plots for Apr-Oct ESP forecasts (ignore forecasts before 4/24):*

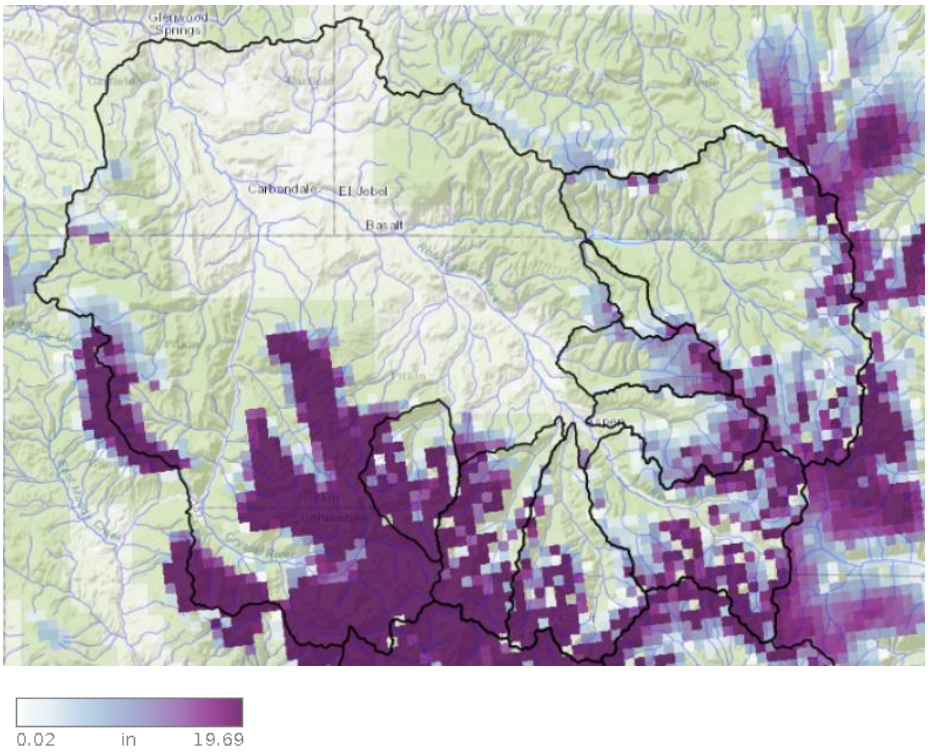


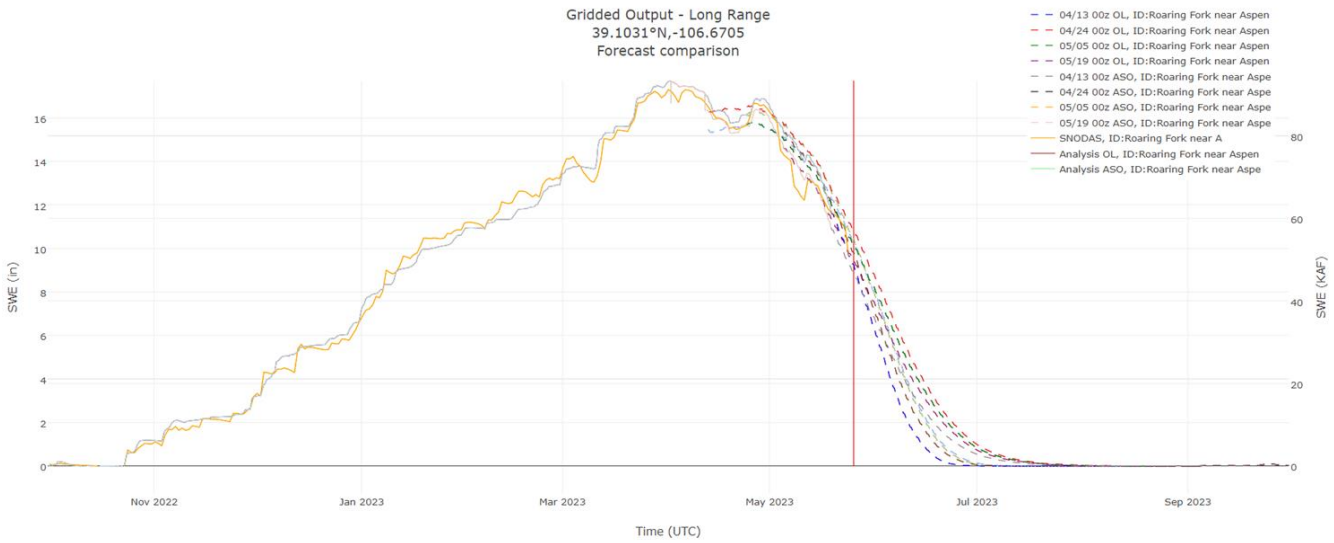
## Roaring Fork/Frying Pan System:

As of May 20 the ASO-assimilated snowpack from the WRF-Hydro model was approximately 58 kac-ft for the Roaring Fork River above Aspen and 54 kac-ft for the Frying Pan River above Ruedi Reservoir. The bulk of the remaining snowpack in the combined Roaring Fork/Frying Pan system resided above 10,000 ft. Basin averaged soil saturation fractions for the combined Roaring Fork/Frying Pan system above Glenwood has remained consistently around 63%.

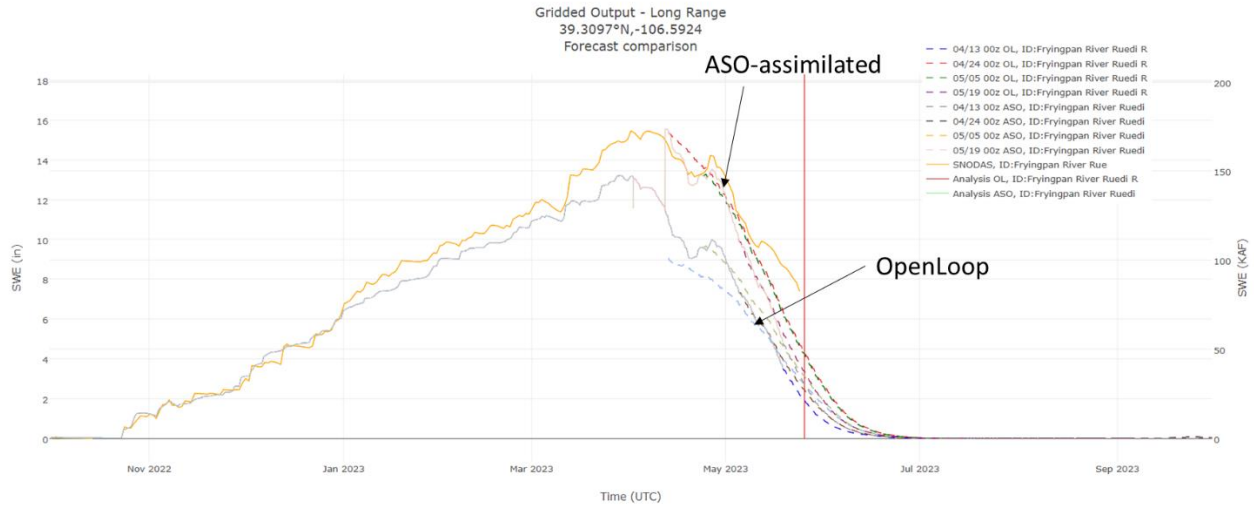
*Spatial map of ASO-assimilated SWE:*



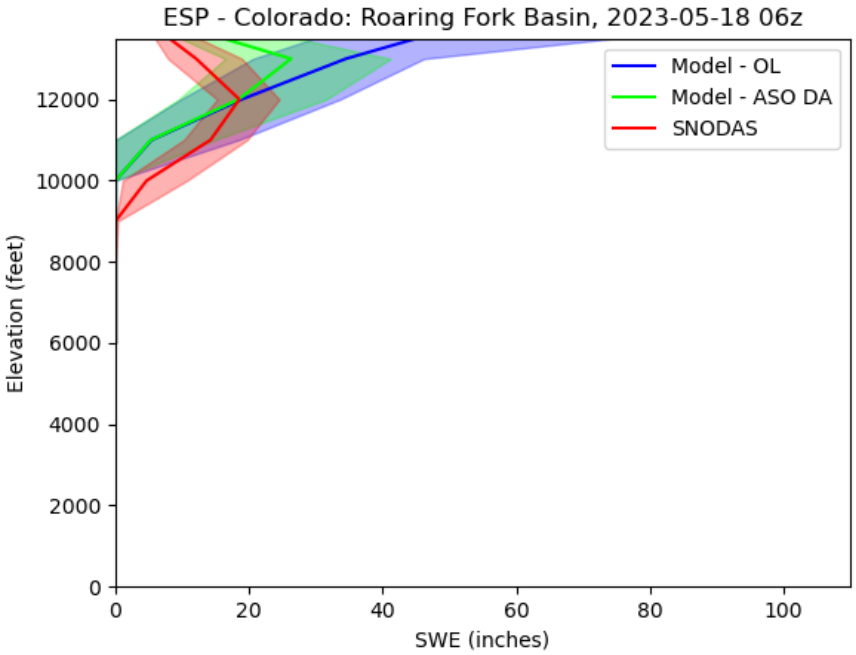
*Basin-averaged analyses and forecasts of ASO-assimilated SWE (Roaring Fork River near Aspen):*



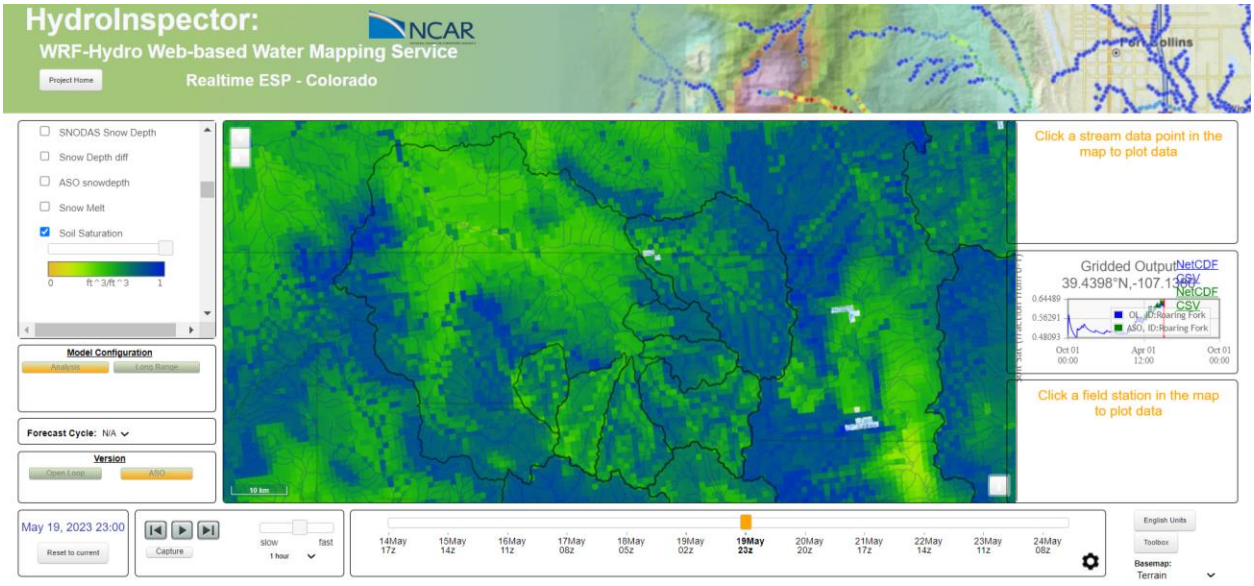

*Basin-averaged analyses and forecasts of ASO-assimilated SWE (Frying Pan River above Ruedi Reservoir):*



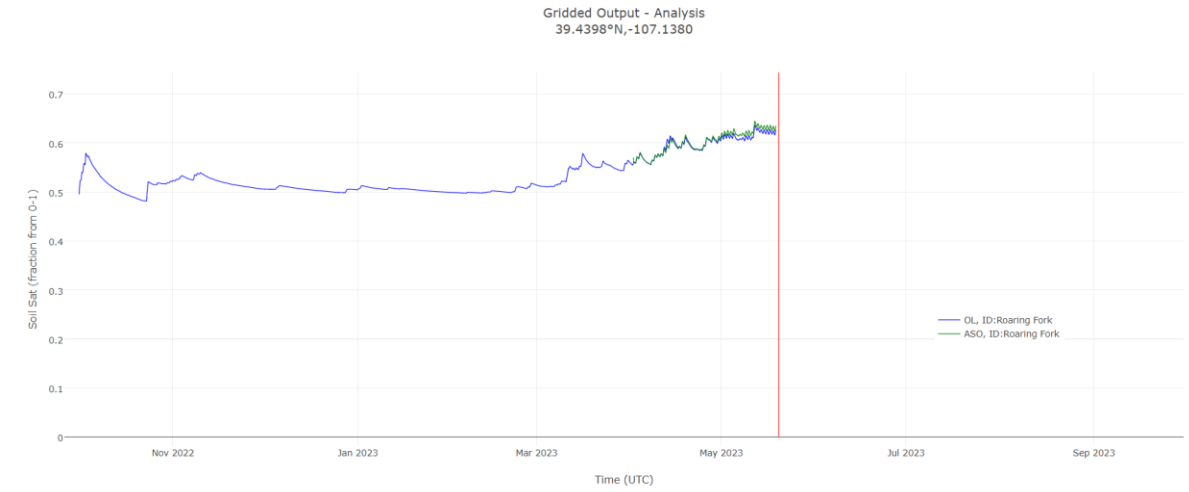

*Elevation profile of SWE for SNODAS (red), ASO-assimilated snowpack (green) and WRF-Hydro OpenLoop (blue) for the combined Roaring Fork/Frying Pan System above Glenwood Springs, CO:*




*Spatial map of WRF-Hydro modelled soil saturation:*



*Basin-averaged soil saturation values:*




*Roaring Fork/Frying Pan April-Jul Median (Q50) Accumulated Runoff/Inflow (initialized on 5/20/2023):*

Roaring Fork near Aspen:  62.4 kac-ft (New forecast site)

Roaring Fork abv Difficult near Aspen: 47.1 kac-ft (New forecast site)

Roaring Fork at Glenwood Springs: 710.9 kac-ft (New forecast site, “naturalized” flow forecast, downstream of major anthropogenics, currently based on actual-obs flows…very experimental)

Snowmass Creek: 40.4 kac-ft (New forecast site)

Frying Pan River @ Meridith: 110.2 kac-ft (New forecast site)

Ruedi Reservoir Inflow: forthcoming…(reservoir processing issue)

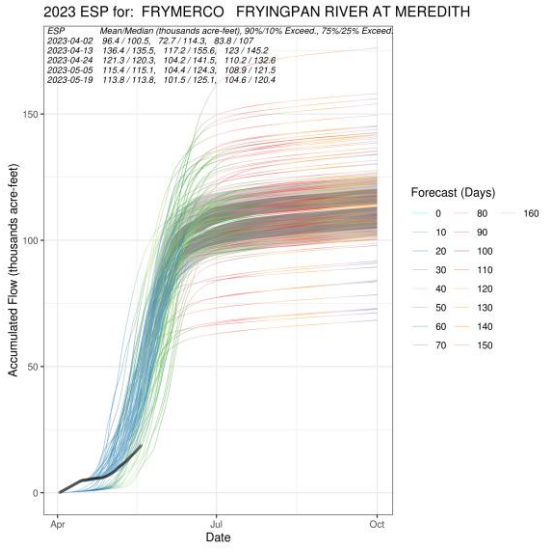
Hunter Cr: 24.3 kac-ft (*based on analyzed past flow, not observed)

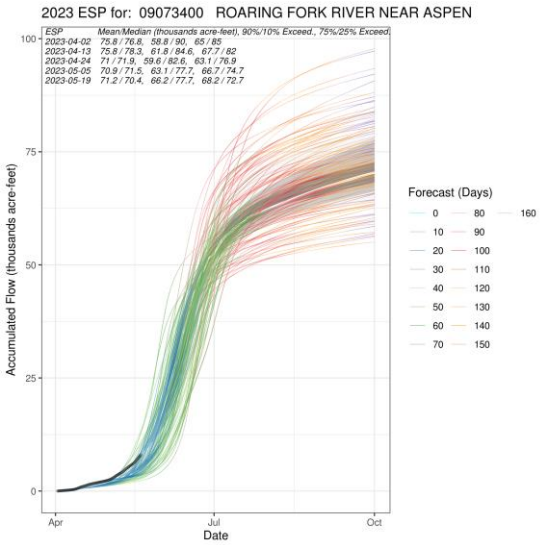
Maroon Cr nr Aspen: 42.8 kac-ft (New forecast site)

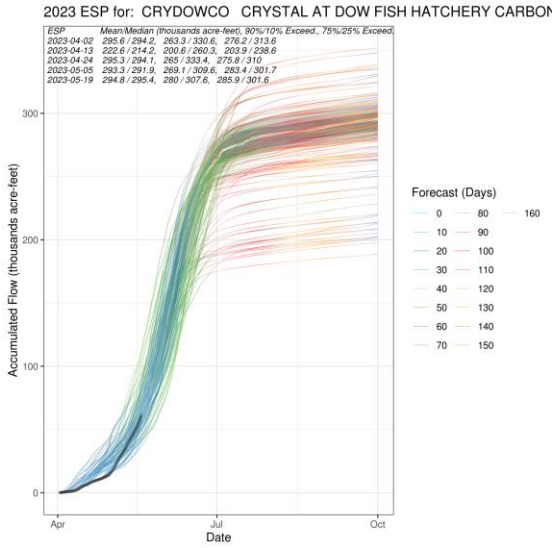
Castle Cr: New station in progress…

Crystal River @ Dow Fish Hatchery nr Carbondale: 283 kac-ft (New forecast site)

*Sample plots for Apr-Oct ESP forecasts (ignore forecasts before 4/24):*



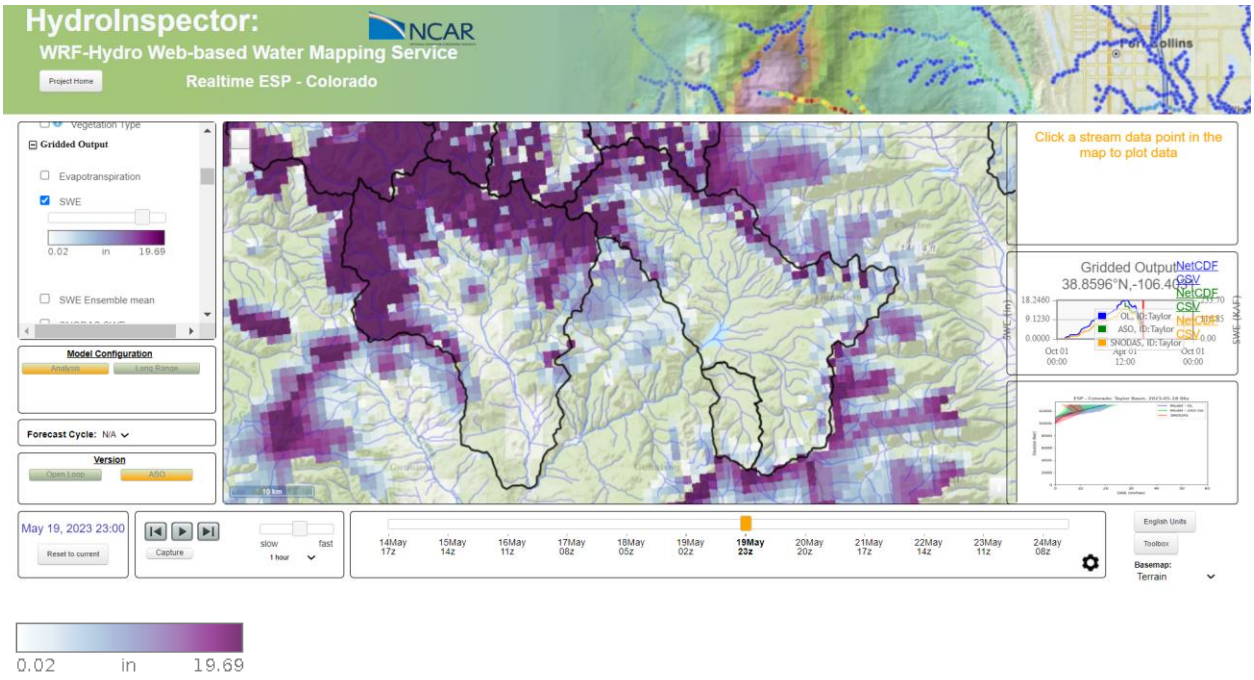



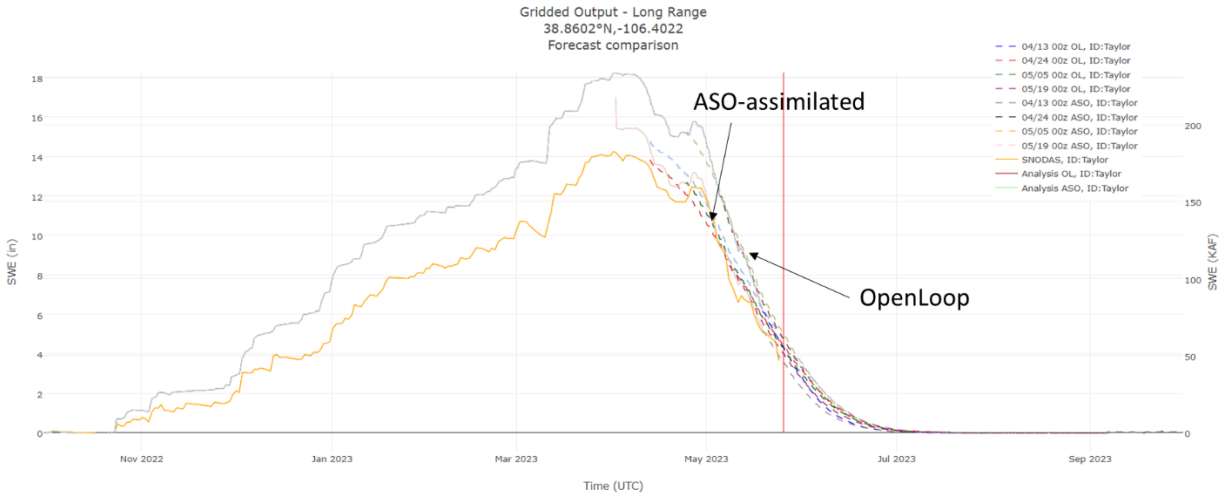
## Taylor River/East River System:

As of May 20 the ASO-assimilated snowpack from the WRF-Hydro model was approximately 66 kac-ft for the Taylor basin above Taylor Reservoir and 217 kac-ft for the East River above Almont. The bulk of the remaining snowpack in the throughout the Upper Taylor basin resided above 10,500 ft and for the East River basin was above 10,000 ft. Basin averaged soil saturation fractions for both systems was over 72%, indicating very wet conditions.

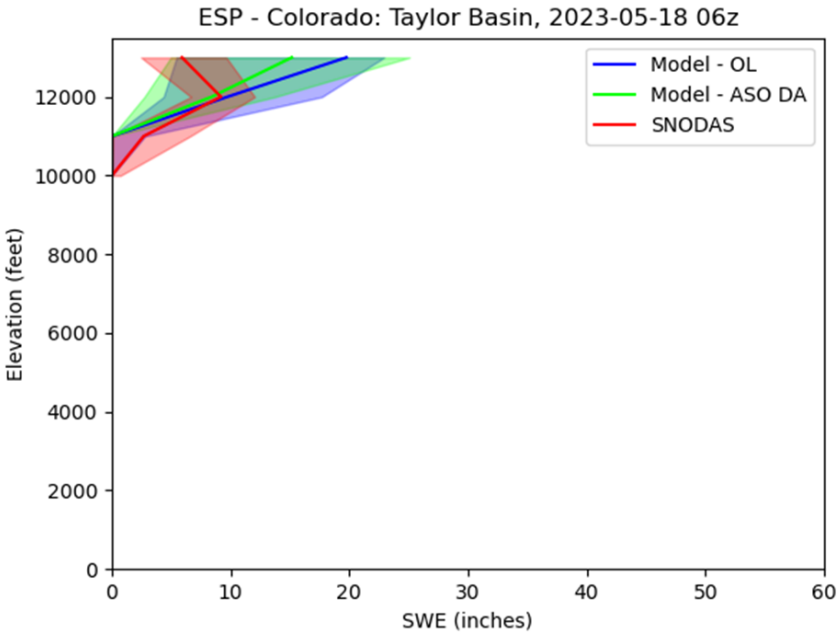
*East and Taylor River Water Equivalent (SWE) Analysis*



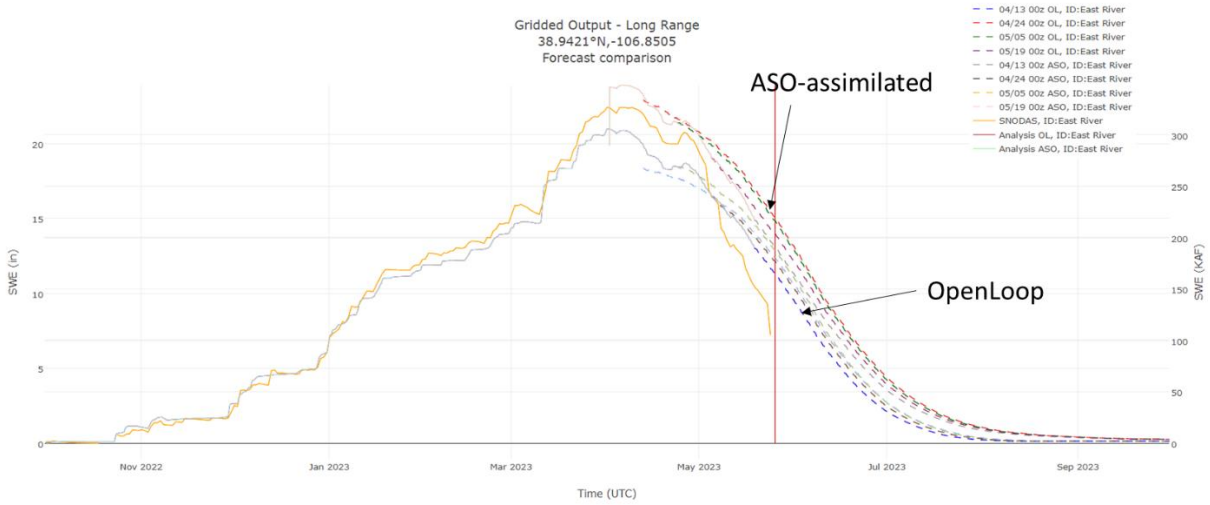

*Taylor Basin Basin-averaged Snow Water Equivalent (SWE) Analysis and Forecasts*



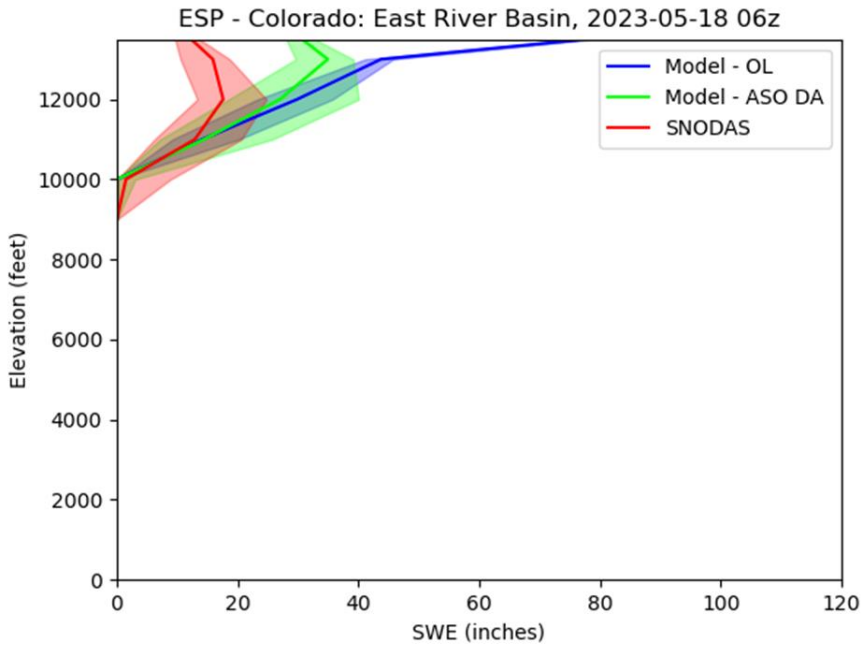
*Elevation profile of SWE for SNODAS (red), ASO-assimilated snowpack (green) and WRF-Hydro OpenLoop (blue) for the Taylor basin above Taylor Park Reservoir:*



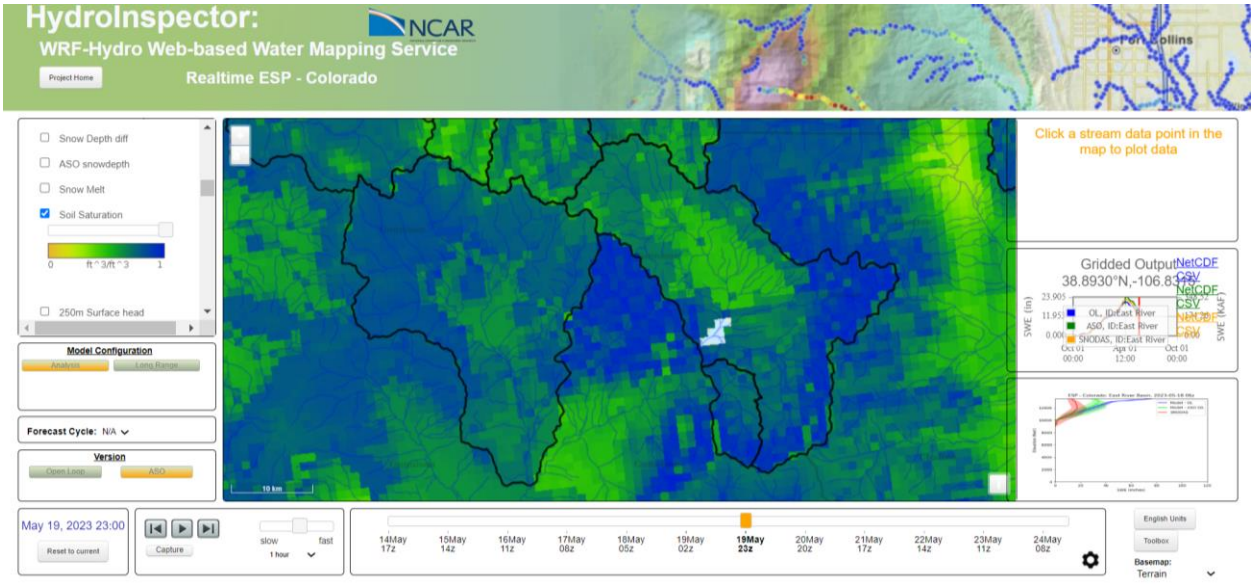

*East River Basin-averaged Snow Water Equivalent (SWE) Analysis and Forecasts:*



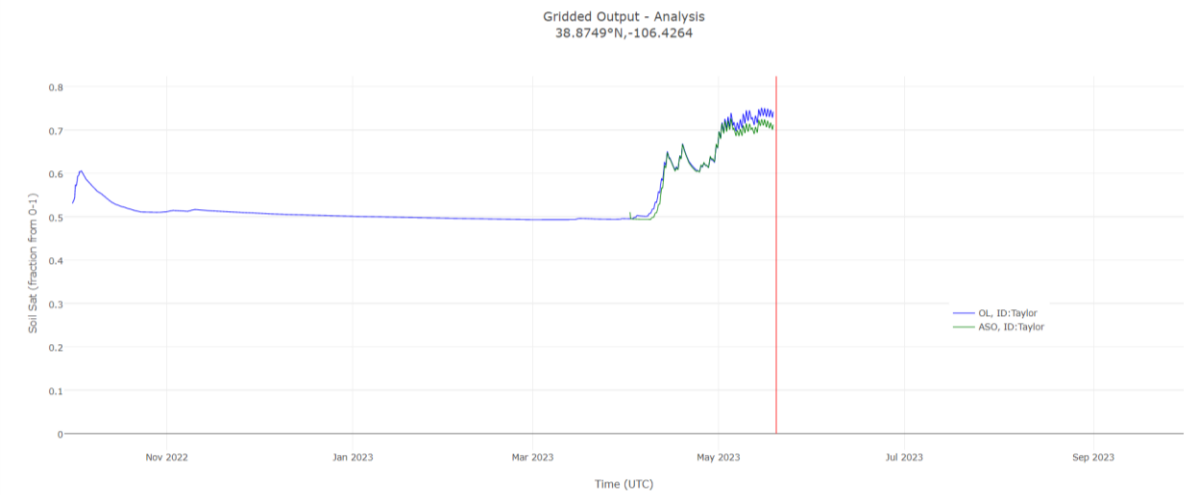
*Elevation profile of SWE for SNODAS (red), ASO-assimilated snowpack (green) and WRF-Hydro OpenLoop (blue) for the East River basin above Almont, CO:*

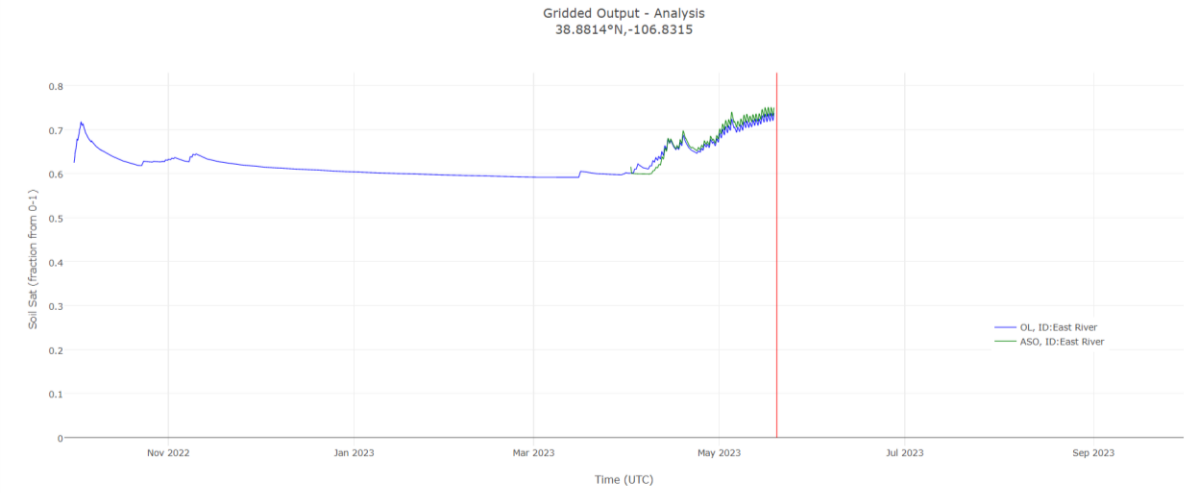



*Spatial map of WRF-Hydro modelled soil saturation:*



*Basin-averaged soil saturation values for the Taylor River basin above Taylor Reservoir and East River above Almont:*




*Taylor and East Rivers April-Jul Median (Q50) Accumulated Runoff/Inflow (initialized on 5/20/2023):*

Taylor Reservoir Inflow: forthcoming…(reservoir processing issue)

Taylor R. abv Taylor Res: 72.7 kac-ft

Texas Cr. abv Taylor Res: 18.5 kac-ft

Willow Crk abv Taylor Res: 11.2 kac-ft

East River at Almont: 303.8 kac-ft

Elk Creek abv Crested Butte: 3.8 kac-ft

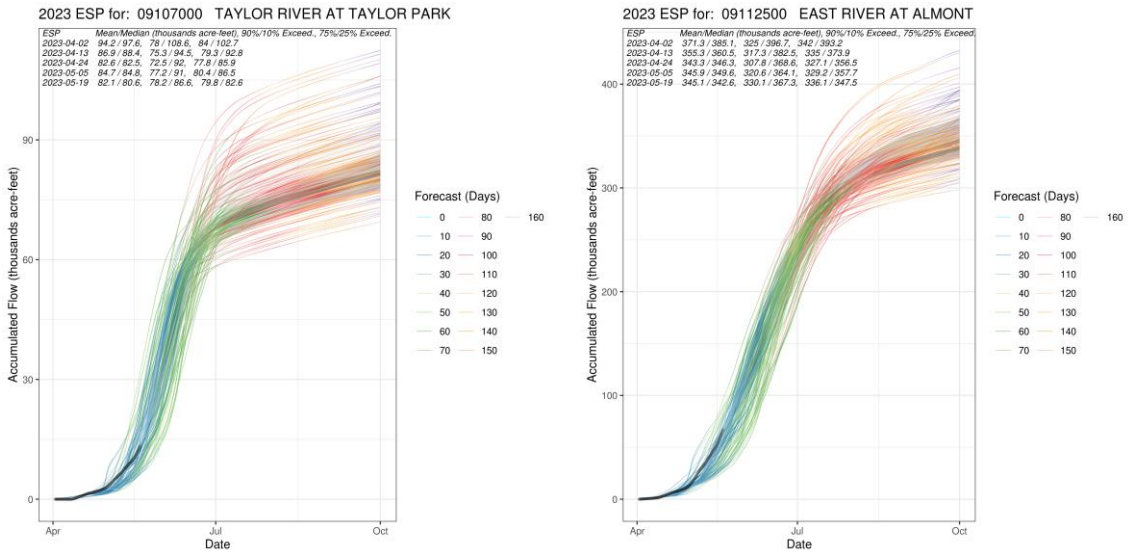
Ohio Creek @ Baldwin: 81.7 kac-ft

Slate River nr Crested Butte: 130.4 kac-ft

Coal Cr nr Crested Butte: 30.8 kac-ft

Blue Mesa inflow: forthcoming…(reservoir processing issue)

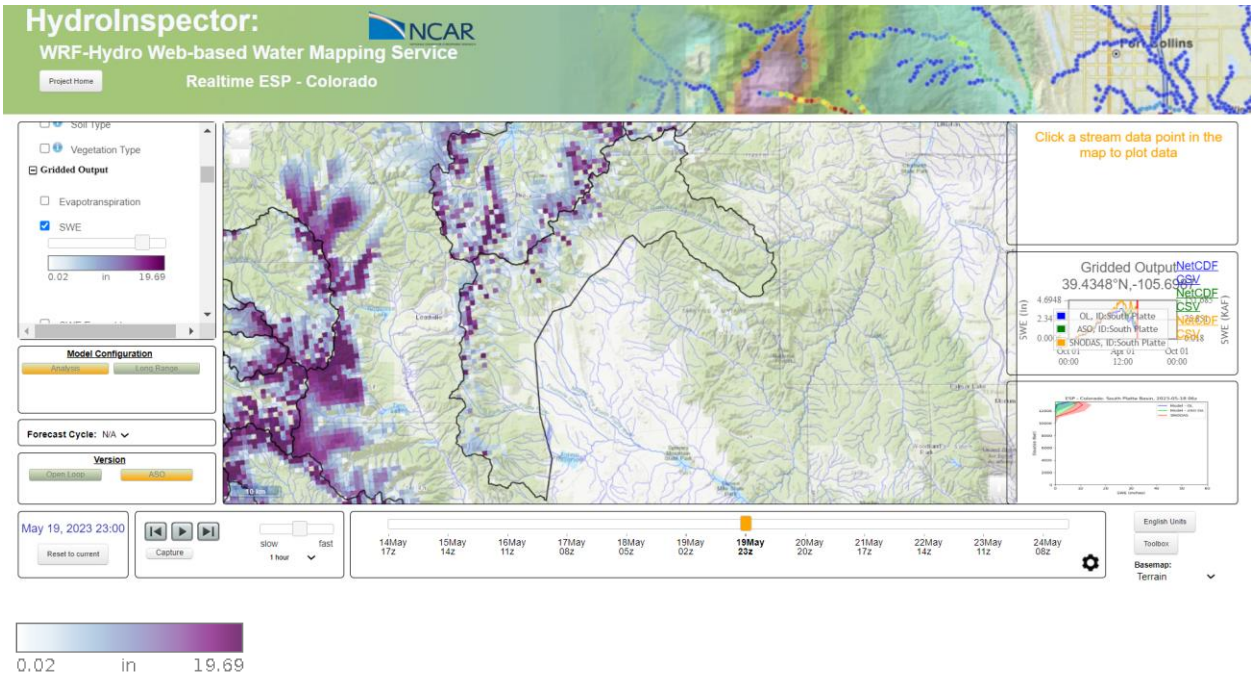
*Example ensemble flow accumulation plot for Apr-Oct inflow:*



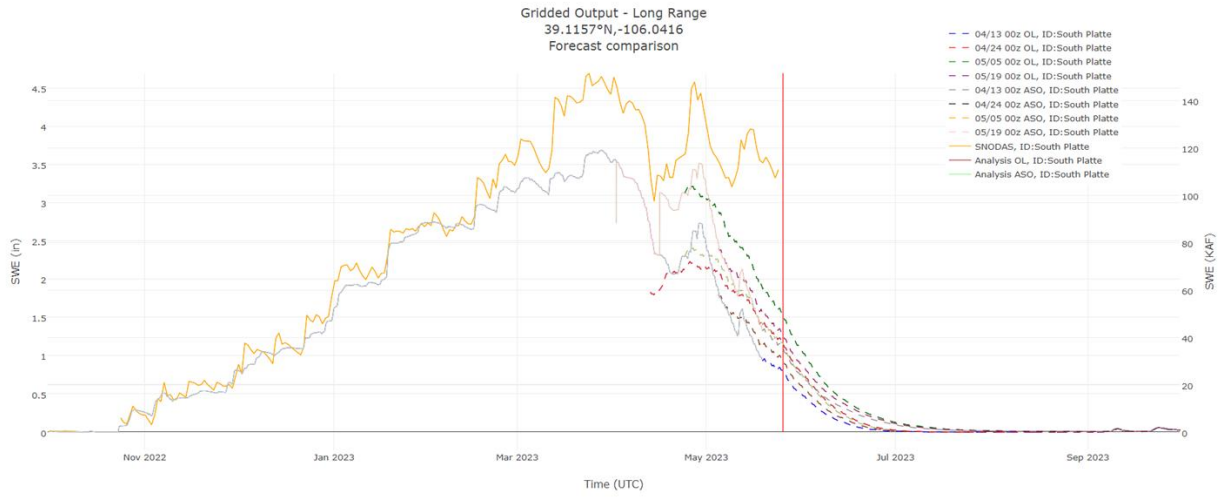
## Upper South Platte River System:

As of May 20 the ASO-assimilated snowpack from the WRF-Hydro model was approximately 43 kac-ft for the Upper South Platte River basin. The bulk of the remaining snowpack in the throughout the region resided above 11,000 ft. Basin averaged soil saturation fractions for basin has started to decline from its peak values of around 77% to around 72%, indicating generally wet conditions.

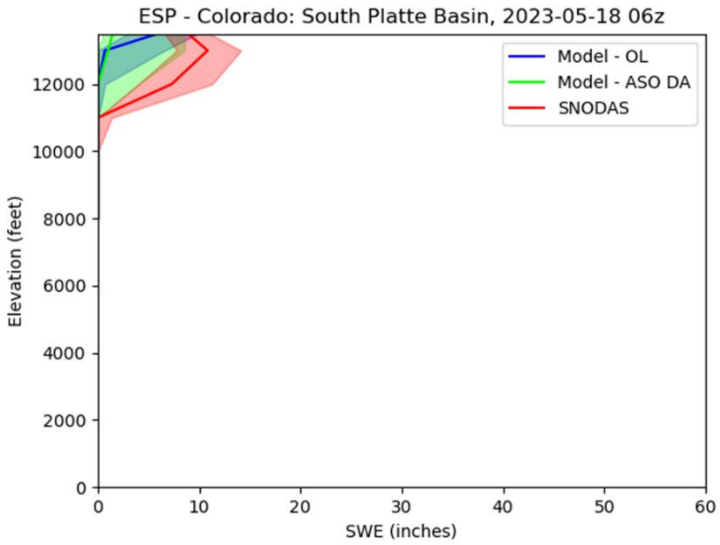
*Upper South Platte River Snow Water Equivalent (SWE) Analysis and Forecasts*



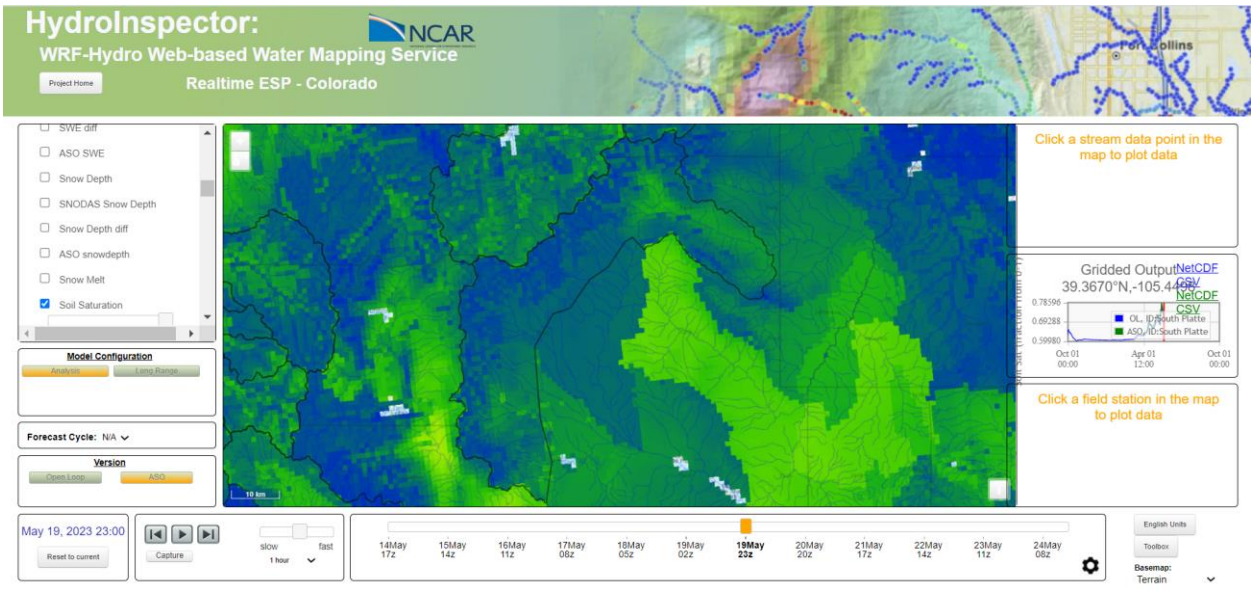

*Upper South Platte River Basin-averaged Snow Water Equivalent (SWE) Analysis and Forecasts:*



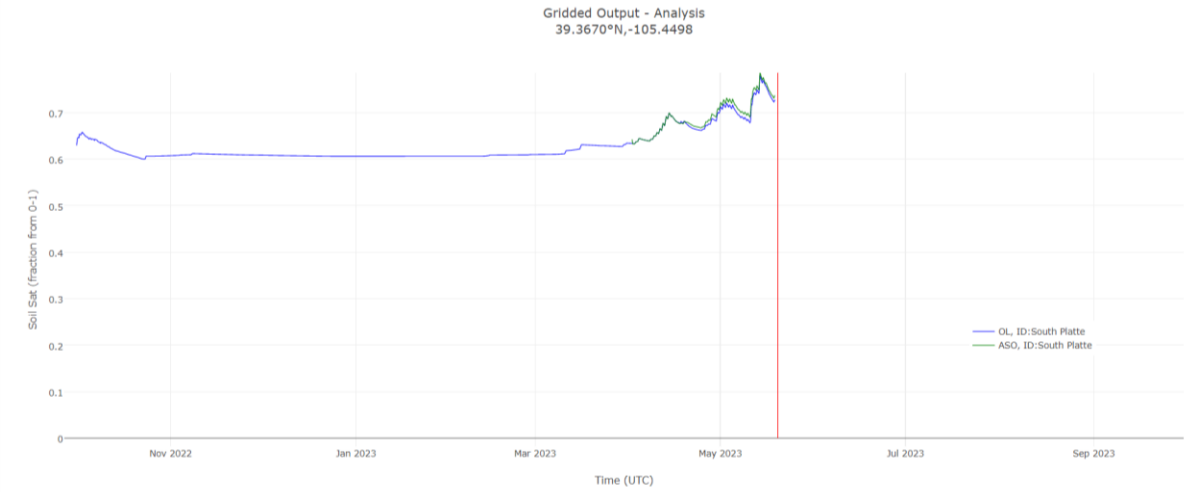
*Elevation profile of SWE for SNODAS (red), ASO-assimilated snowpack (green) and WRF-Hydro OpenLoop (blue) for Upper South Platte River basin:*




*Spatial map of WRF-Hydro modelled soil saturation:*



*Basin-averaged soil saturation values for the Upper South Platte River basin:*




*Upper South Platte April-Jul Median (Q50) Accumulated Runoff/Inflow (initialized on 5/20/2023):*

N. Fork, S. Platte at Bailey (CDWR PLABAICO): 24.8 kac-ft (New forecast site, considerable anthropogenics upstream, no naturalized observed flow data yet available)

Jefferson Cr. near Jefferson (CDWR JEFJEFCO): 4.4 kac-ft (New forecast site, clear evidence of managed flow in observations)

Michigan Cr. near Jefferson (CDWR MCHJEFCO): 6 kac-ft (New forecast site)

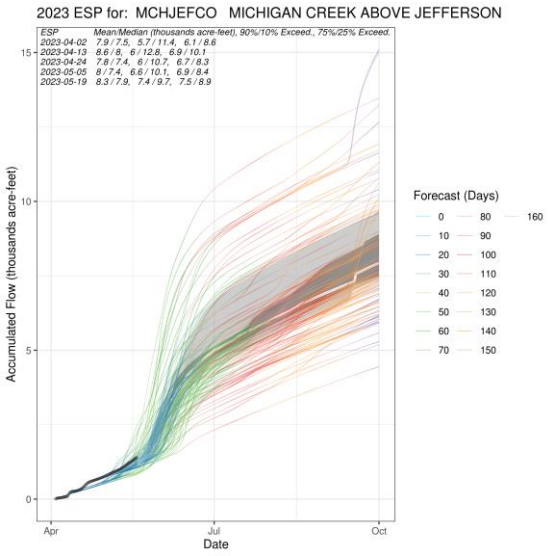
Tarryall Cr at Upper Station (CDWR TARRUPCO): 6.5 kac-ft (New forecast site, no actual observations yet integrated)

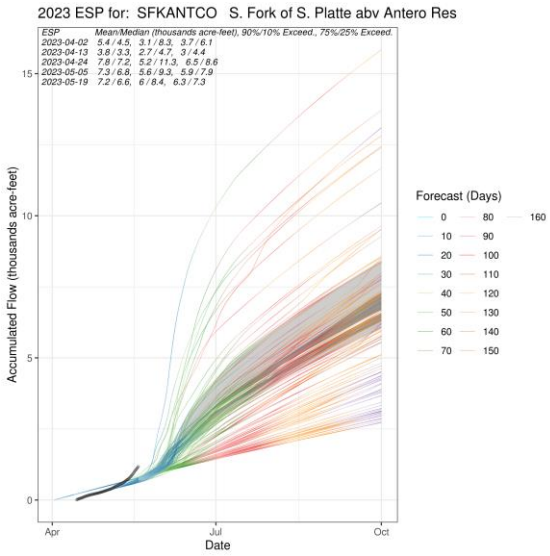
Middle Frk S. Platte abv Montgomery Res (CDWR MFKABMCO): 1.3 kac-ft (New forecast site)

S. Fork of S. Platte abv Antero Res (CDWR SFKANTCO): 4.4 kac-ft (New forecast site)

Antero Res. Inflow: forthcoming…(reservoir processing issue)

*Example ensemble flow accumulation plot for Apr-Oct inflow:*

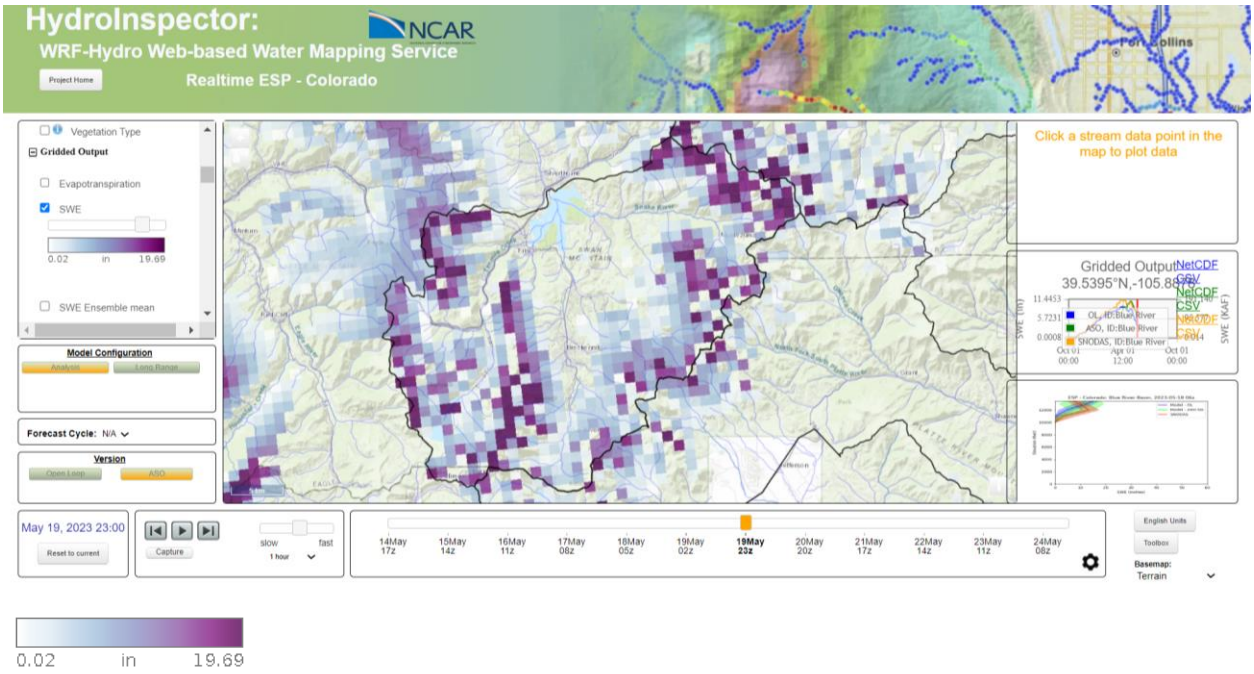


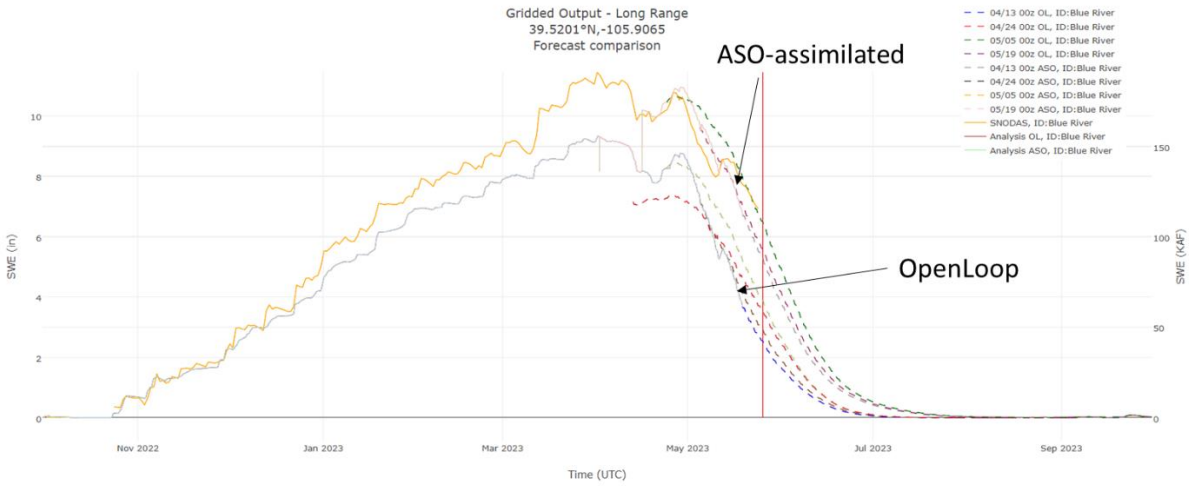
## Blue River/Dillon Reservoir System:

As of May 20 the ASO-assimilated snowpack from the WRF-Hydro model was approximately 113 kac-ft for the Blue River/Dillon Reservoir basin. The bulk of the remaining snowpack in the throughout the region resided above 10,000 ft. Basin averaged soil saturation fractions for the basin was remaining steady at around 70%, indicating generally wet conditions.

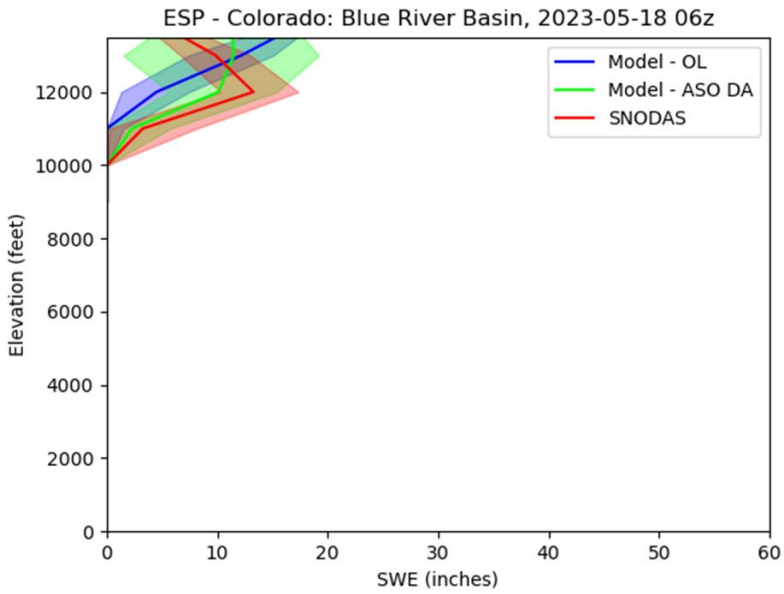
*Blue River/Dillon Reservoir Snow Water Equivalent (SWE) Analysis*



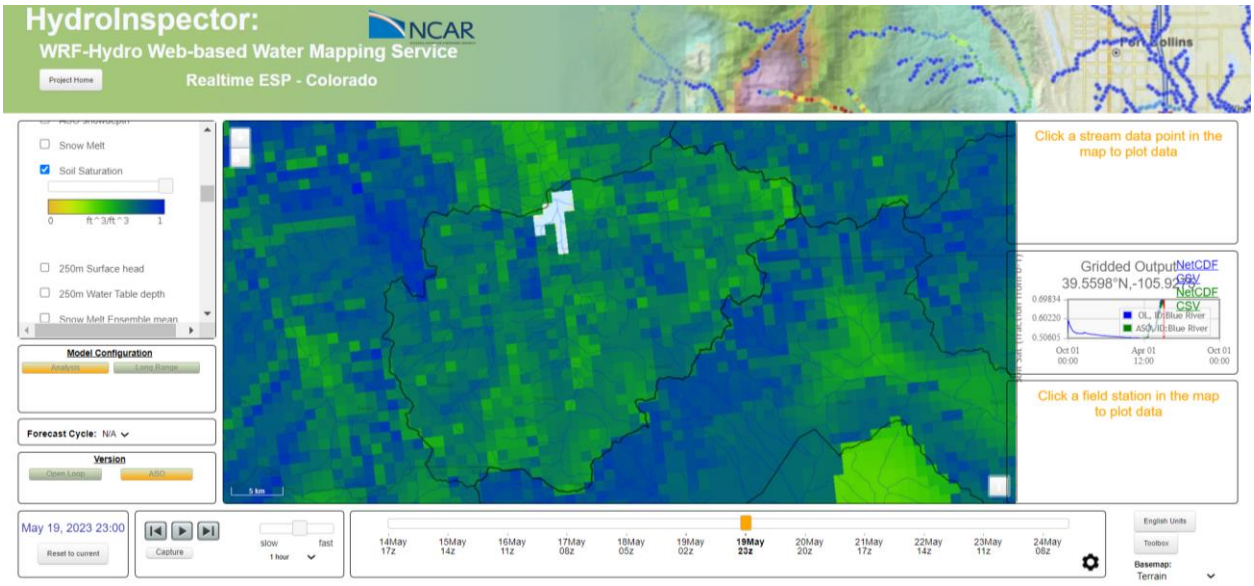

*Blue River/Dillon Reservoir basin-averaged Snow Water Equivalent (SWE) Analysis and Forecasts:*



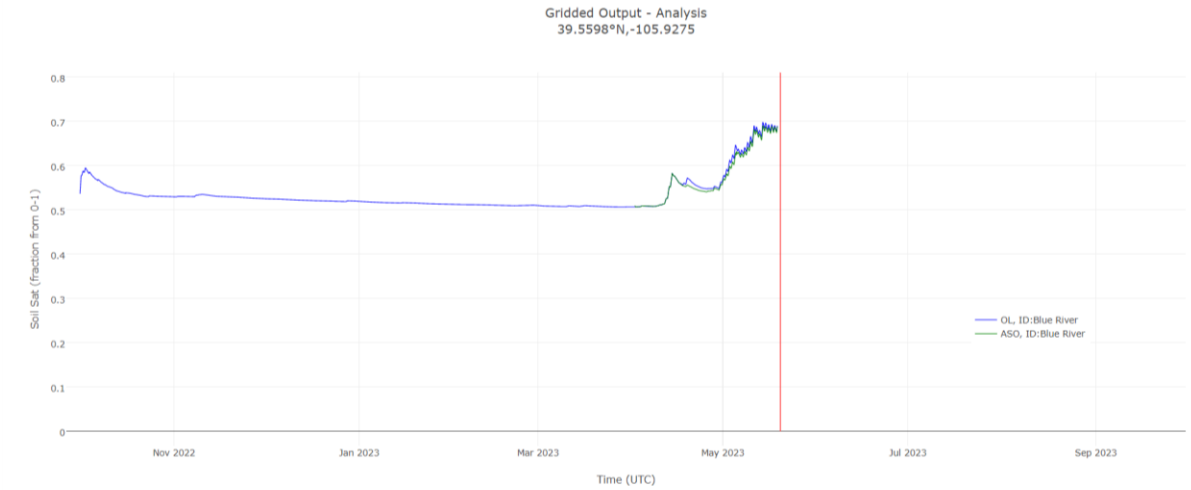
*Elevation profile of SWE for SNODAS (red), ASO-assimilated snowpack (green) and WRF-Hydro OpenLoop (blue) for the Blue River/Dillon Reservoir basin:*




*Spatial map of WRF-Hydro modelled soil saturation:*



*Basin-averaged soil saturation values for the Upper South Platte River basin:*




*Blue River/Dillon Reservoir April-Jul Median (Q50) Accumulated Runoff/Inflow (initialized on 5/20/2023):*

Dillon Reservoir: forthcoming…(reservoir processing issue)

Blue River abv Dillon: 42.5 kac-ft

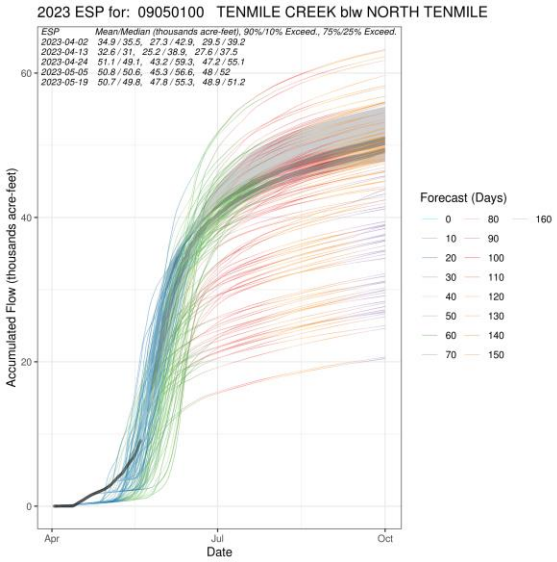
Snake River nr Montezuma: 25.2 kac-ft

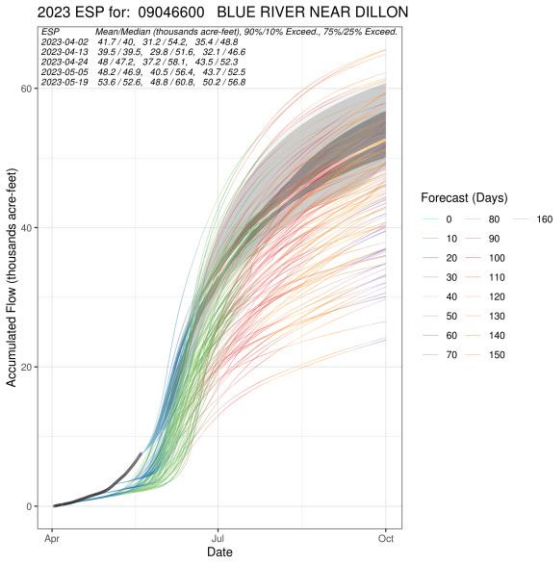
Tenmile Creek nr Frisco: 45.5 kac-ft

Keystone Gulch nr Keystone: 3.1 kac-ft

Straight Cr. Nr Dillon: 4.1 kac-ft

*Example ensemble flow accumulation plot for Apr-Oct inflow:*

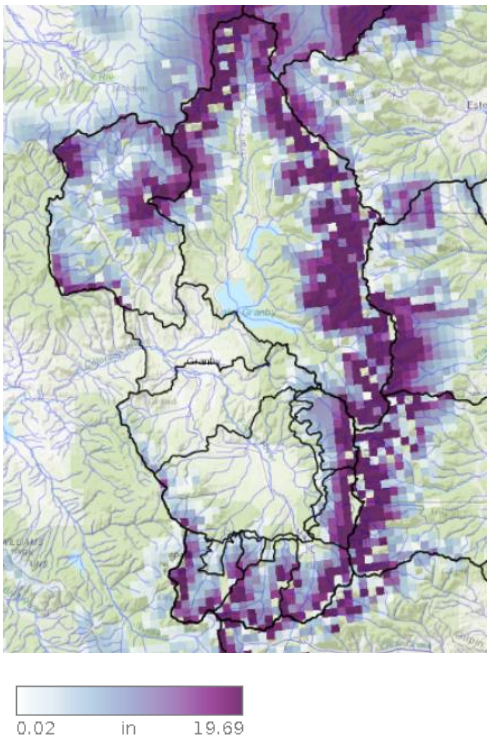


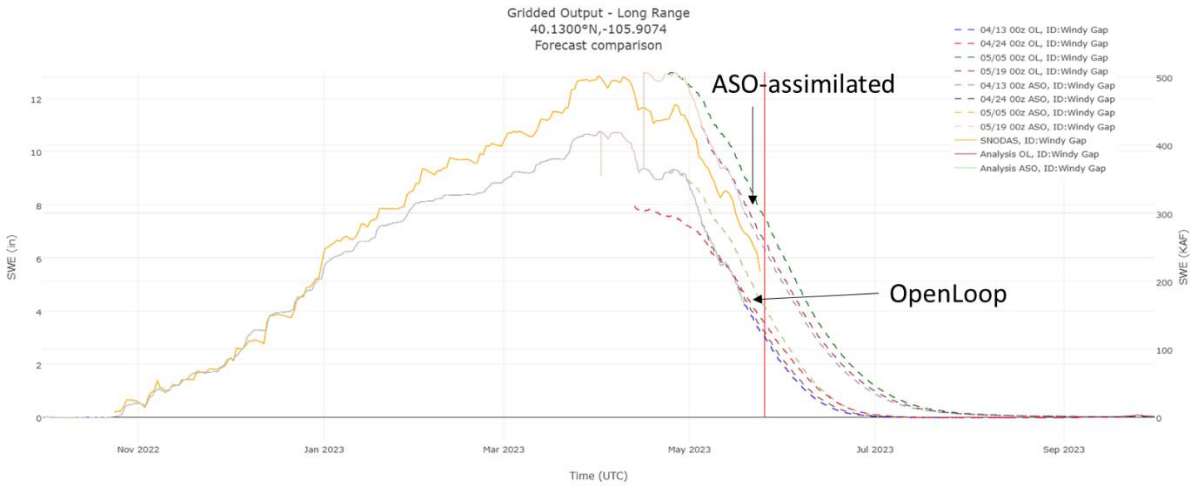
## Upper Colorado River/Windy Gap System:

As of May 20 the ASO-assimilated snowpack from the WRF-Hydro model was approximately 302 kac-ft for the Upper Colorado Windy Gap basin. The bulk of the remaining snowpack in the throughout the region resided above 9,500 ft. Basin averaged soil saturation fractions for the basin was around 64%.

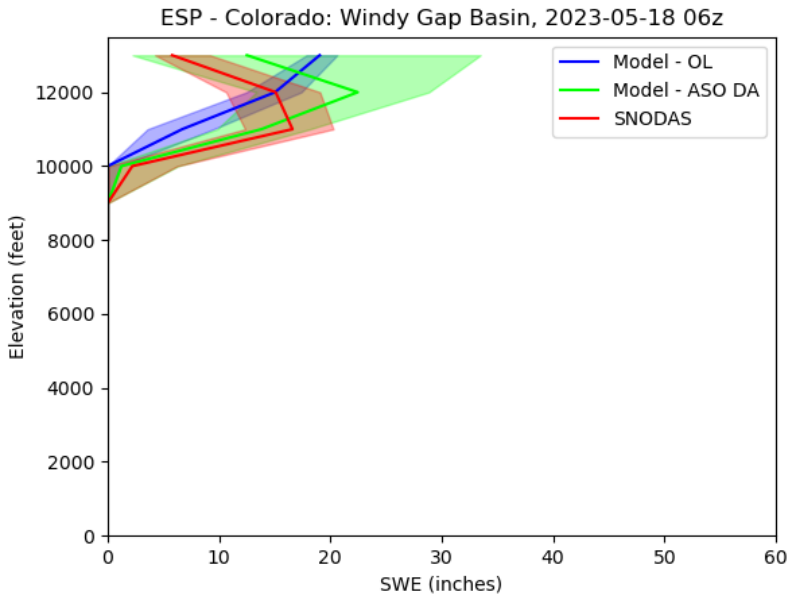
*Upper Colorado/Windy Gap Snow Water Equivalent (SWE) Analysis*



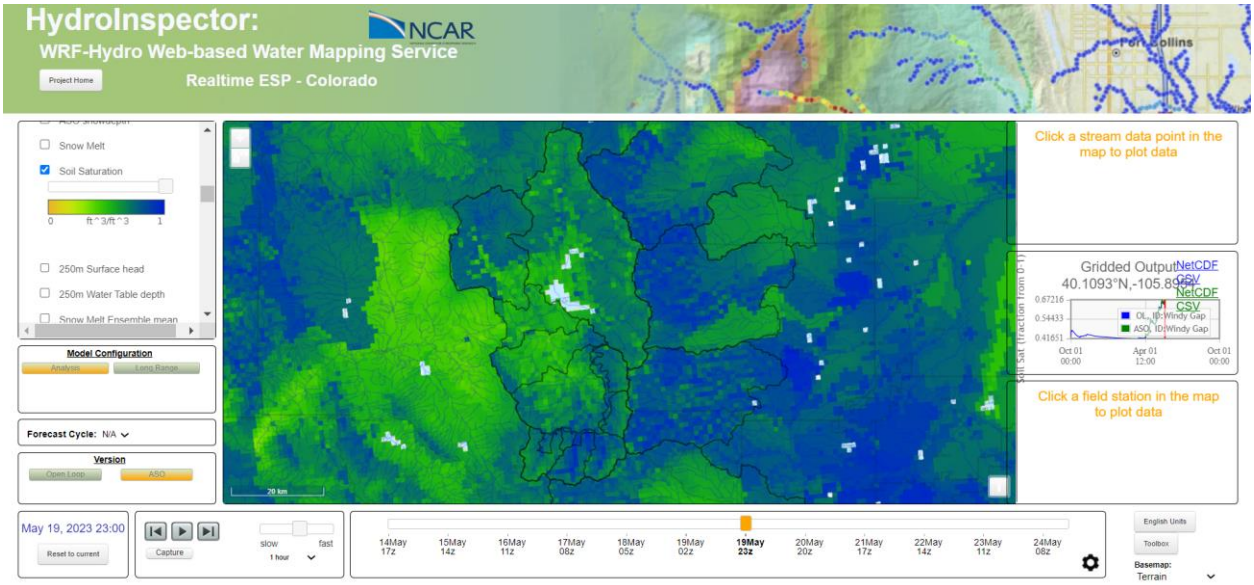

*Upper Colorado/Windy Gap basin-averaged Snow Water Equivalent (SWE) Analysis and Forecasts:*



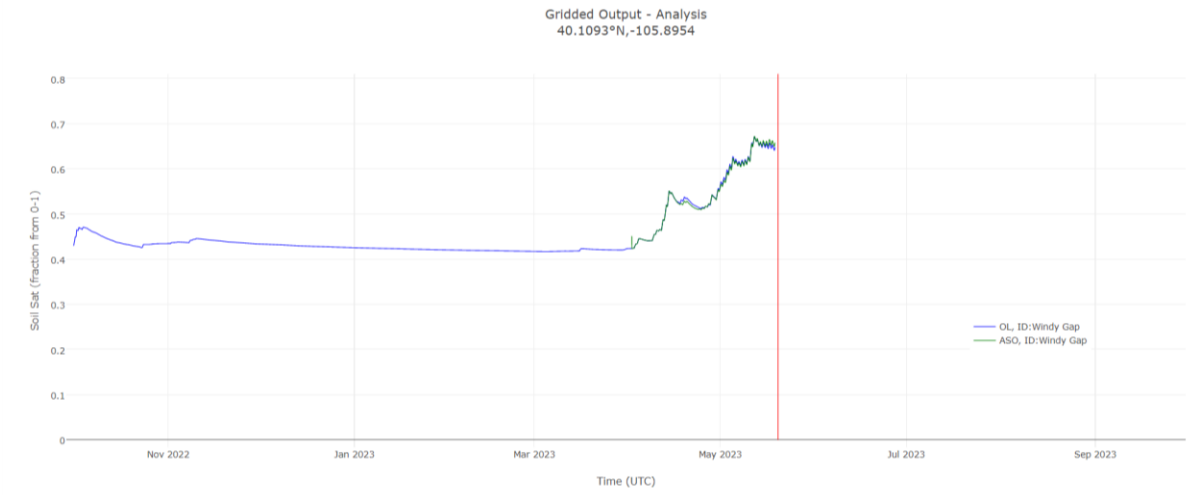
*Elevation profile of SWE for SNODAS (red), ASO-assimilated snowpack (green) and WRF-Hydro OpenLoop (blue) for the Upper Colorado/Windy Gap basin:*




*Spatial map of WRF-Hydro modelled soil saturation:*



*Basin-averaged soil saturation values for the Upper Colorado/Windy Gap basin:*




*Upper Colorado/Fraser to Windy Gap April-Jul Median (Q50) Accumulated Runoff/Inflow:*

Col. R. blw Baker Gulch: 40.7 kac-ft (using analyzed observed flow for period without actual observations)

North Inlet Cr.: 29.1 kac-ft (using analyzed observed flow for period without actual observations)

East Inlet Cr.: 23.6 kac-ft (using analyzed observed flow for period without actual observations)

Fraser R @ Upper Sta: 6.9 kac-ft (uses actual observed flows, naturalized flow record needed)

Fraser R @ Winter Park: 14 kac-ft (uses actual observed flows, naturalized flow record needed)

Vazquez Cr. nr Winter Park: 11.6 kac-ft (uses actual observed flows)

Ranch Cr. nr Fraser: 8.1 kac-ft (uses actual observed flows)

Cabin Cr nr Fraser: 4 kac-ft (uses actual observed flows)

St. Louis Cr. nr Fraser: 8.5 kac-ft (uses actual observed flows, naturalized flow record needed)

Fraser R @ Tabernash: 40.8 kac-ft (uses actual observed flows, naturalized flow record needed)

Fraser R blw Crooked @ Tabernash: 65.2 ka-cft (uses actual observed flows from CDWR, needs naturalized flow time series, uses estimated observed flows for April before gauge comes online = 5 kac-ft)

Fraser R @ Granby: 79 kac-ft (using CDWR plus April-estimated flow values), 84 kac-ft (using Northern Water Conservancy naturalized flow from 4/1-5/17)

Willow Cr. Reservoir inflow: forthcoming…(reservoir processing issue)

Grand Lake inflow: forthcoming…(reservoir processing issue)

Lake Granby inflow: forthcoming…(reservoir processing issue)

Col. R. nr Granby: 182.47 kac-ft (needs naturalized flow time series)

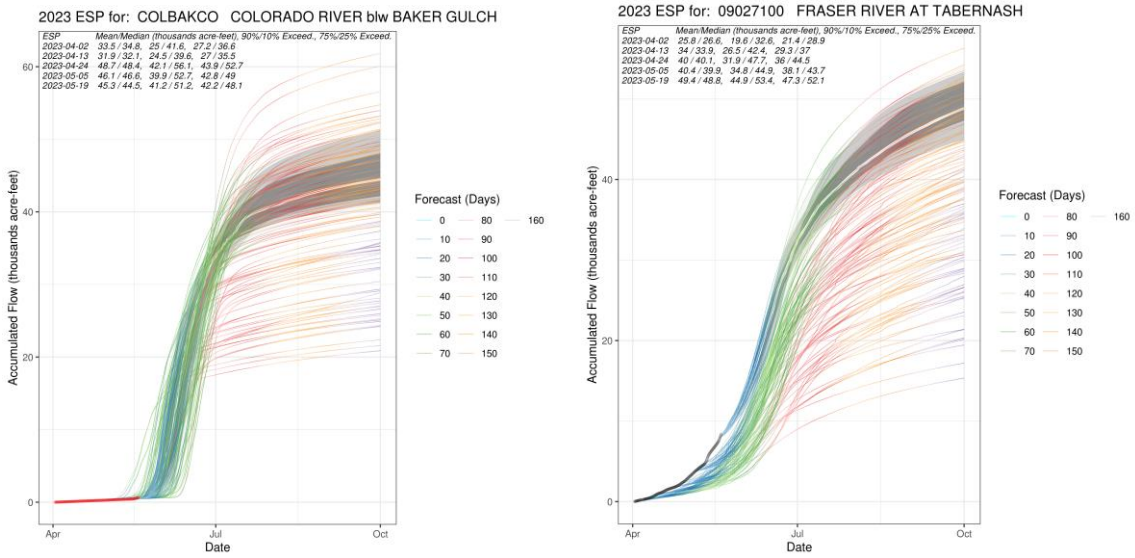
Williams Frk nr Leal: 38.7 kac-ft

S. Frk Williams Crk nr Leal: 14 kac-ft

Bobtail Cr. Nr Jones Pass: 3.6 kac-ft

Williams Frk Res. Inflow: forthcoming…(reservoir processing issue)

*Example ensemble flow accumulation plot for Apr-Oct inflow:*



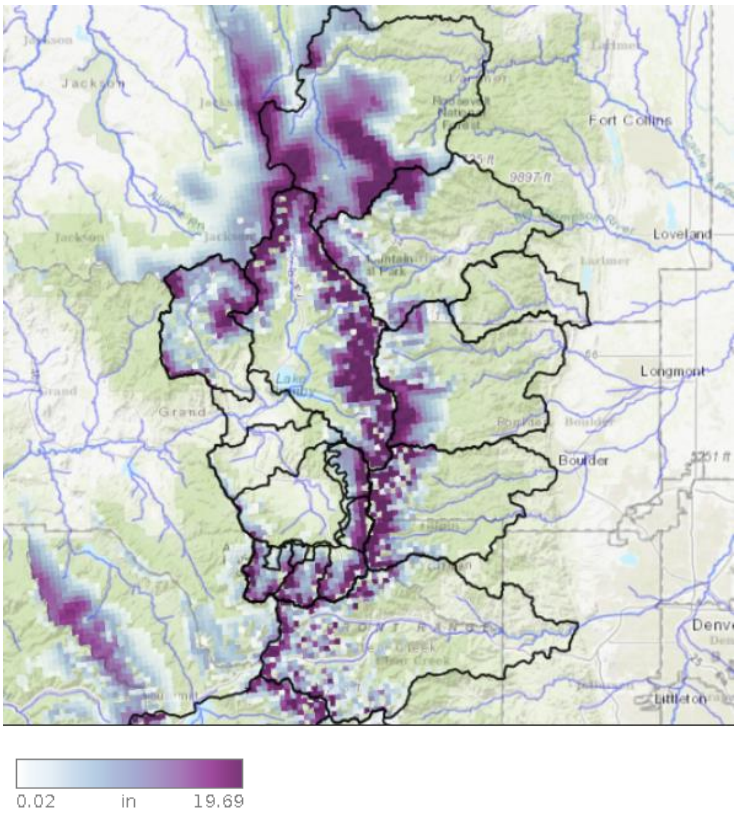
## Front Range System:

As of May 20 the ASO-assimilated snowpack from the WRF-Hydro model for the 5 Front Range basins was: [ASO survey data assimilated into the Boulder Creek and Clear Creek basins only…]

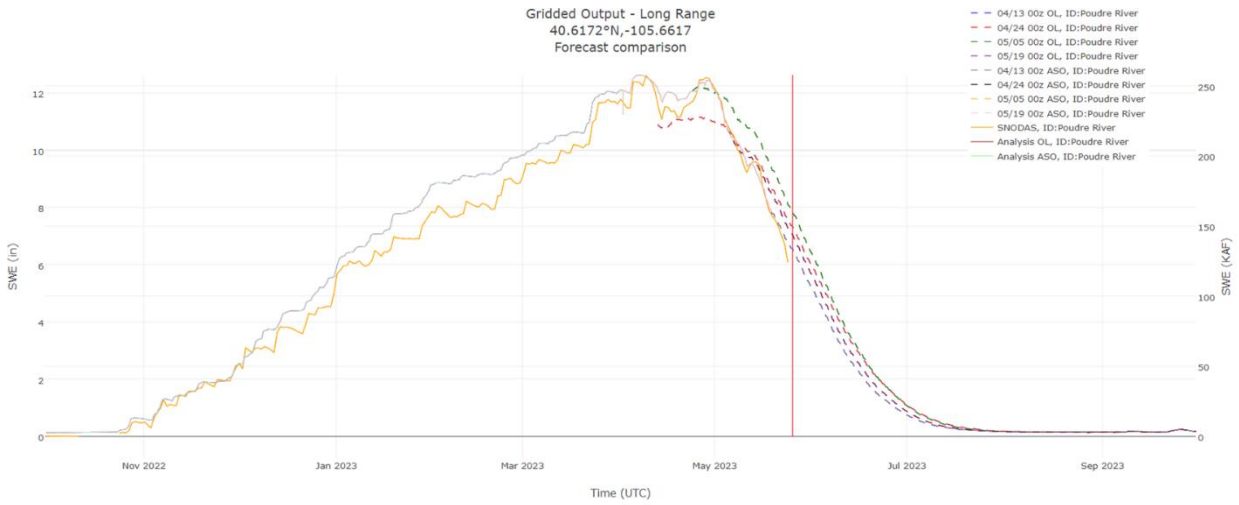
| | |
|---|---|
| Poudre River Basin (no ASO): | 160 kac-ft |
| Big Thompson River Basin (no ASO): | 41 kac-ft |
| Little Thompson River Basin (no ASO): | 0.6 kac-ft |
| St. Vrain River Basin (no ASO): | 81 kac-ft |
| Boulder Creek Basin (with ASO): | 65 kac-ft |
| Clear Creek Basin (with ASO): | 62 kac-ft |

Nearly all remaining snowpack in the throughout the region resided above 10,000 ft.

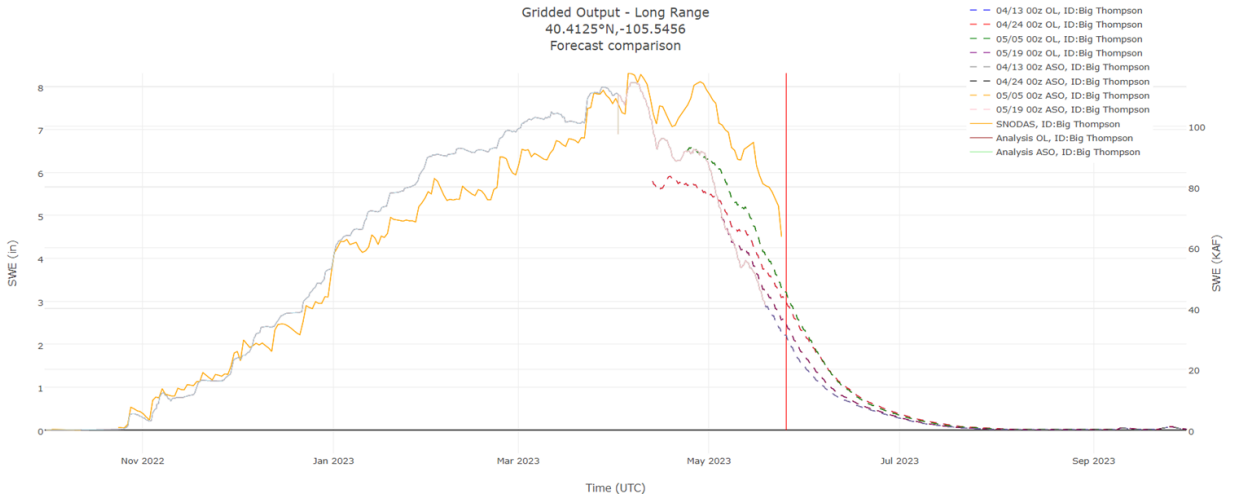
*Front Range System Snow Water Equivalent (SWE) Analysis*



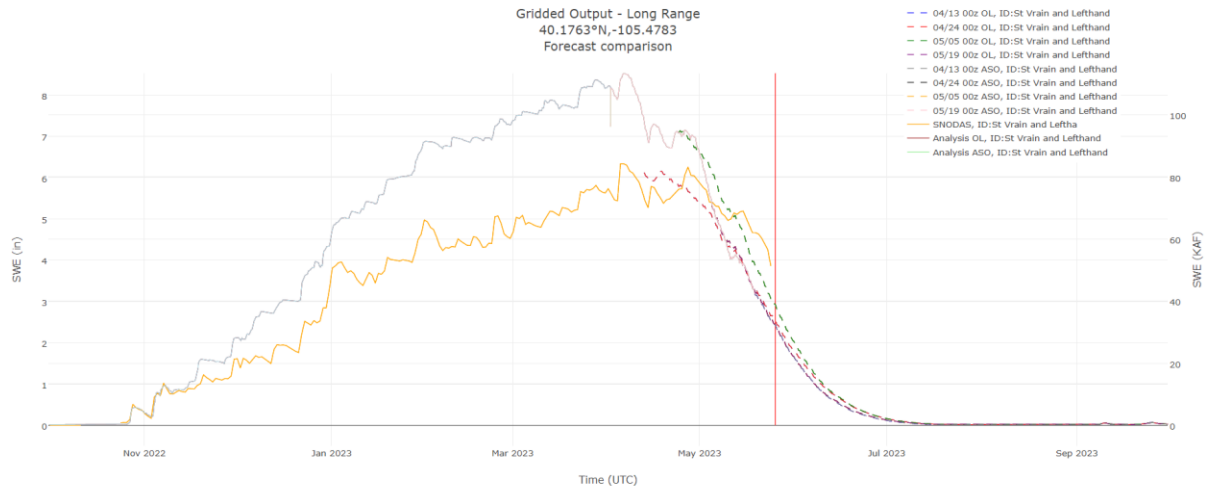
*Poudre River basin-averaged SWE:*



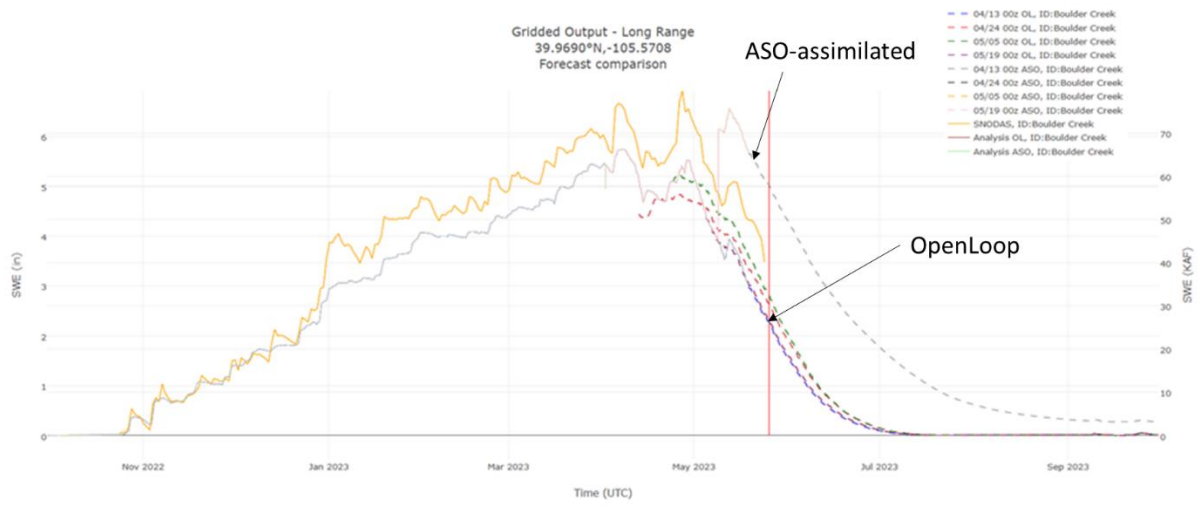

*Big Thompson basin-averaged SWE:*



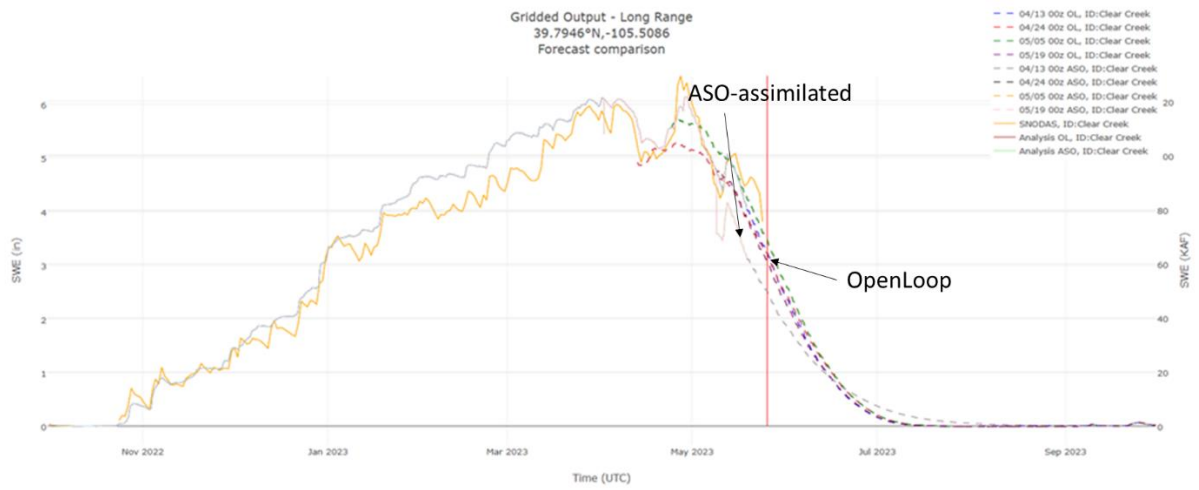
*St. Vrain basin-averaged SWE:*




*Boulder Creek basin-averaged SWE:*



*Clear Creek basin-averaged SWE:*




*Poudre River Sub-basin forecast flow, (initialized on 5/20/2023):*

Cache La Poudre nr Fort Collins: 179.5 kac-ft (New forecast site, considerable anthropogenics upstream, no naturalized observed flow data yet available)

*Big Thompson/Little Thompson River Sub-basin forecast flow, (initialized on 5/20/2023):*

Big Thompson at Moraine Park (CDWR BTBMORCO)… in progress…

Big Thompson abv Lake Estes (CDWR BTABESCO): 42 kac-ft (New forecast site)

N. Fork Big Thompson at Drake (CDWR BTNDFRCO): 16.6 kac-ft (New forecast site)

Little Thompson River nr Berthoud (CDWR LTCANYCO): 11.4 kac-ft (New forecast site)

*St. Vrain River Sub-basin forecast flow, (initialized on 5/20/2023):*

Button Rock Reservoir Inflow...in progress…[Is observed reservoir inflow available?]

South St Vrain near Ward, CO…(CDWR SSVWARCO): 11.4 kac-ft (New forecast site)

North St. Vrain abv Button Rock Reservoir (CDWR NSVABRCO)…CDWR station discontinued in 2019

Middle Fork St. Vrain at Peaceful Valley (CDWR MIDSTECO): 20.7 kac-ft (New forecast site)

St. Vrain at Lyons (CDWR SVCLYCO): 78.9 kac-ft (New forecast site)

*Boulder Creek Sub-basin forecast flow, (initialized on 5/20/2023):*

Middle Boulder Cr at Nederland…(CDWR BOCMIDCO)…in progress…

Boulder Cr. at Orodell (CDWR BOCOROCO): 46.1 kac-ft (New forecast site, considerable anthropogenics upstream, no naturalized observed flow data yet available)

*Clear Creek Sub-basin forecast flow, (initialized on 5/20/2023):*

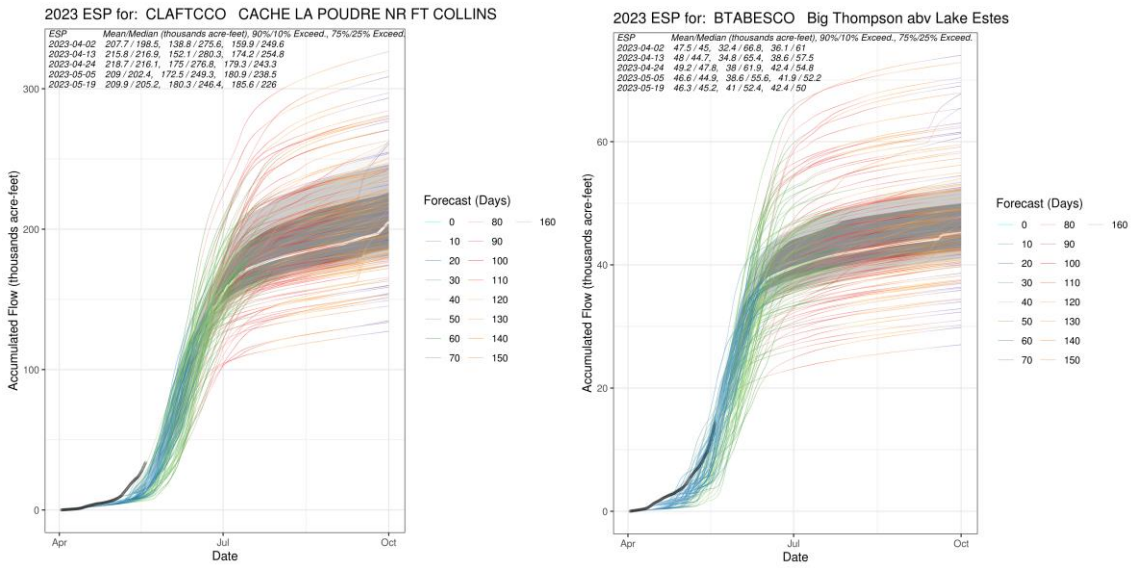
Clear Creek abv Georgetown (CDWR CLEGLKCO): 31.3 kac-ft (New forecast site)

Clear Creek at Lawson (CDWR CLELAWCO): 54.6 kac-ft (New forecast site, some anthropogenics upstream, no naturalized observed flow data yet available)

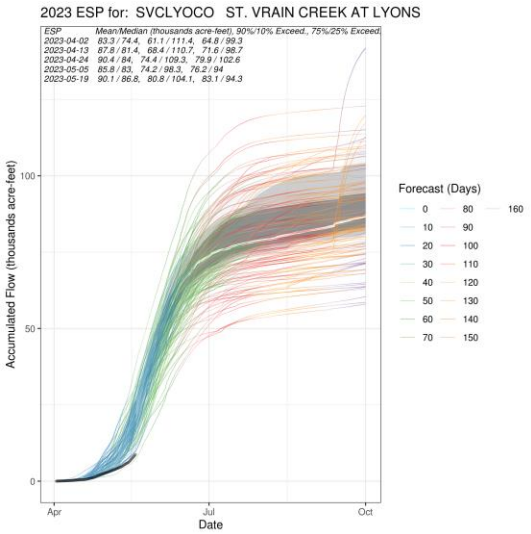
North Fork Clear Creek abv mouth at Black Hawk (CDWR NCCBLACO)…in progress…

Clear Creek at Golden (CDWR CLEGOLCO): 68.3 kac-ft (New forecast site, some anthropogenics upstream, no naturalized observed flow data yet available)

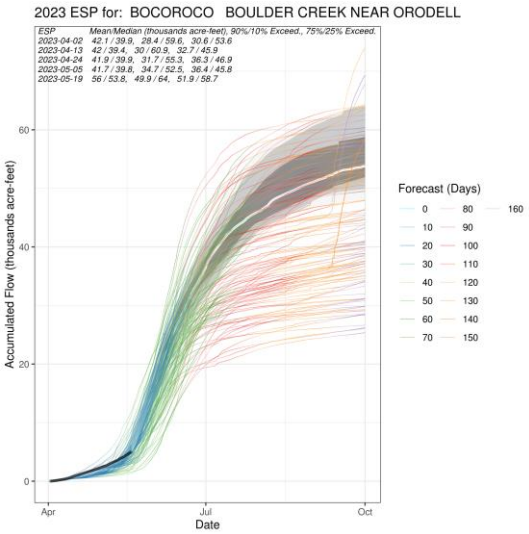
*Example ensemble flow accumulation plot for Apr-Oct inflow:*



2023 ESP for: SVCLYOCO ST. VRAIN CREEK AT LYONS




2023 ESP for: BOCOROCO BOULDER CREEK NEAR ORODELL




2023 ESP for: 06719505 CLEAR CREEK AT GOLDEN