

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

Date of report generation: Jun 8, 2023

[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

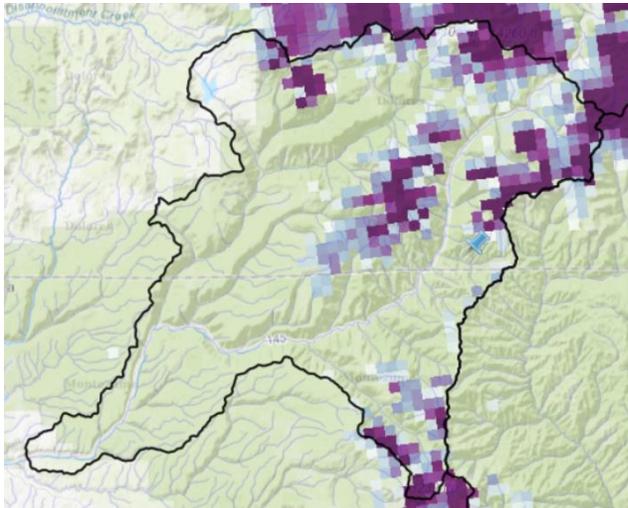
Additional model outputs are being prepared and will be added to future reports as they become available. Additionally, as noted above, several forecast locations are new or are having issues addressed that relate to the availability of timely and quality unregulated flow information for model calibration 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.

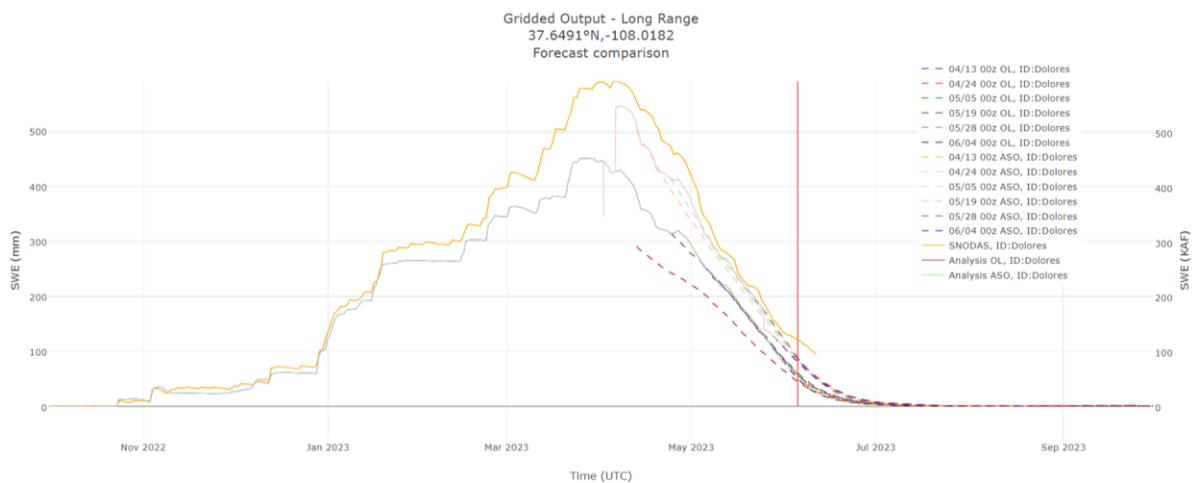
Dolores River Basin:

As of June 4 the ASO-assimilated snowpack from the WRF-Hydro model with ASO survey assimilation acquired on May 25 was approximately 91 kac-ft and dropping quickly. Snowpack ablation forecasts have tracked subsequent analyses quite well. Nearly all snowpack resided above 10,000 ft. Basin-averaged soil saturation fraction remained over 70% indicating very wet conditions though values have continued to decrease from their seasonal peaks.

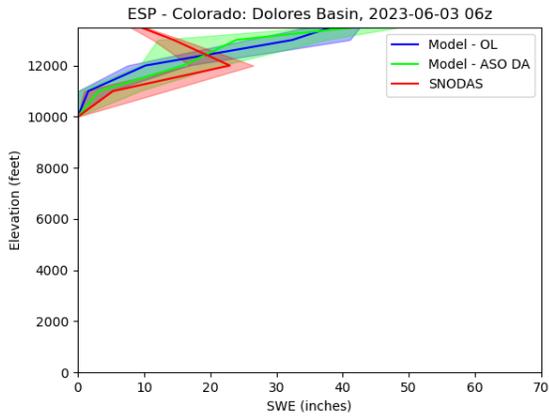
Spatial map of ASO-assimilated SWE:



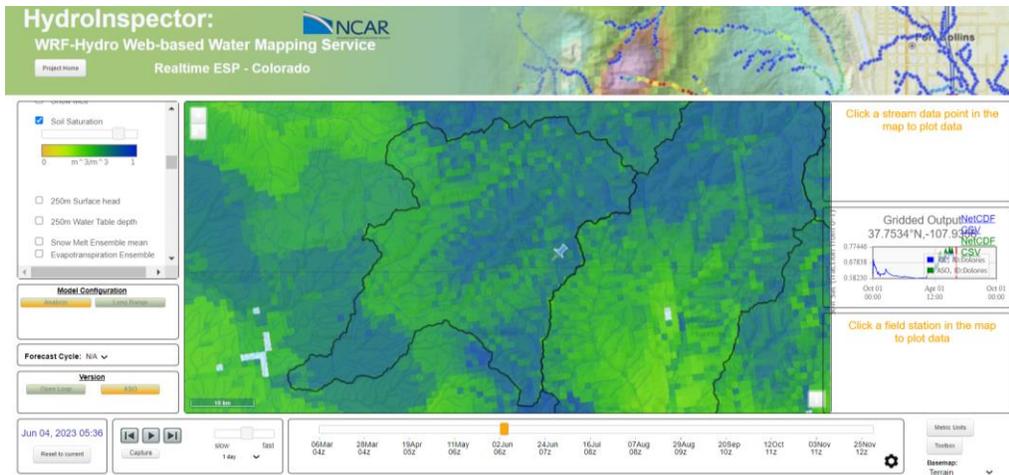
Basin-averaged analyses and forecasts of ASO-assimilated SWE:



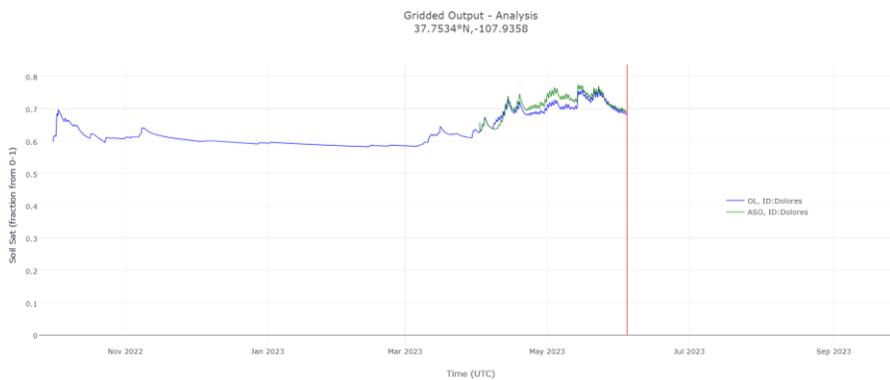
Elevation profile of SWE for SNODAS (red), ASO-assimilated snowpack (green) and WRF-Hydro OpenLoop (blue)



Spatial map of WRF-Hydro modelled soil saturation:



Basin-averaged soil saturation values:



Dolores R. at Dolores, CO, median (Q50) runoff forecast (initialized on 6/4/2023):

Apr-Jul: 408.9 kac-ft *(Noted major diversion upstream to Groundhog Res.: 20.6 kac-ft and climbing....adjusted total = 429.5 kac-ft)

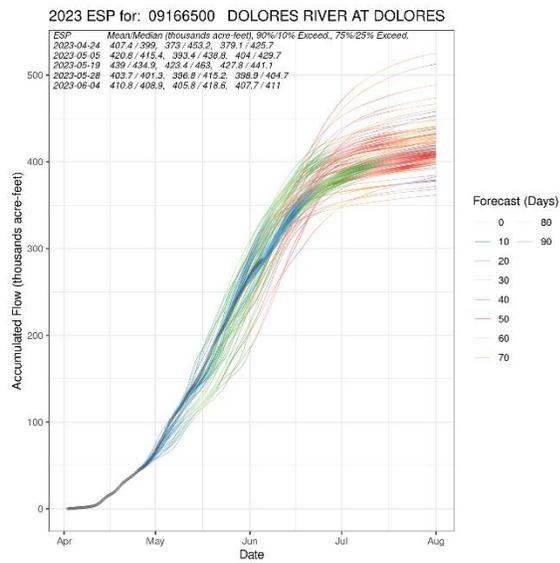
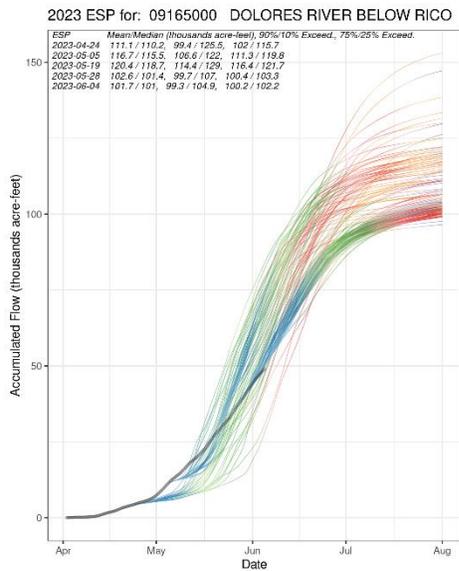
Apr-Sep: 434.6 kac-ft *(Noted major diversion upstream to Groundhog Res.: 20.6 kac-ft and climbing....adjusted total = 455.2 kac-ft)

Dolores R. blw Rico, CO, median (Q50) runoff forecast (initialized on 6/4/2023):

Apr-Jul: 101 kac-ft

Apr-Sep: 110 kac-ft

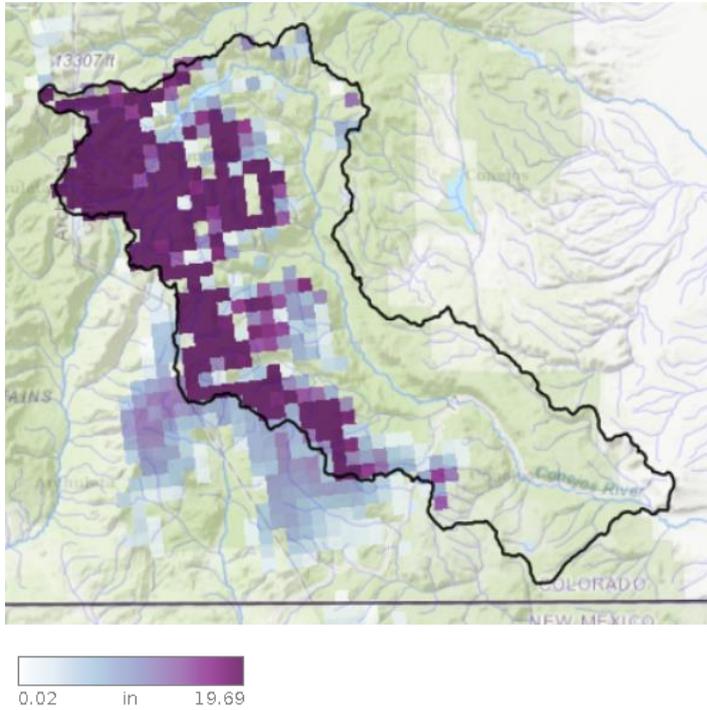
Sample plots for Apr-Jul ESP forecasts (ignore forecasts before 4/24):



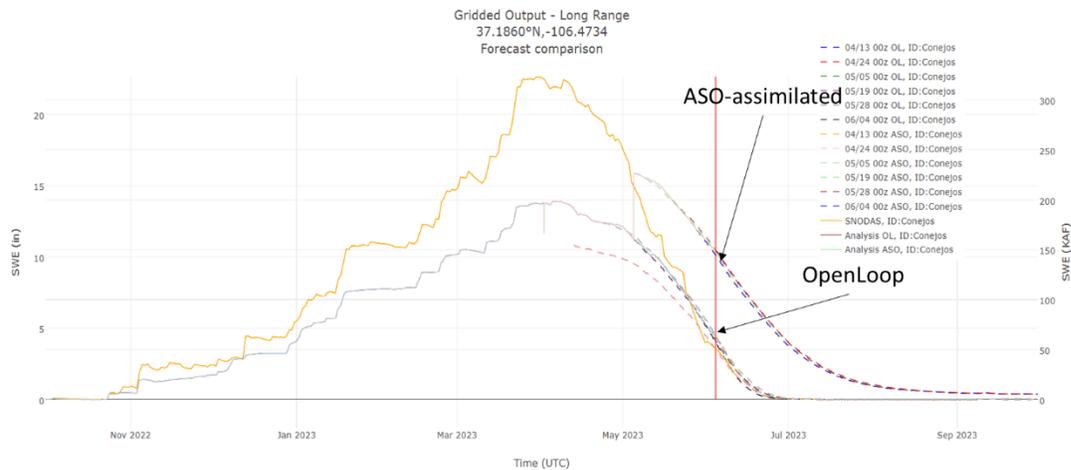
Conejos System:

As of May 27 the ASO-assimilated snowpack from the WRF-Hydro model was approximately 150 kac-ft for the Conejos basin above Mogote. Nearly all snowpack in both basins resided largely above 10,500 ft. Basin averaged soil saturation fraction have continued to fall below their seasonal maximum values and currently reside below 70%.

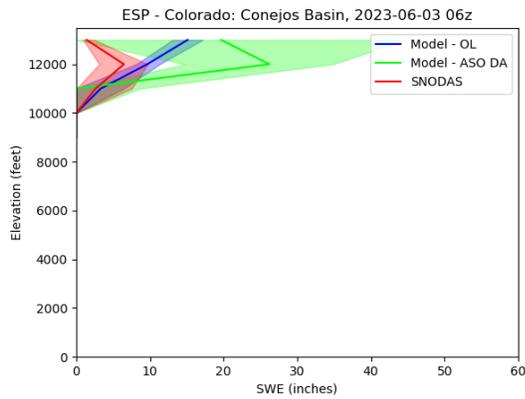
Spatial map of ASO-assimilated SWE:



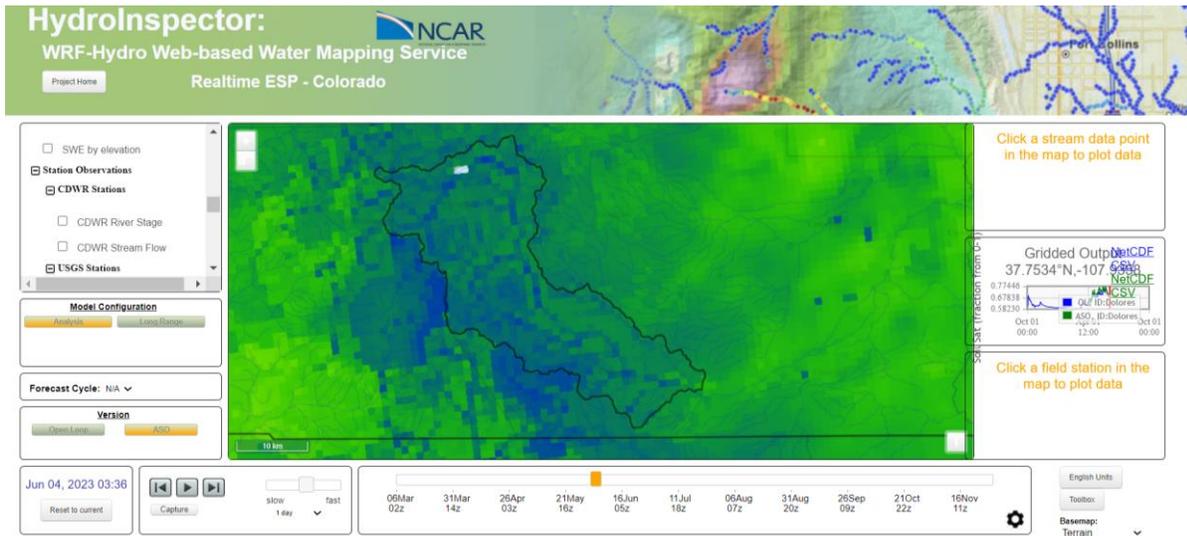
Conejos basin-averaged analyses and forecasts of ASO-assimilated SWE:



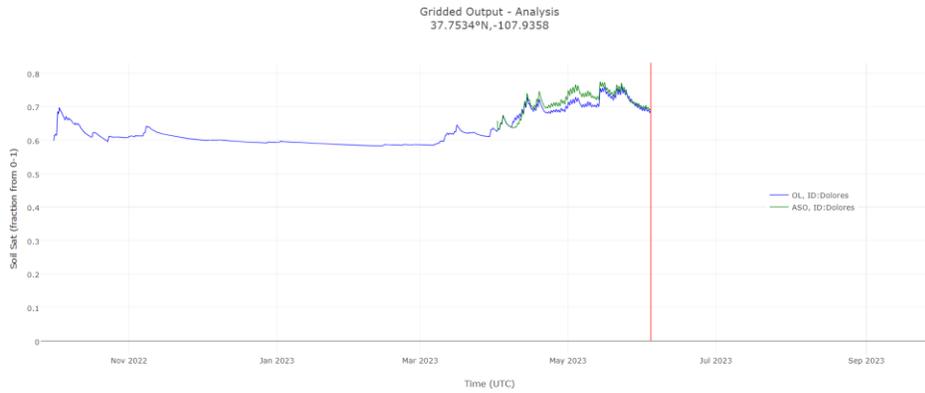
Elevation profile of SWE for SNODAS (red), ASO-assimilated snowpack (green) and WRF-Hydro OpenLoop (blue)



Spatial map of WRF-Hydro modelled soil saturation:



Basin-averaged soil saturation values:



Conejos April-Sep and April-July Median (Q50) Accumulated Runoff/Inflow (initialized on 6/4/2023):

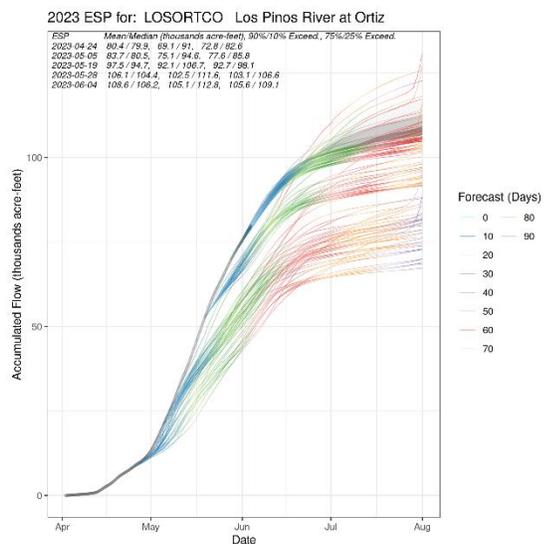
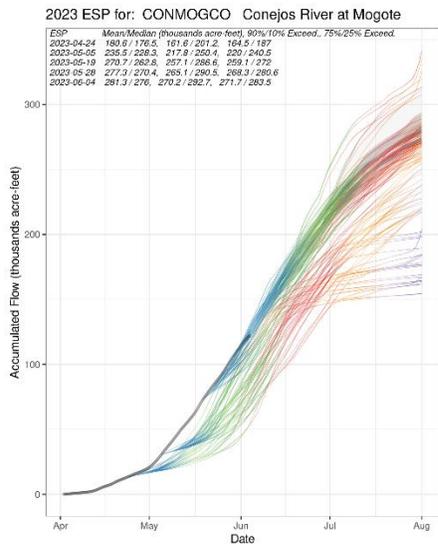
Conejos System: WRF-Hydro/ASO: 409.4 kac-ft (Apr-Jul): 460 kac-ft (Apr-Sep)

Conejos at Mogote: WRF-Hydro/ASO: 276 kac-ft (Apr-Jul): 312 kac-ft (Apr-Sep)

San Antonio @ Ortiz: WRF-Hydro/ASO: 27.2 kac-ft (Apr-Jul): 29.1 kac-ft (Apr-Sep)

Los Pinos @ Ortiz: WRF-Hydro/ASO: 106.2 kac-ft (Apr-Jul): 119 kac-ft (Apr-Sep)

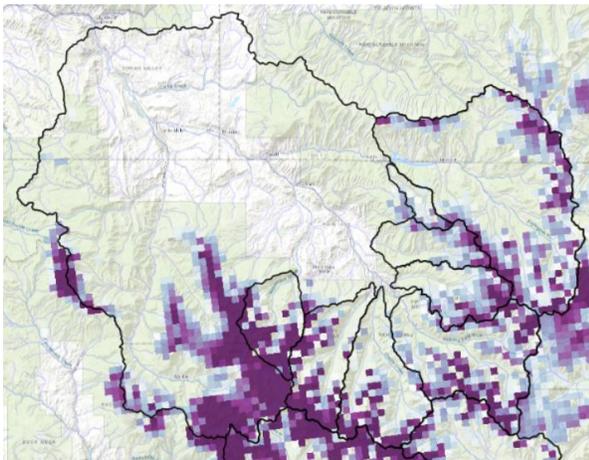
Sample plots for Apr-Sep ESP forecasts (ignore forecasts before 4/24):



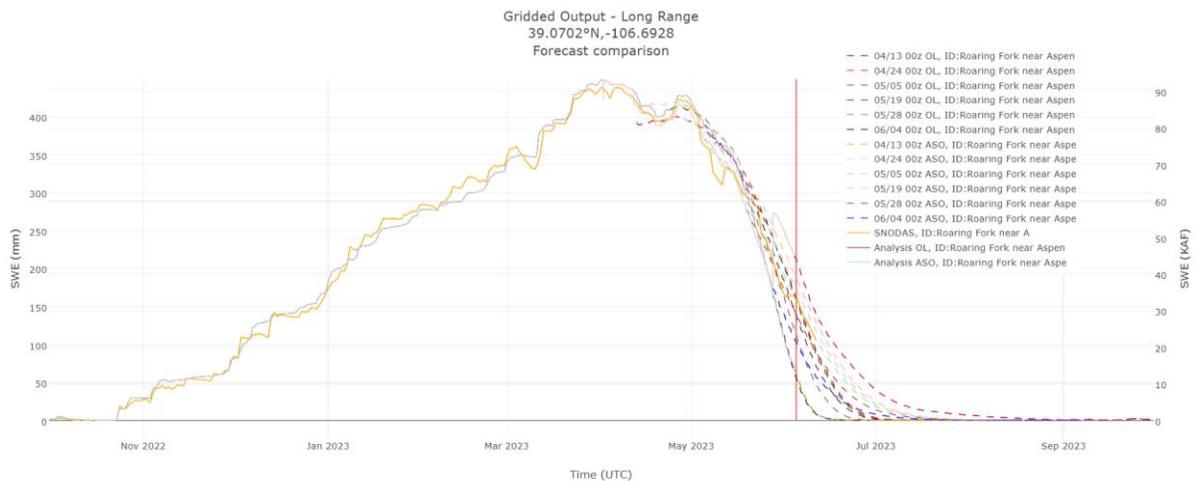
Roaring Fork/Frying Pan System:

As of June 4 the ASO-assimilated snowpack from the WRF-Hydro model was approximately 45 kac-ft for the Roaring Fork River above Aspen and 55 kac-ft for the Frying Pan River above Ruedi Reservoir following the latest available ASO survey conducted on May 27-28. Both basins saw a sizeable increase in SWE through assimilation of ASO data indicating prior analyses were likely too aggressive in ablation rate estimates. The bulk of the remaining snowpack in the combined Roaring Fork/Frying Pan system resided above 11,000 ft. Basin averaged soil saturation fractions for the combined Roaring Fork/Frying Pan system above Glenwood saw a modest increase as a result of the ASO assimilation and consequent melt of that snowpack into the basin.

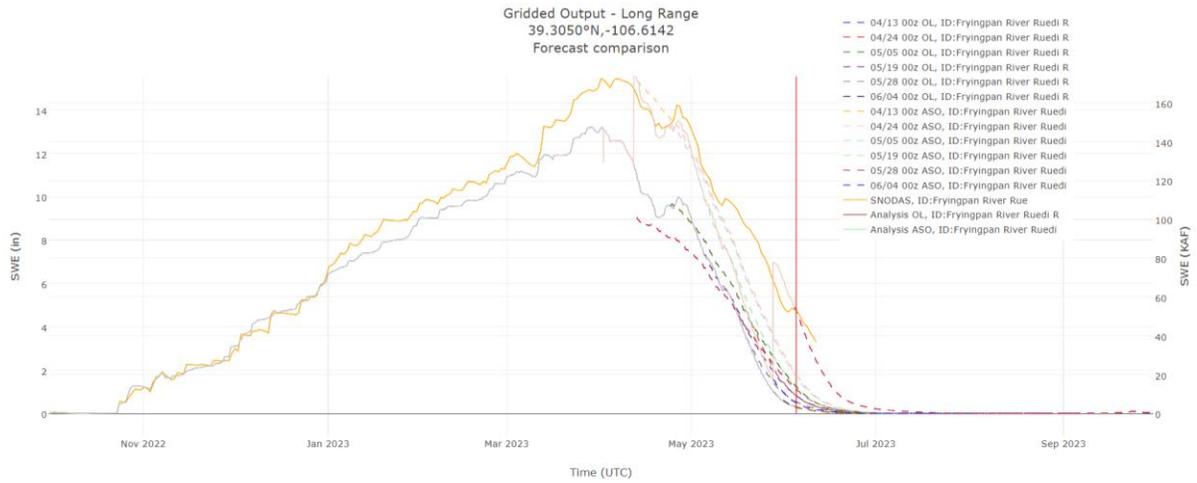
Spatial map of ASO-assimilated SWE:



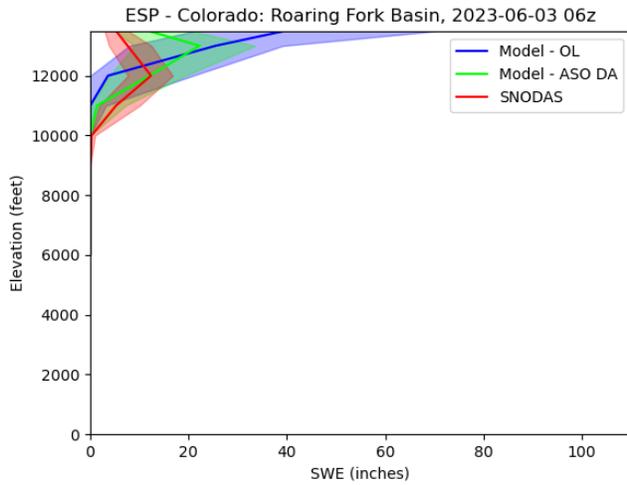
Basin-averaged analyses and forecasts of ASO-assimilated SWE (Roaring Fork River near Aspen):



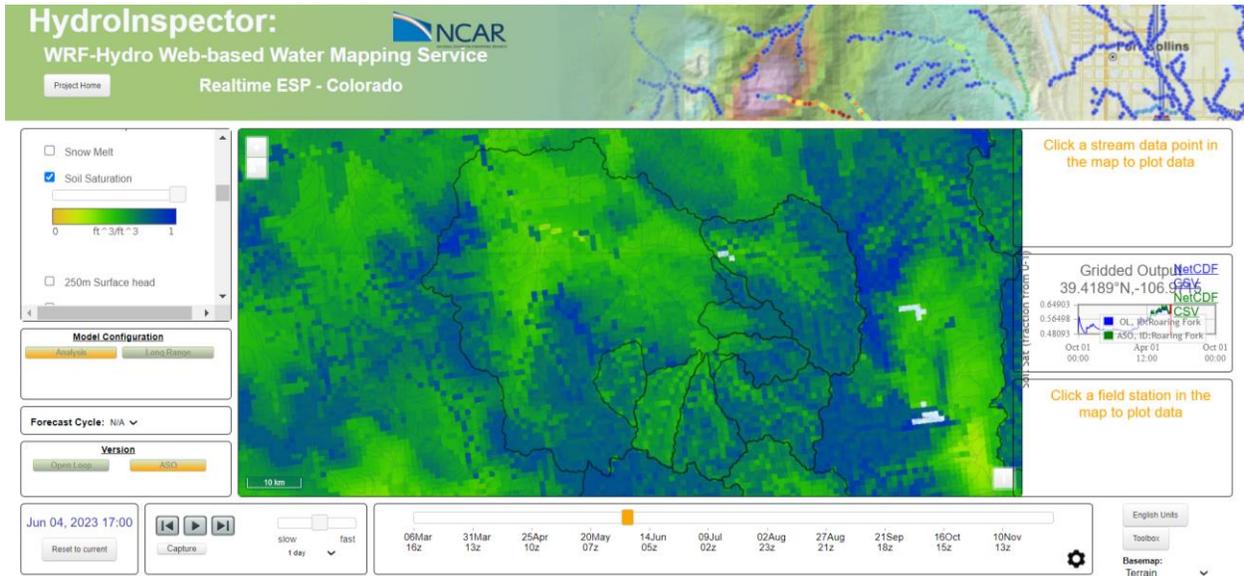
Basin-averaged analyses and forecasts of ASO-assimilated SWE (Frying Pan River above Ruedi Reservoir):



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 6/4/2023):

Roaring Fork near Aspen: 73.3 kac-ft (New forecast site)

Roaring Fork abv Difficult near Aspen: 52.8 kac-ft (New forecast site)

Roaring Fork at Glenwood Springs: 701.5 kac-ft (New forecast site, “naturalized” flow forecast, downstream of major anthropogenics, currently based on actual-obs flows...very experimental)

Snowmass Creek: 39.7 kac-ft (New forecast site)

Frying Pan River @ Meridith: 98.7 kac-ft (New forecast site...looks impacted from upstream diversions...)

Ruedi Reservoir Inflow: 106.5 kac-ft (New forecast site...looks impacted from upstream diversions...)

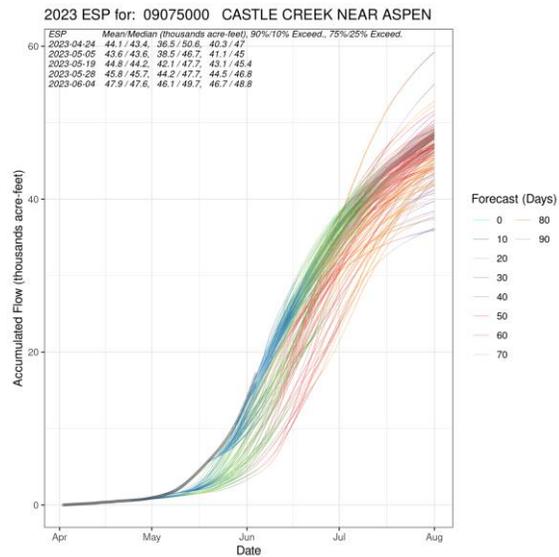
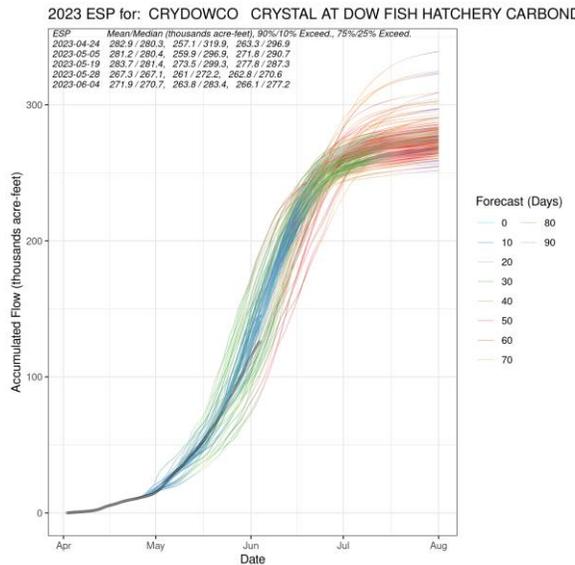
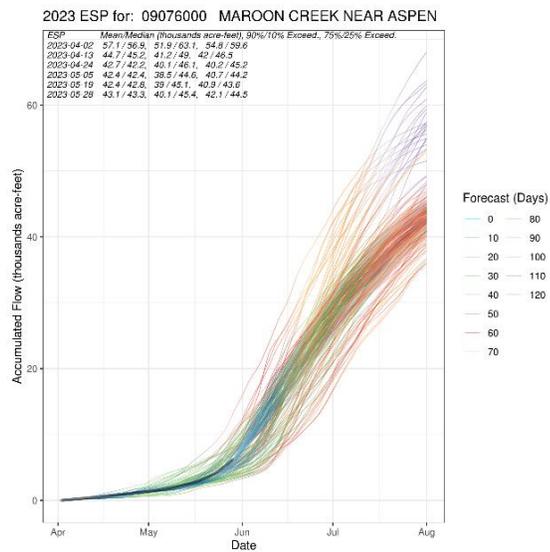
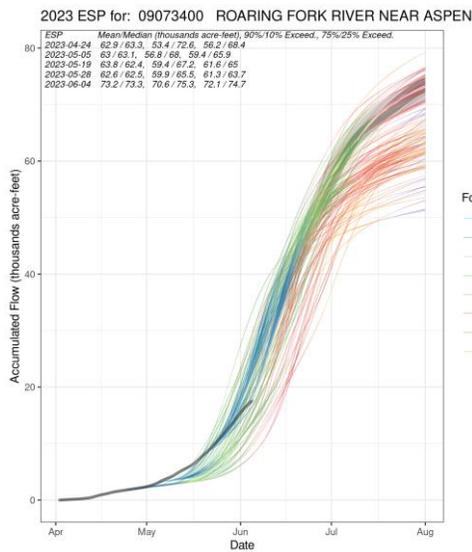
Hunter Cr: 33.1 kac-ft (*based on analyzed past flow, not observed)

Maroon Cr nr Aspen: 37.8 kac-ft (New forecast site)

Castle Cr: 47.6 kac-ft (New forecast site)

Crystal River @ Dow Fish Hatchery nr Carbondale: 271 kac-ft (New forecast site)

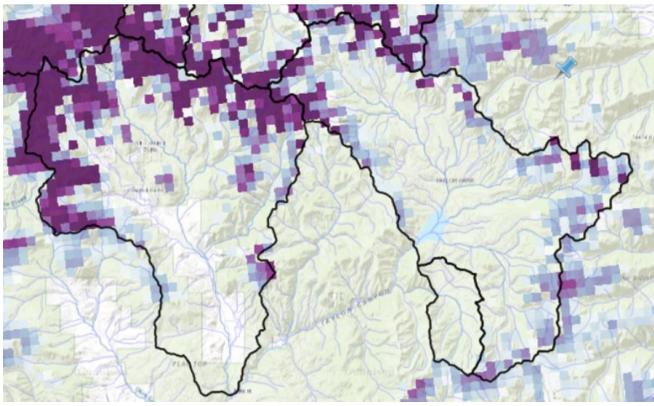
Sample plots for Apr-Oct ESP forecasts (ignore forecasts before 4/24):



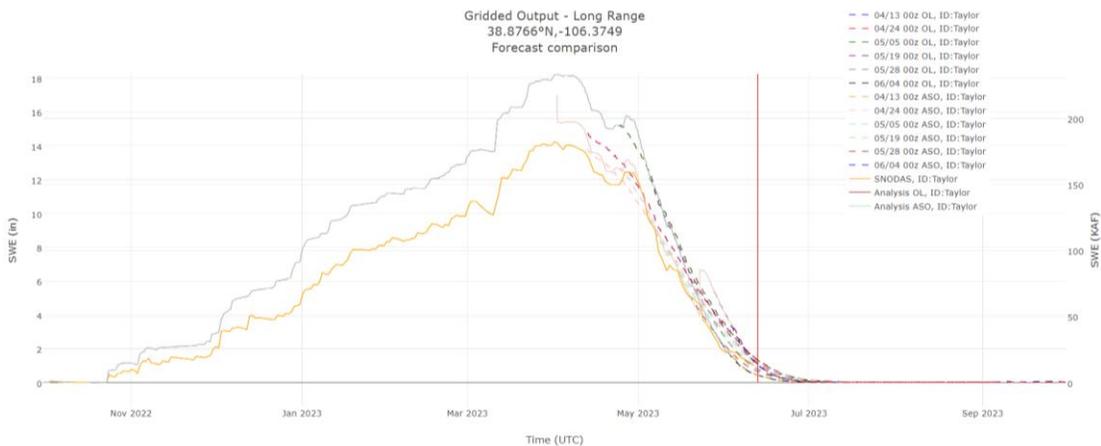
Taylor River/East River System:

As of June 4 the ASO-assimilated snowpack from the WRF-Hydro model was approximately 42 kac-ft for the Taylor basin above Taylor Reservoir and 126 kac-ft for the East River above Almont. These new analysis values are after the ASO surveys of the Upper Taylor and East River basins which were acquired on May 23. The Upper Taylor ASO survey resulted in a net increase in SWE values and flow forecasts while the East River ASO survey resulted in a net decrease in SWE values and also in the flow forecasts. The bulk of the remaining snowpack in the throughout the Upper Taylor and East River basins resided above 11,000 ft. Basin averaged soil saturation fractions for both systems remained near 70%, indicating very wet conditions.

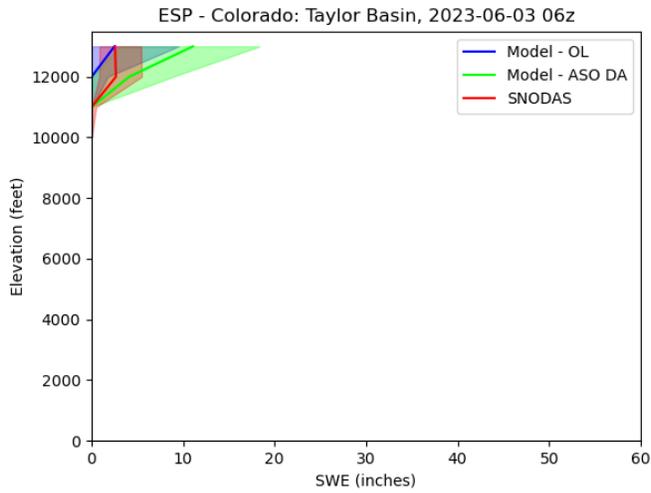
East and Taylor River Water Equivalent (SWE) Analysis



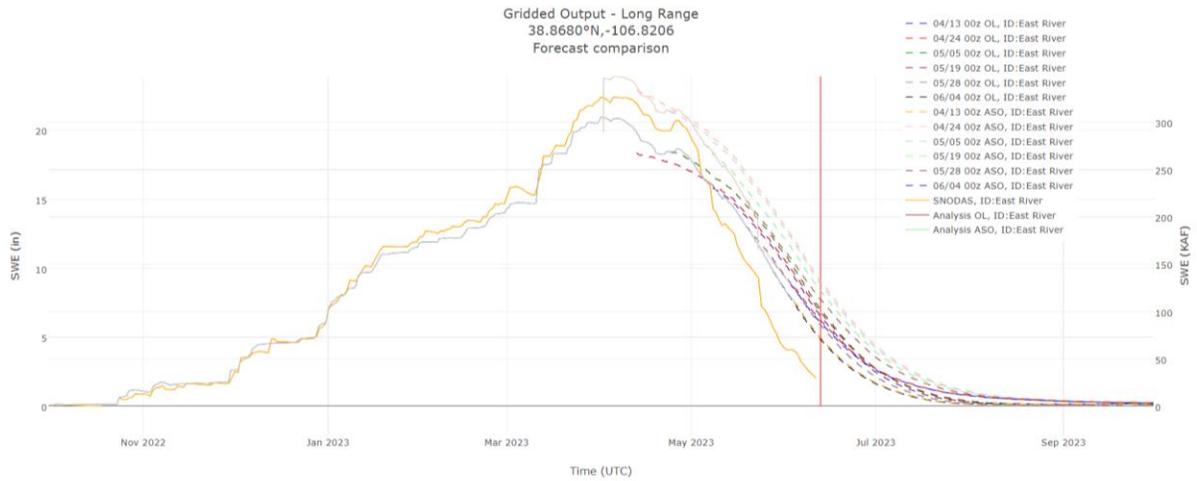
Taylor Basin Basin-averaged Snow Water Equivalent (SWE) Analysis and Forecasts



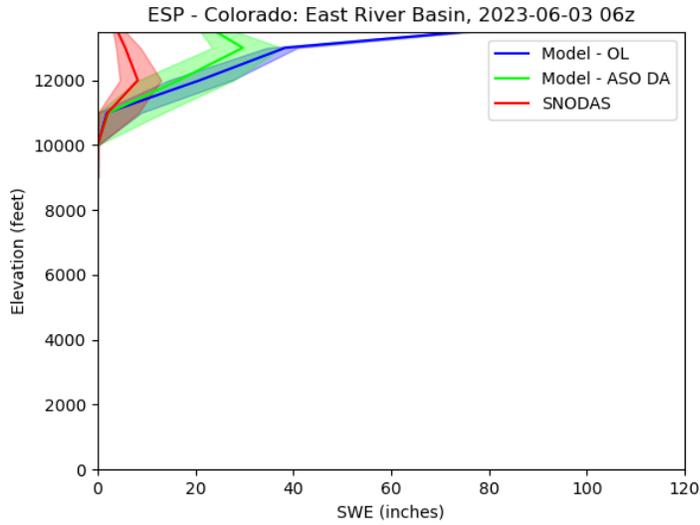
Elevation profile of SWE for SNODAS (red), ASO-assimilated snowpack (green) and WRF-Hydro OpenLoop (blue) for the Taylor basin above Taylor Park Reservoir:



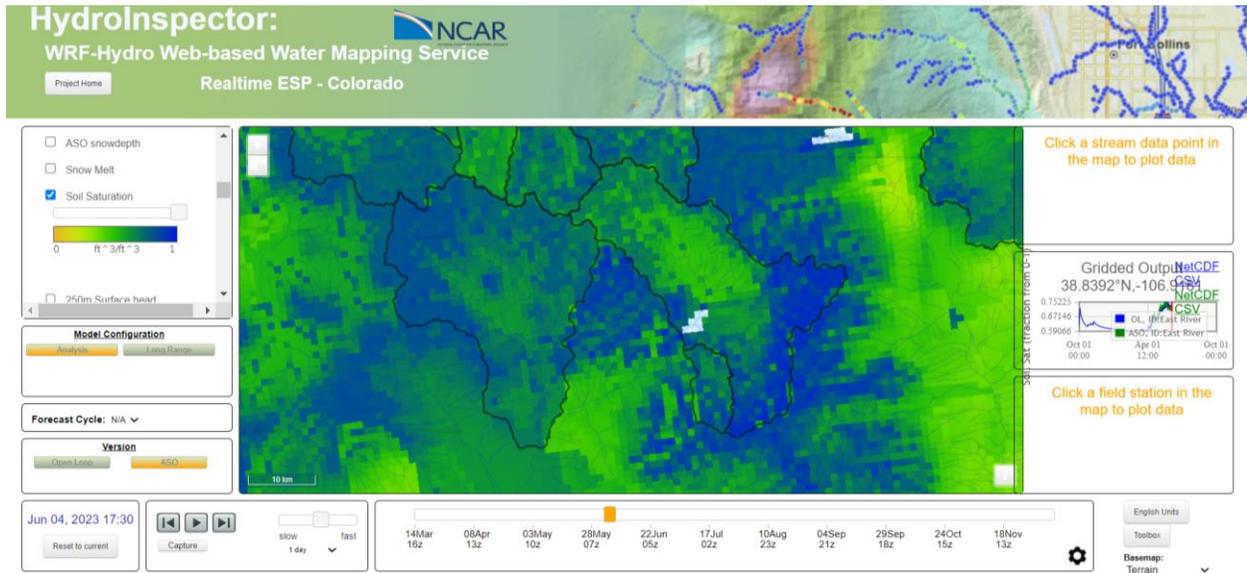
East River Basin-averaged Snow Water Equivalent (SWE) Analysis and Forecasts:



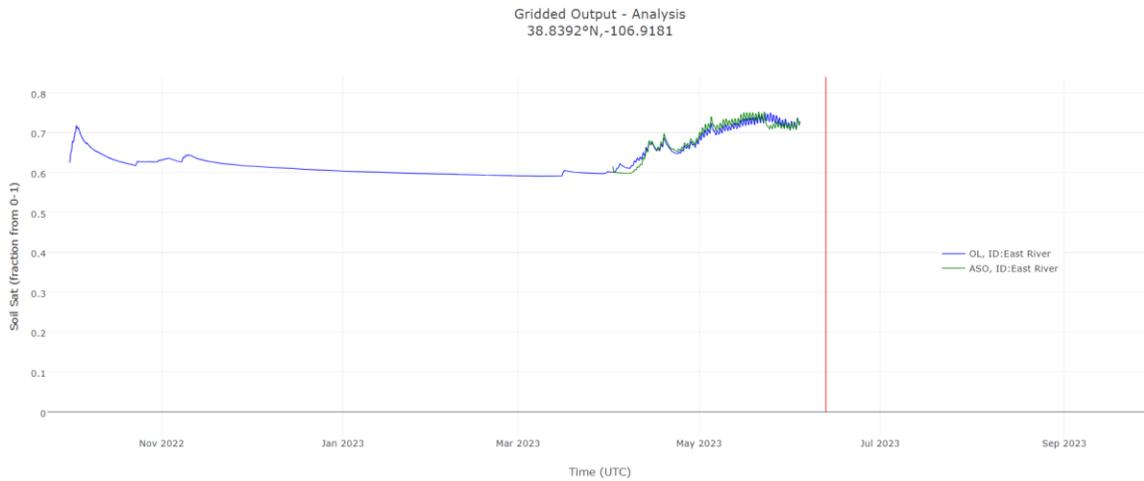
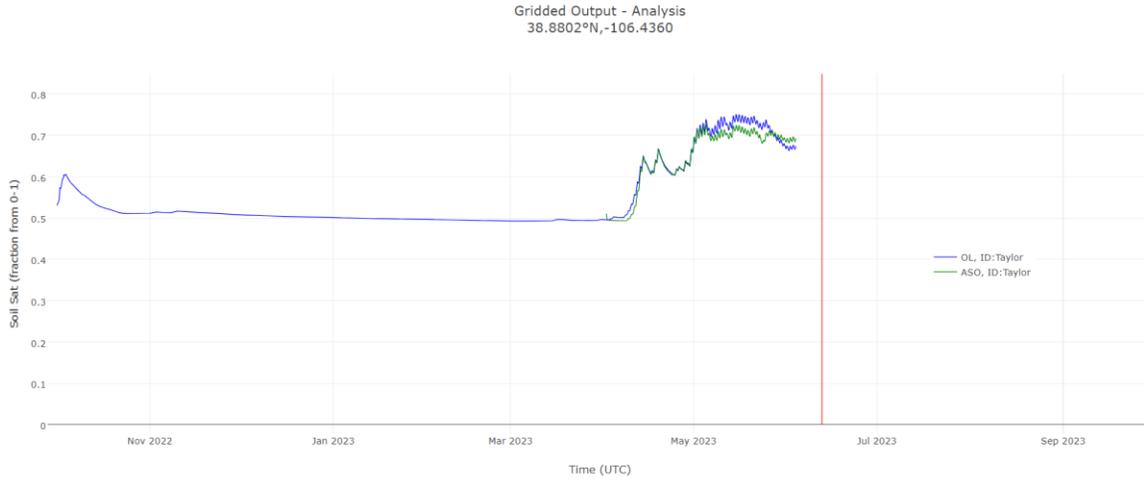
Elevation profile of SWE for SNODAS (red), ASO-assimilated snowpack (green) and WRF-Hydro OpenLoop (blue) for the East River basin above Almont, CO:



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 6/4/2023):

Taylor Reservoir Inflow: 130 kac-ft (following 5/23 ASO survey)

Taylor R. abv Taylor Res: 68 kac-ft

Texas Cr. abv Taylor Res: 23.4 kac-ft

Willow Crk abv Taylor Res: 19.2 kac-ft

East River at Almont: 279 kac-ft

Elk Creek abv Crested Butte: 2.9 kac-ft

Ohio Creek @ Baldwin: 75 kac-ft

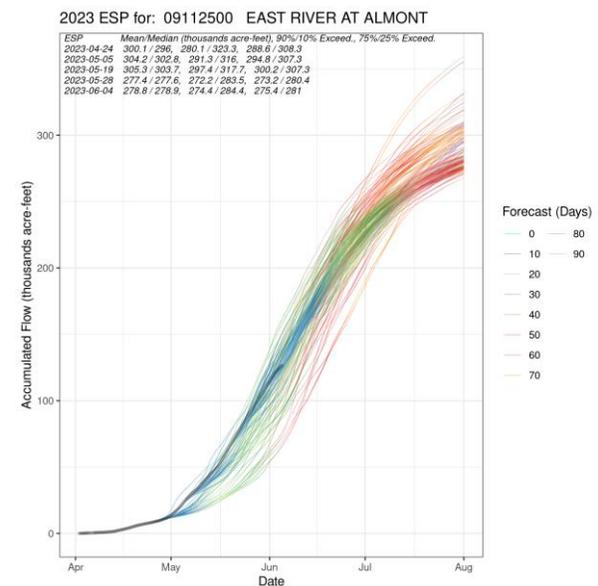
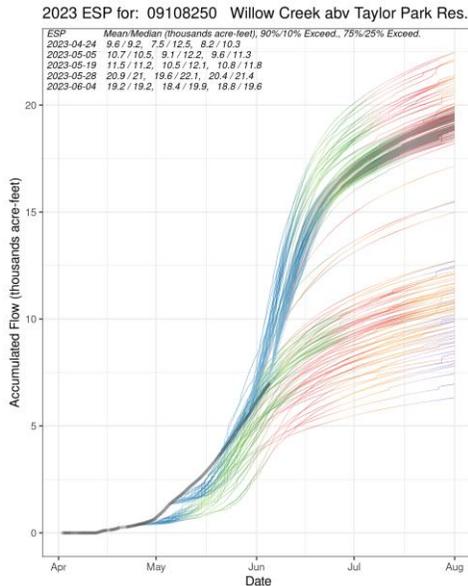
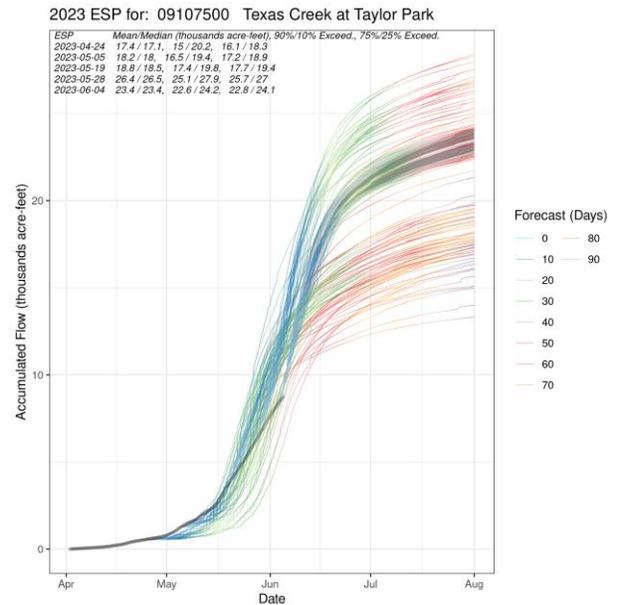
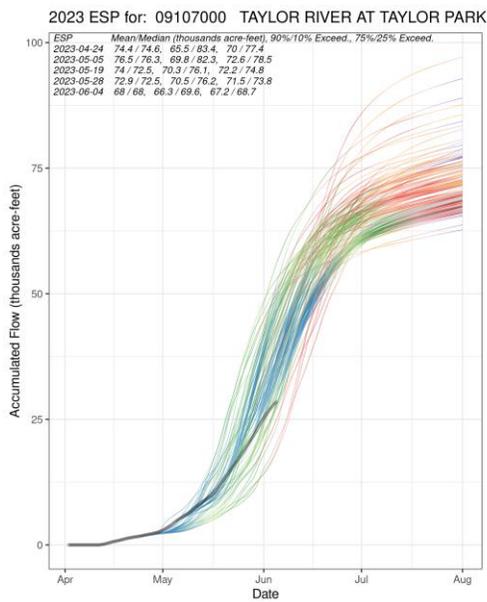
Slate River nr Crested Butte: 127.9 kac-ft

Coal Cr nr Crested Butte: 30 kac-ft

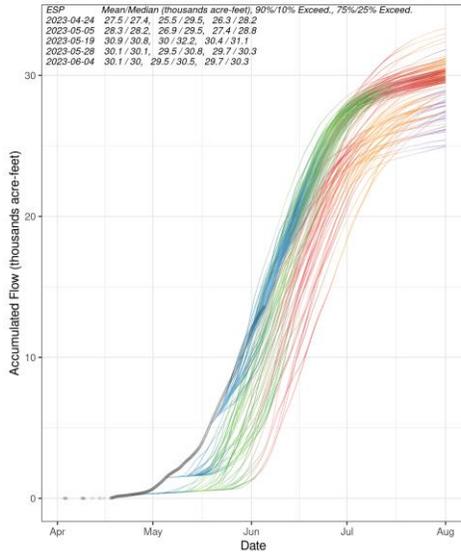
Tomichi Cr @ Sargents: 44.1 kac-ft

Blue Mesa inflow: 917 kac-ft (notable upstream diversions/management)

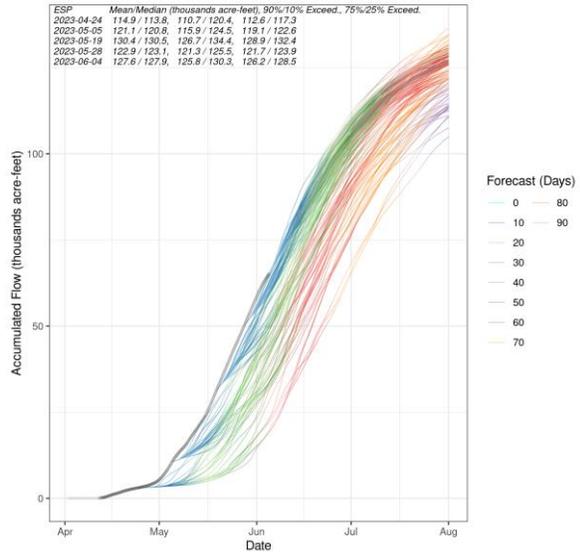
Example ensemble flow accumulation plot for Apr-Jul inflow (initialized 6/4/2023):



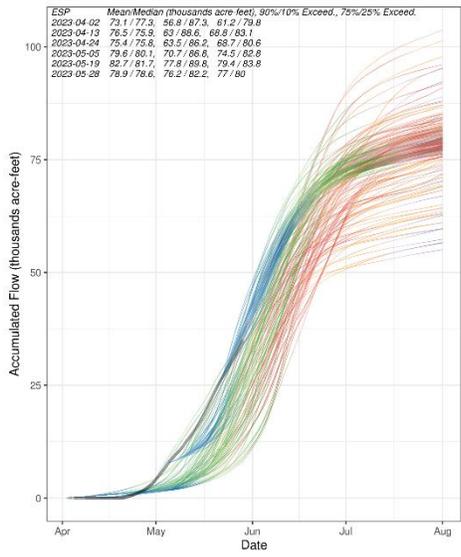
2023 ESP for: 09111250 COAL CREEK abv MCCORMICK CRESTED BUTTE



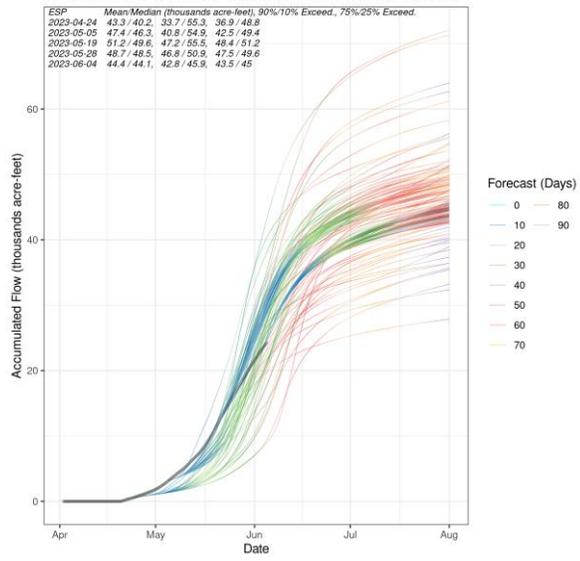
2023 ESP for: 385106106571000 Slate River nr Crested Butte



2023 ESP for: 091113500 OHIO CREEK NEAR BALDWIN



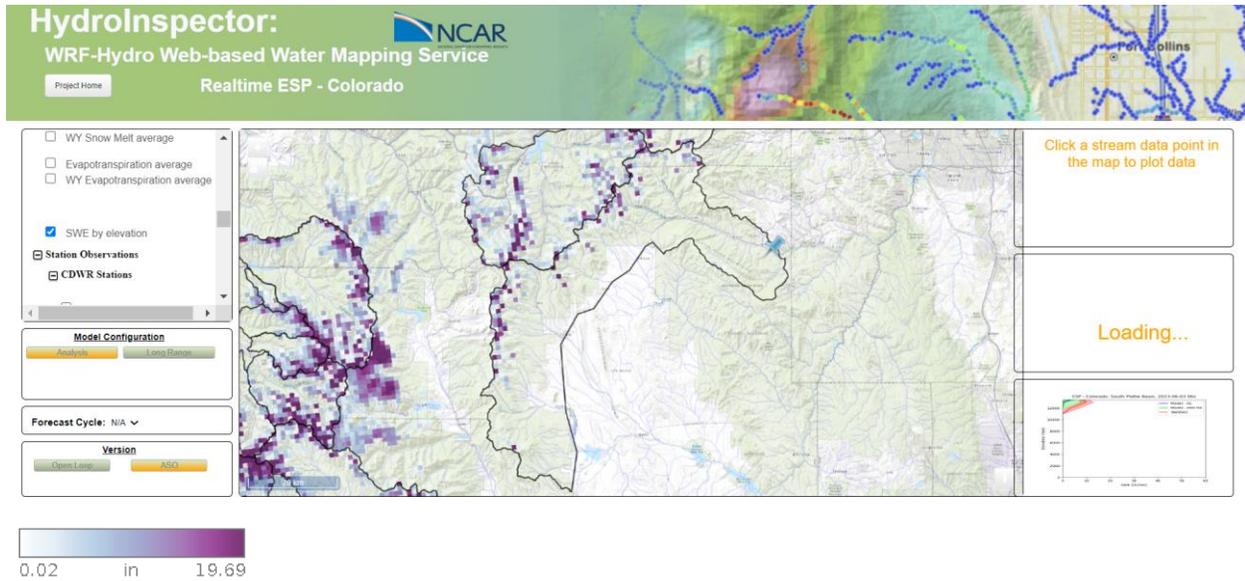
2023 ESP for: 091115500 TOMICHI CREEK AT SARGENTS



Upper South Platte River System:

As of June 4 the ASO-assimilated snowpack from the WRF-Hydro model was approximately 30 kac-ft for the Upper South Platte River basin. This new value includes the ASO survey conducted on May 26 which resulted in a net increase in SWE compared to the prior WRF-hydro analysis value. The bulk of the remaining snowpack in the throughout the region remained above 11,500-12,000 ft. Basin averaged soil saturation fractions have continued to remain around 70-72%, continuing to indicate generally wet conditions.

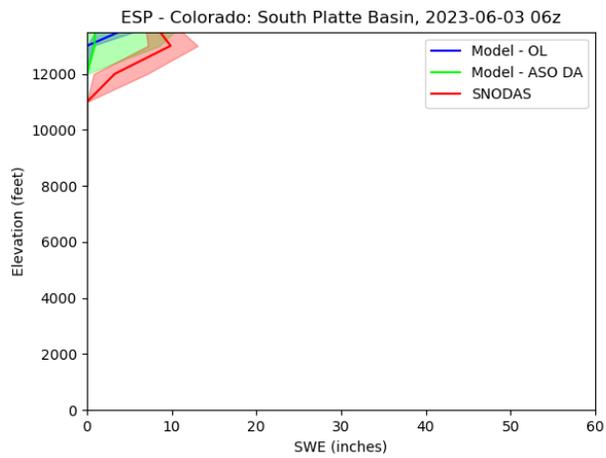
Upper South Platte River Snow Water Equivalent (SWE) Analysis and Forecasts



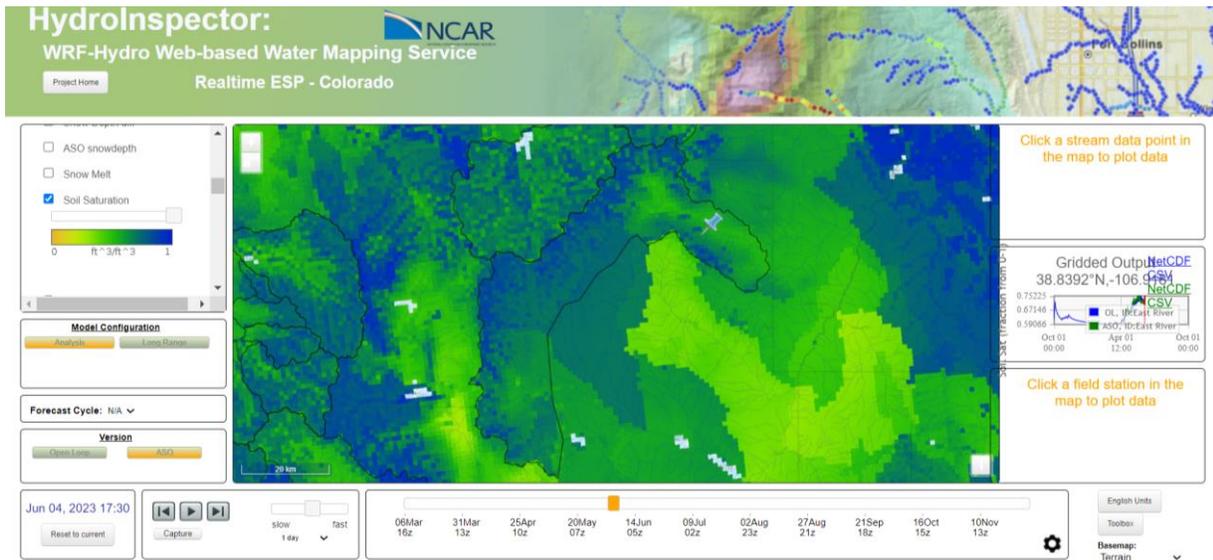
Upper South Platte River Basin-averaged Snow Water Equivalent (SWE) Analysis and Forecasts:



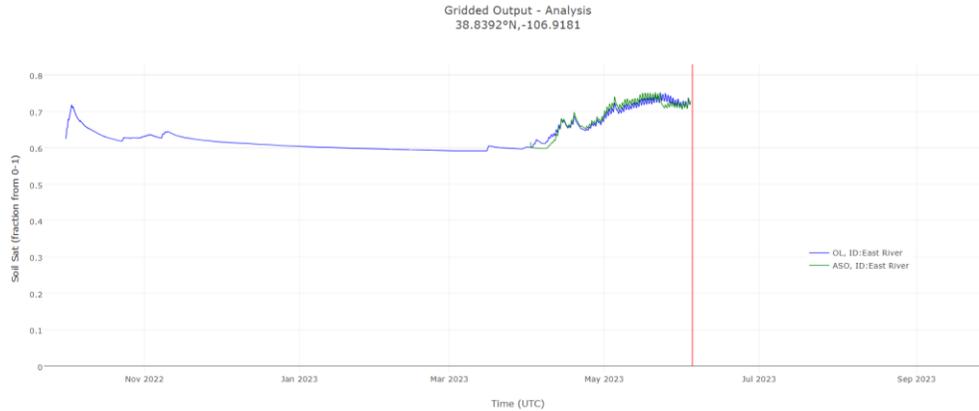
Elevation profile of SWE for SNODAS (red), ASO-assimilated snowpack (green) and WRF-Hydro OpenLoop (blue) for Upper South Platte River basin:



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 6/4/2023):

N. Fork, S. Platte at Bailey (CDWR PLABAICO): 28.1 kac-ft (New forecast site, considerable anthropogenics upstream, no naturalized observed flow data yet available)

Jefferson Cr. near Jefferson (CDWR JEFJFCO): 4.1 kac-ft (New forecast site, clear evidence of managed flow in observations)

Michigan Cr. near Jefferson (CDWR MCHJFCO): 6.3 kac-ft (New forecast site)

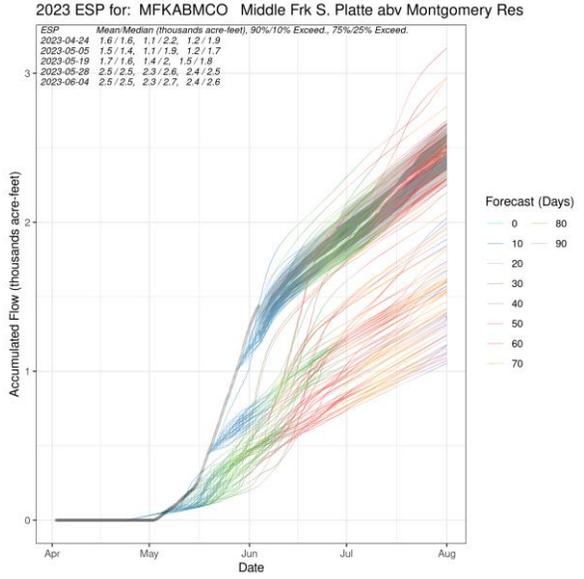
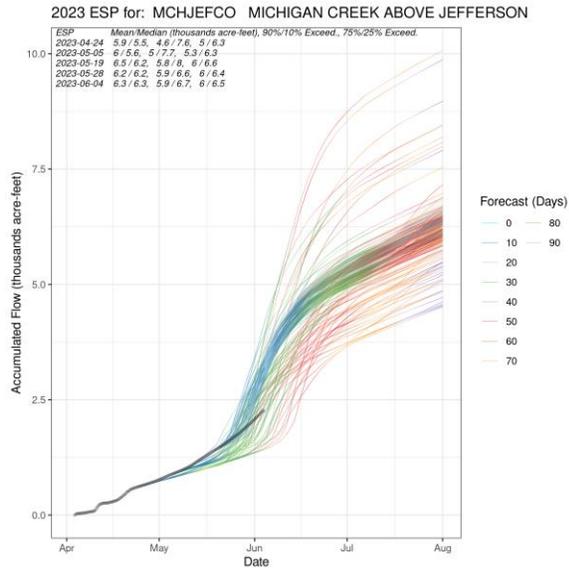
Tarryall Cr at Upper Station (CDWR TARRUPCO): 8.2 kac-ft (New forecast site, no actual observations yet integrated)

Middle Frk S. Platte abv Montgomery Res (CDWR MFKABMCO): 2.5 kac-ft (New forecast site)

S. Fork of S. Platte abv Antero Res (CDWR SFKANTCO): 6.6 kac-ft (New forecast site...suspect observational data before 4/15)

Antero Res. Inflow: Lacking proper usable observed inflow data...

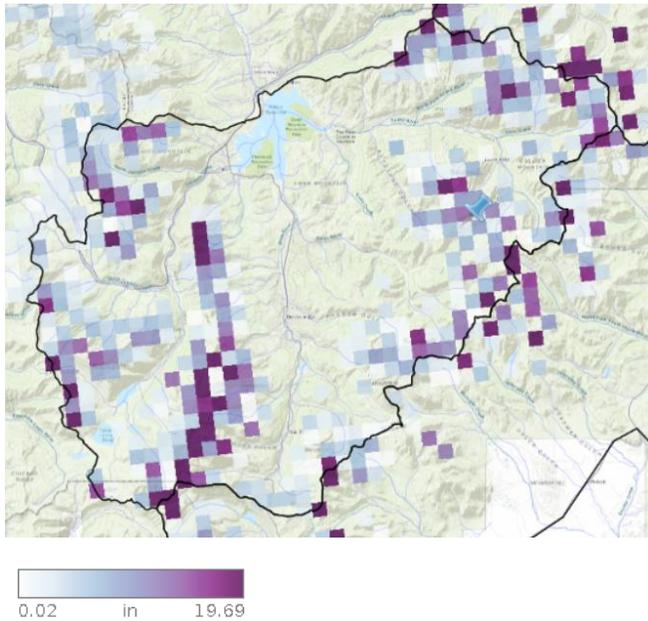
Example ensemble flow accumulation plot for Apr-Oct inflow:



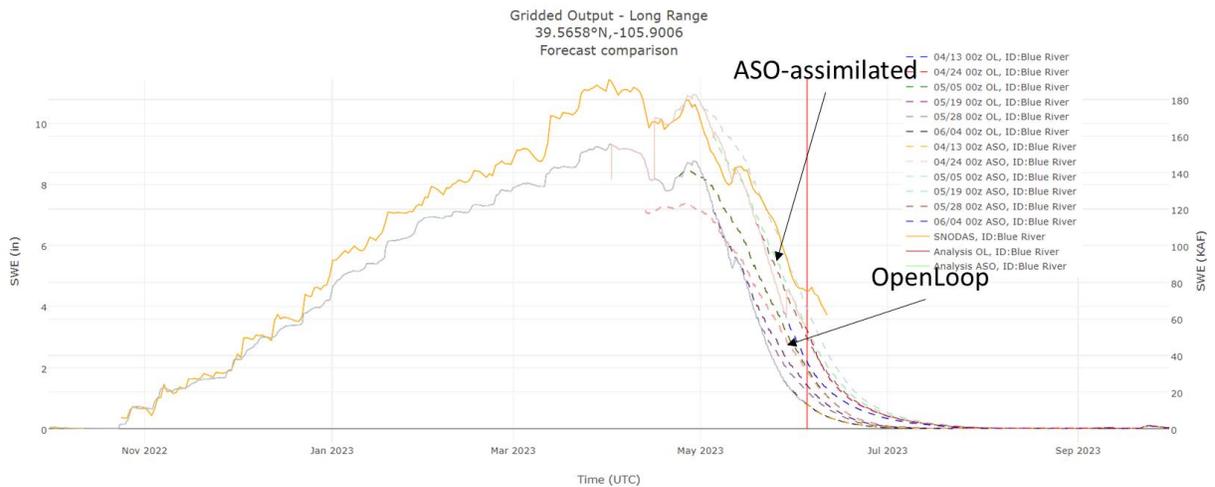
Blue River/Dillon Reservoir System:

As of June 4 the ASO-assimilated snowpack from the WRF-Hydro model was approximately 56 kac-ft for the Blue River/Dillon Reservoir basin. A modest increment in basin-average SWE was incurred as a result of the ASO survey assimilation which occurred on May 28-29. The bulk of the remaining snowpack in the throughout the region resided above 11,000 ft. Basin averaged soil saturation fractions for the basin was remaining fairly steady at around 70%, indicating generally wet conditions.

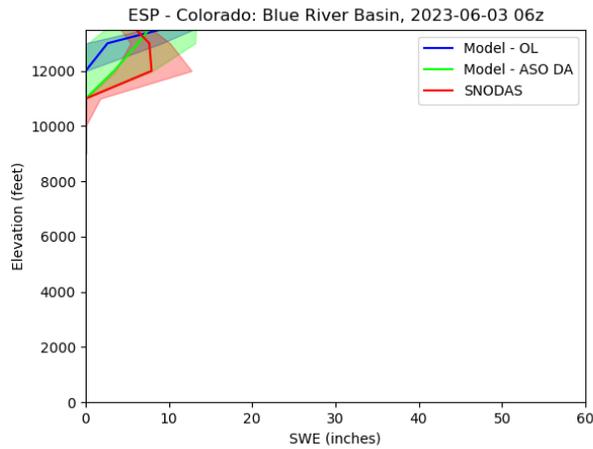
Blue River/Dillon Reservoir Snow Water Equivalent (SWE) Analysis



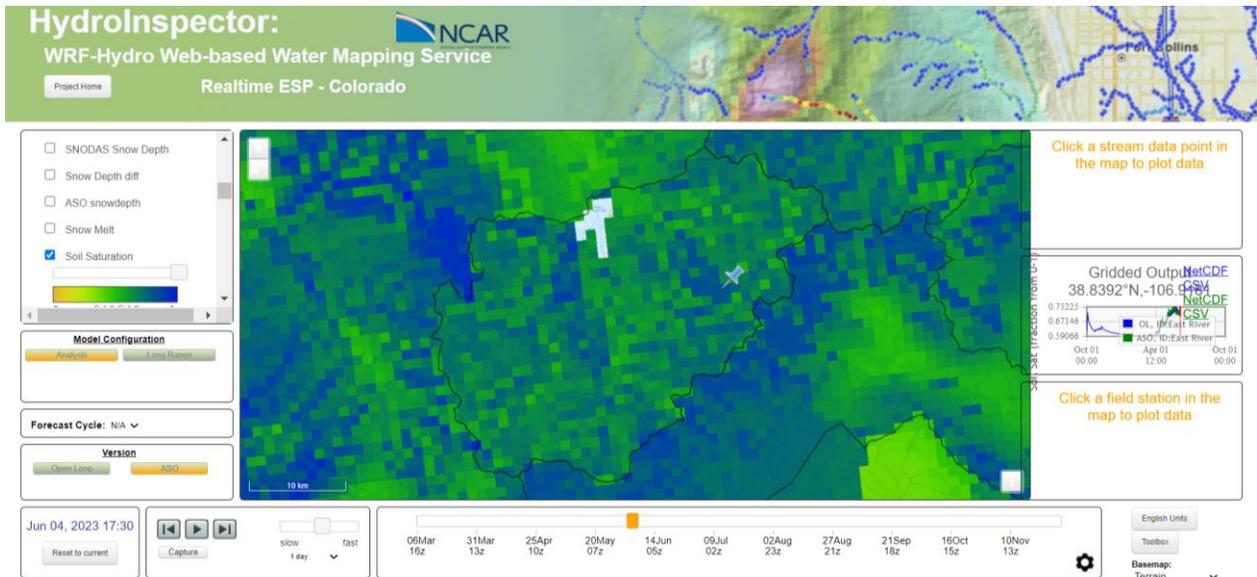
Blue River/Dillon Reservoir basin-averaged Snow Water Equivalent (SWE) Analysis and Forecasts:



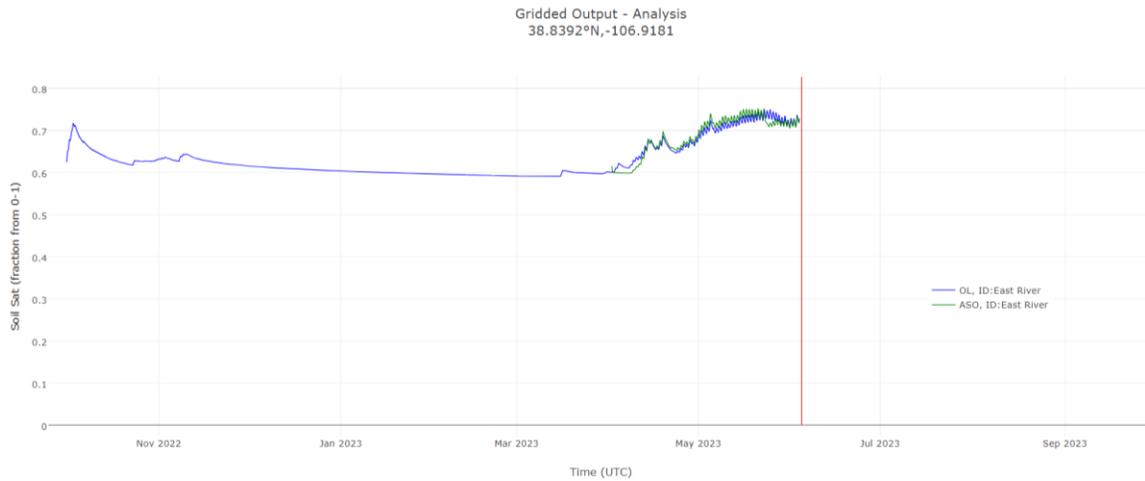
Elevation profile of SWE for SNODAS (red), ASO-assimilated snowpack (green) and WRF-Hydro OpenLoop (blue) for the Blue River/Dillon Reservoir basin:



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 6/4/2023):

Dillon Reservoir: 136.1 kac-ft

Blue River abv Dillon: 45.5 kac-ft

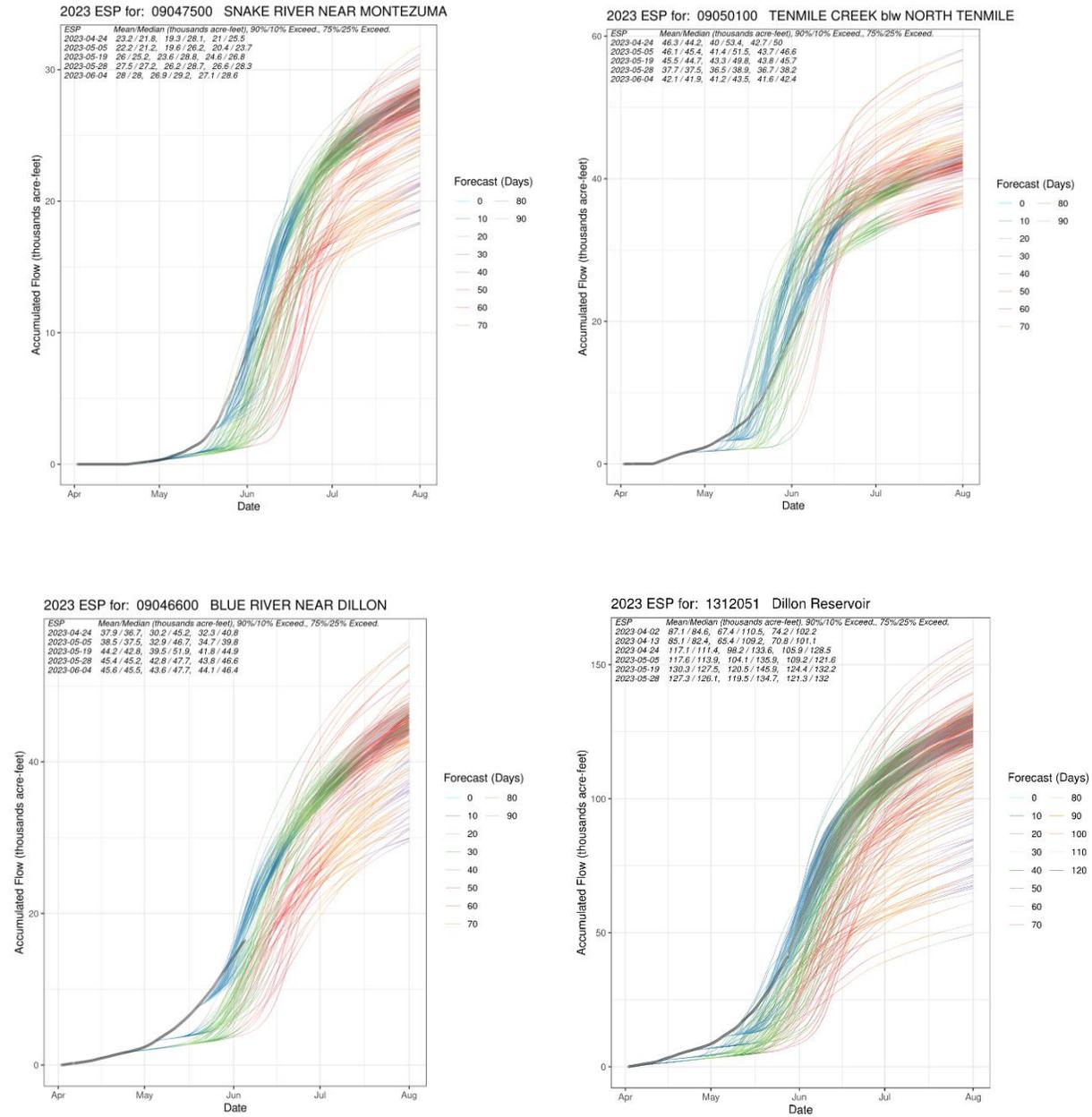
Snake River nr Montezuma: 28 kac-ft

Tenmile Creek nr Frisco: 31.9 kac-ft

Keystone Gulch nr Keystone: 2.9 kac-ft

Straight Cr. nr Dillon: 4.7 kac-ft

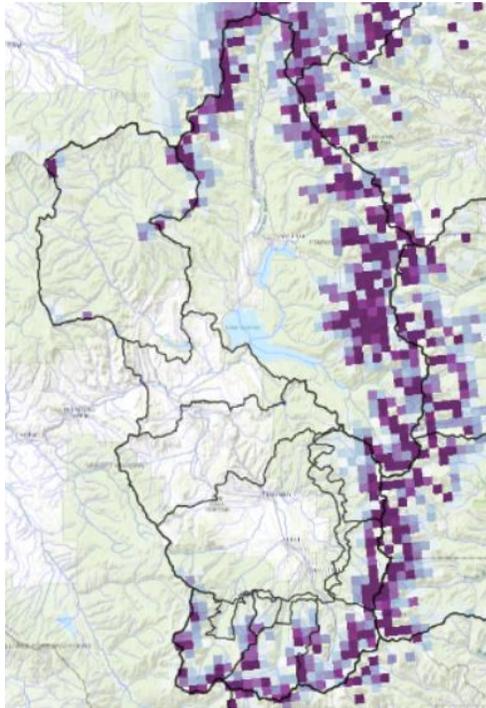
Example ensemble flow accumulation plot for Apr-Oct inflow:



Upper Colorado River/Windy Gap System:

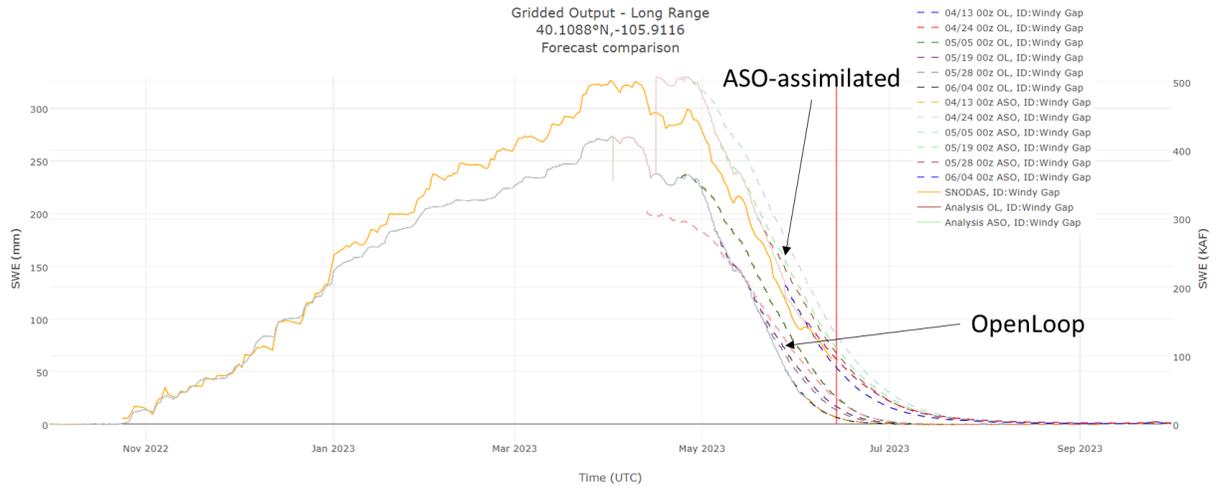
As of June 4 the ASO-assimilated snowpack from the WRF-Hydro model was approximately 148 kac-ft for the Upper Colorado Windy Gap basin. The bulk of the remaining snowpack in the throughout the region largely resided above 11,000 ft. Basin averaged soil saturation fractions for the basin have continued to decline slowly over the last few weeks.

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

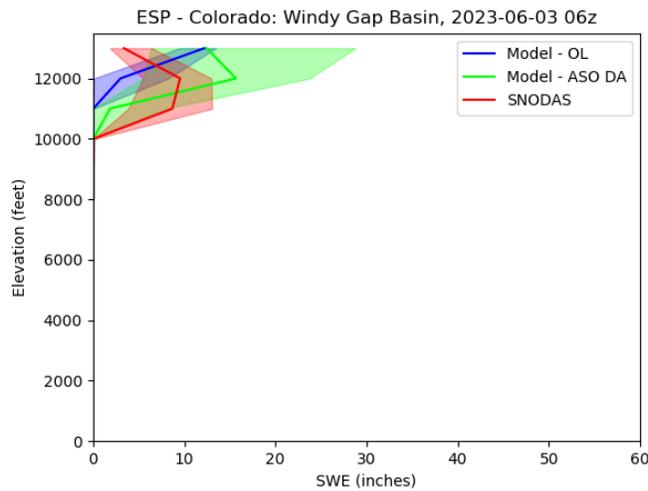


0.02 in 19.69

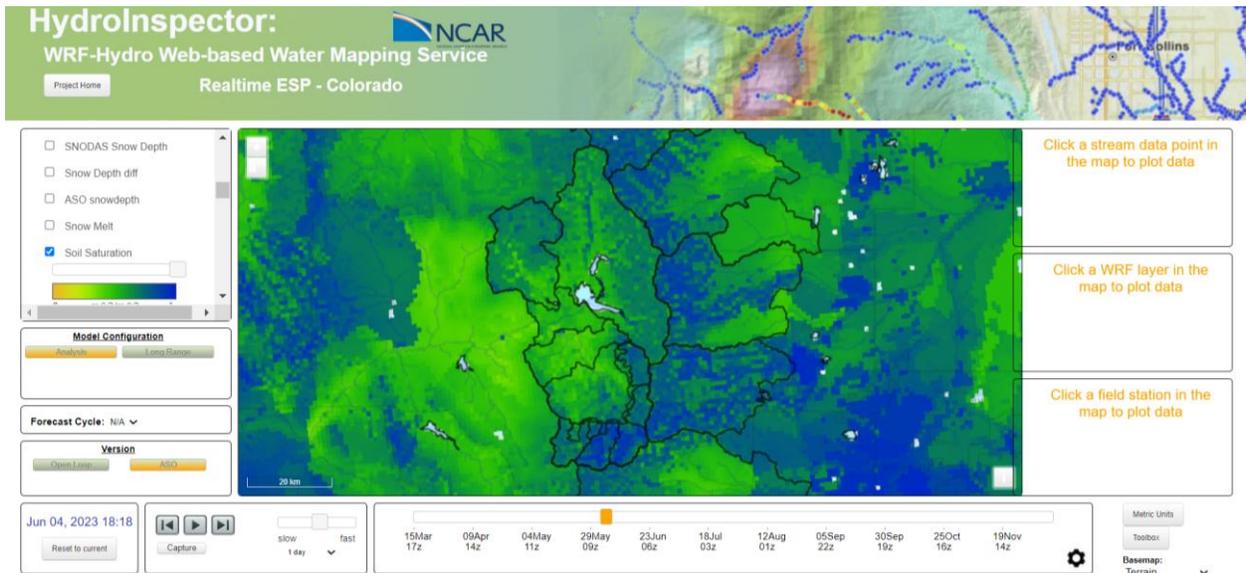
Upper Colorado/Windy Gap basin-averaged Snow Water Equivalent (SWE) Analysis and Forecasts:



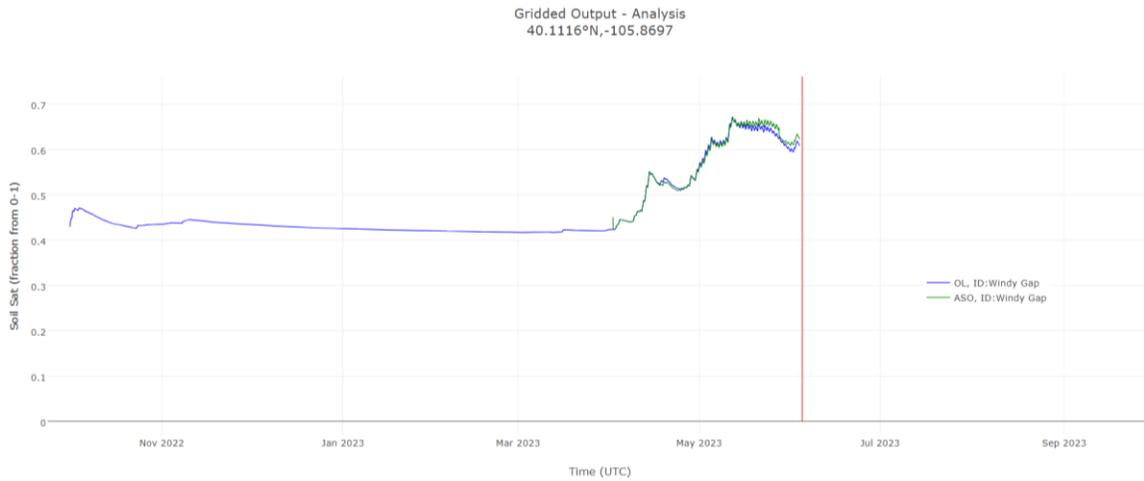
Elevation profile of SWE for SNODAS (red), ASO-assimilated snowpack (green) and WRF-Hydro OpenLoop (blue) for the Upper Colorado/Windy Gap basin:



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 (initialized on 6/8/2023):

Col. R. blw Baker Gulch: 47.6 kac-ft

North Inlet Cr.: 31.9 kac-ft (using analyzed observed flow for period without actual observations)

East Inlet Cr.: 24.9 kac-ft (using analyzed observed flow for period without actual observations)

Fraser R @ Upper Sta: 9.6 kac-ft (uses actual observed flows, naturalized flow record needed)

Fraser R @ Winter Park: 21 kac-ft (uses actual observed flows, naturalized flow record needed)

Vazquez Cr. nr Winter Park: 14.9 kac-ft (uses actual observed flows)

Ranch Cr. nr Fraser: 11.1 kac-ft (uses actual observed flows)

Cabin Cr nr Fraser: 4.5 kac-ft (uses actual observed flows)

St. Louis Cr. nr Fraser: 11.8 kac-ft (uses actual observed flows, naturalized flow record needed)

Fraser R @ Tabernash: 56 kac-ft (uses actual observed flows, naturalized flow record needed)

Fraser R @ Granby: 114 kac-ft (using naturalized flow at gauge location provided by Northern WCD of 68 kac-ft)

Willow Cr. Reservoir inflow: 79 kac-ft (using naturalized Willow Cr. Reservoir inflow provided by Northern WCD of 70 kac-ft)

Grand Lake inflow: 102.6 kac-ft (no observed inflows available...used model analysis)

Lake Granby inflow: 288 kac-ft (using naturalized Lake Granby inflow provided by Northern WCD of 139 kac-ft)

Col. R. nr Granby: needs naturalized flow timeseries

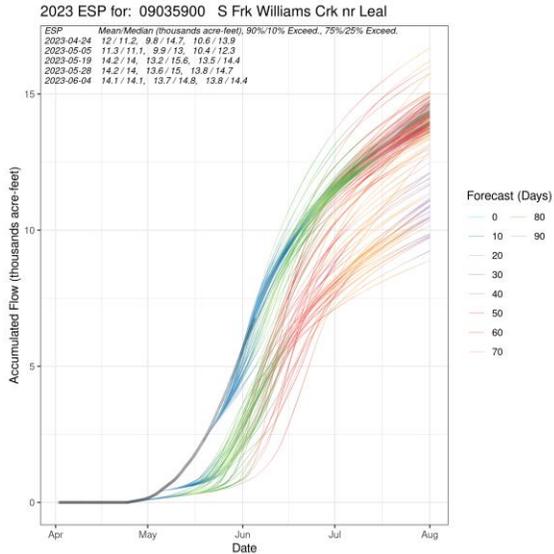
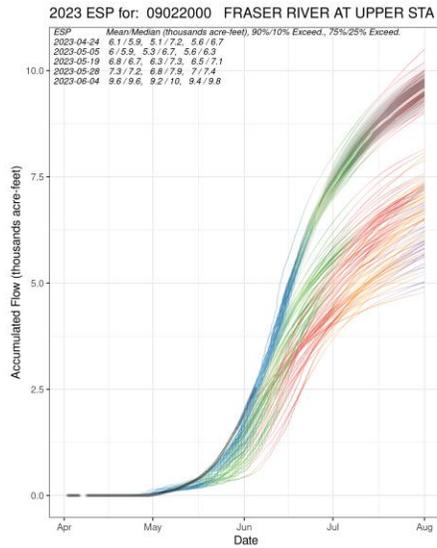
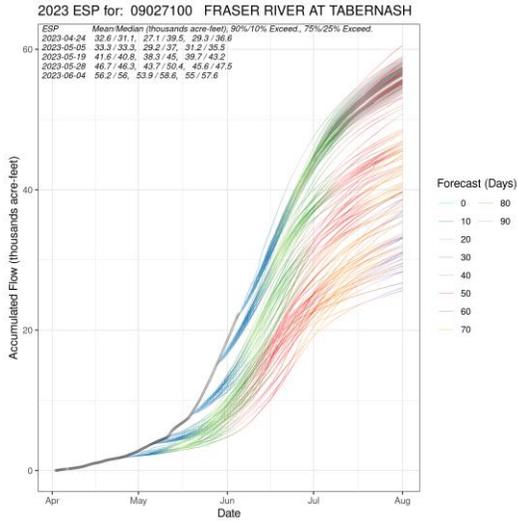
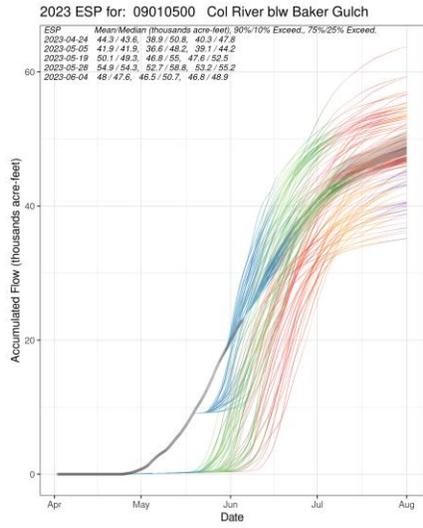
Williams Frk nr Leal: 40.4 kac-ft

S. Frk Williams Crk nr Leal: 14.1 kac-ft

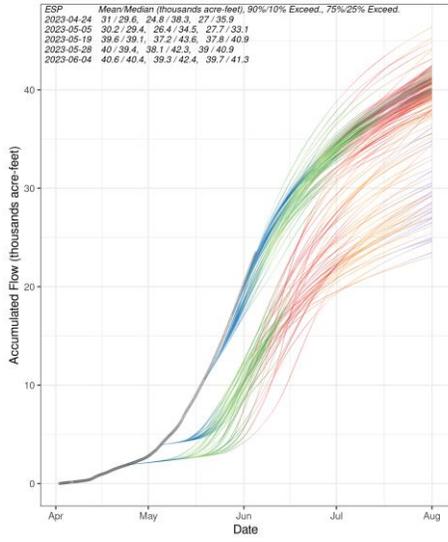
Bobtail Cr. Nr Jones Pass: 3.9 kac-ft

Williams Frk Res. Inflow: 41.4 (no observed inflows available...used model analysis)

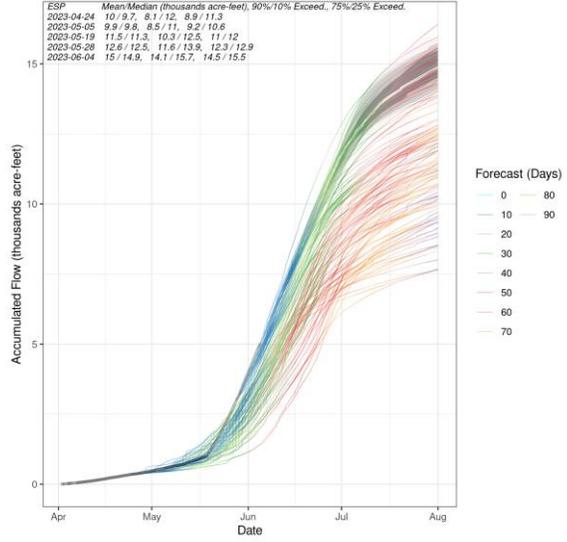
Example ensemble flow accumulation plot for Apr-Oct inflow (initialized on 6/4/2023):



2023 ESP for: 09036000 Williams Frk nr Leal



2023 ESP for: 09025000 VASQUEZ CREEK AT WINTER PARK



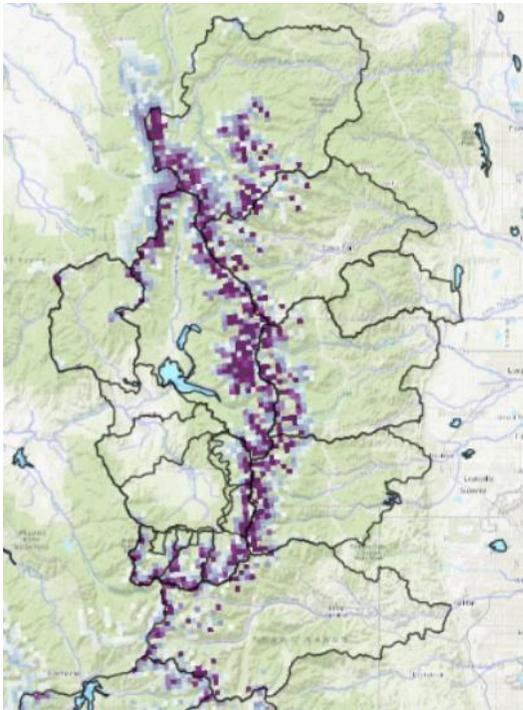
Front Range System:

As of June 4 the ASO-assimilated snowpack from the WRF-Hydro model for the 5 Front Range basins was: [ASO survey data for all Front Range basins has now been assimilated into the WRF-Hydro model]

Poudre River Basin (no ASO):	74 kac-ft
Big Thompson River Basin (no ASO):	33 kac-ft
Little Thompson River Basin (no ASO):	0.0 kac-ft
St. Vrain River Basin (no ASO):	33 kac-ft
Boulder Creek Basin (with ASO):	42 kac-ft
Clear Creek Basin (with ASO):	27.1 kac-ft

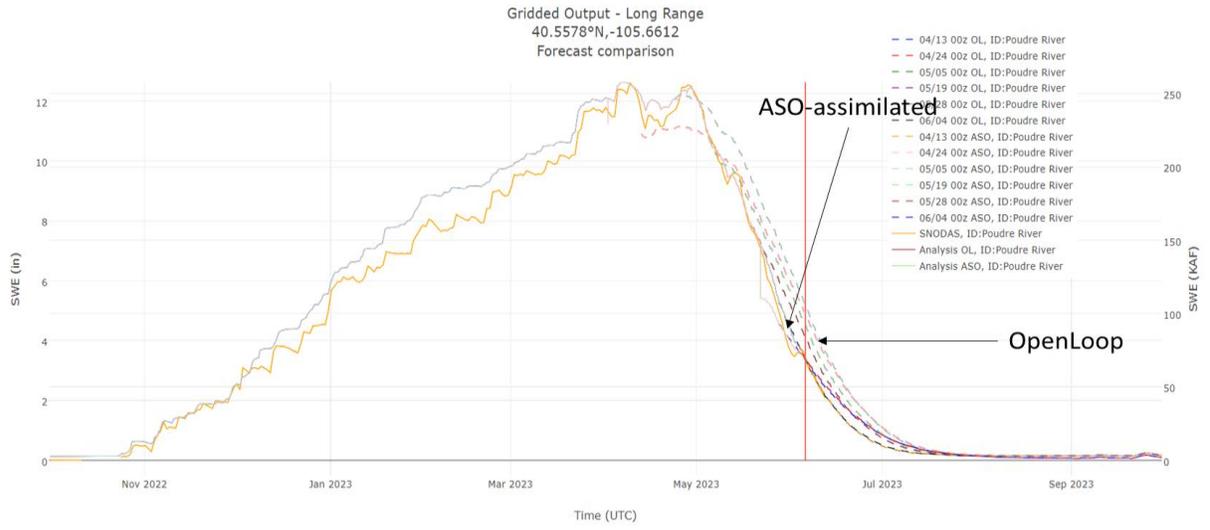
Nearly all remaining snowpack in the throughout the region resided above 10,500 ft.

Front Range System Snow Water Equivalent (SWE) Analysis

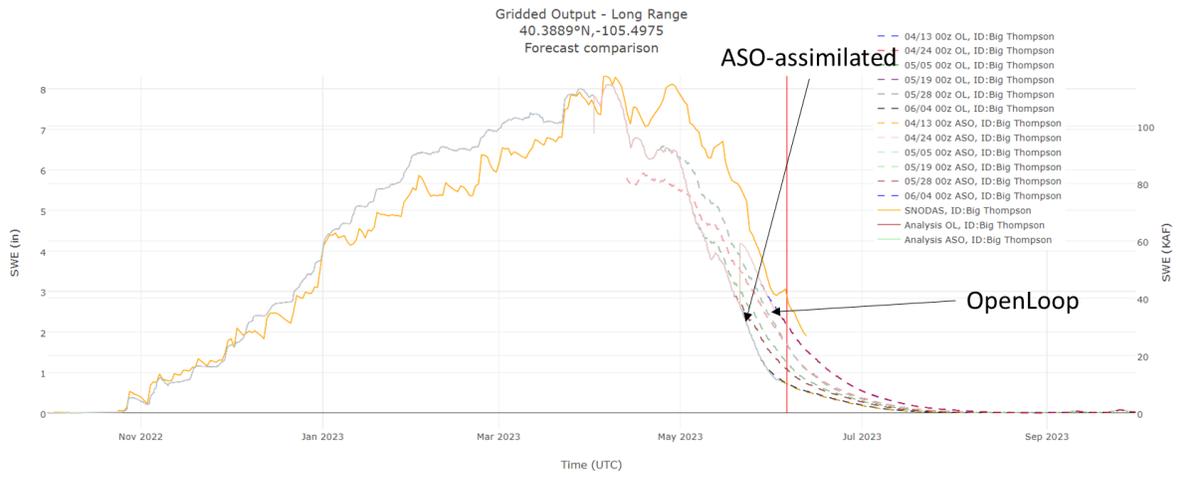


0.02 in 19.69

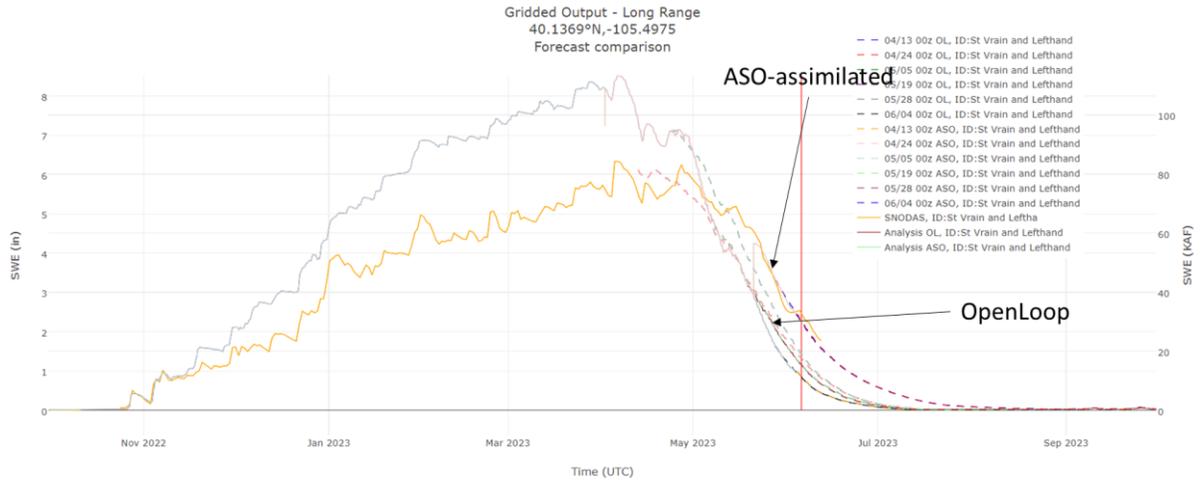
Poudre River basin-averaged SWE:



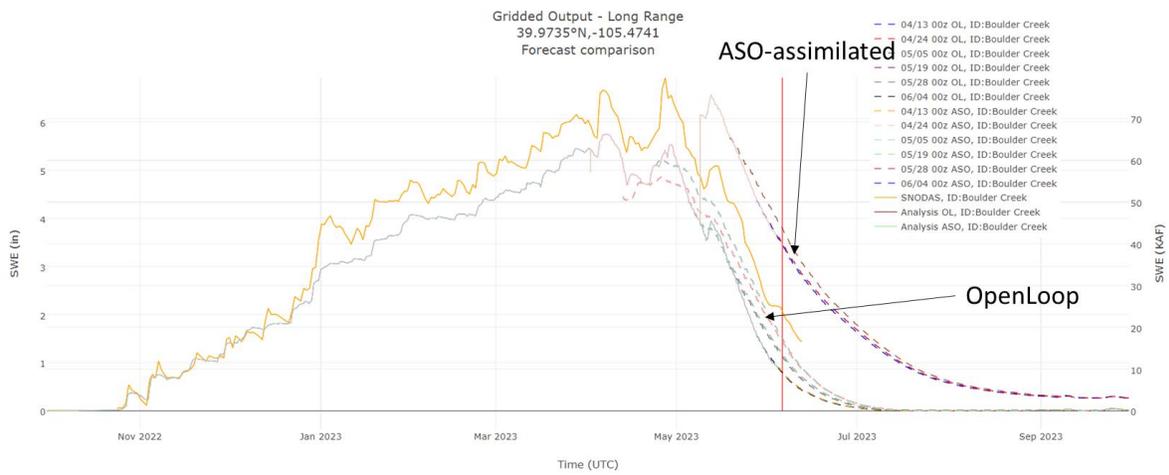
Big Thompson basin-averaged SWE:



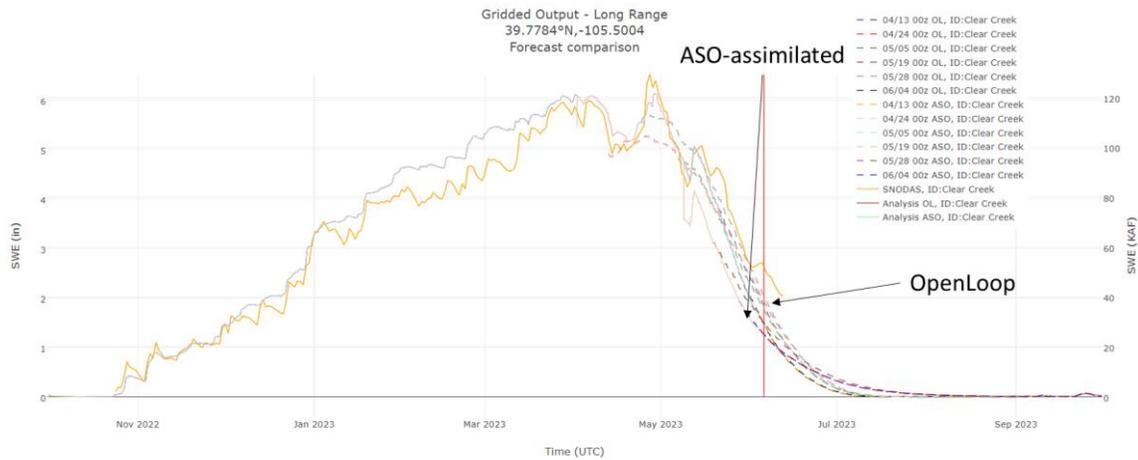
St. Vrain basin-averaged SWE:



Boulder Creek basin-averaged SWE:



Clear Creek basin-averaged SWE:



Poudre River Sub-basin forecast flow, (initialized on 6/4/2023):

Cache La Poudre nr Fort Collins (CDWR CLAFTCCO): 161.1 kac-ft (New forecast site, considerable anthropogenics upstream considerable anthropogenics upstream...using naturalized flow from Northern of 132 kac-ft WCD yields total of 216 kac-ft)

Big Thompson/Little Thompson River Sub-basin forecast flow, (initialized on 6/4/2023):

Big Thompson abv Lake Estes (CDWR BTABESCO): 65.9 kac-ft (New forecast site)

N. Fork Big Thompson at Drake (CDWR BTNDFRCO): 14 kac-ft (New forecast site)

Little Thompson River nr Berthoud (CDWR LTCANYCO): 7.5 kac-ft (New forecast site...upstream diversions not yet accounted for)

St. Vrain River Sub-basin forecast flow, (initialized on 6/4/2023):

Button Rock Reservoir Inflow...no inflow data yet available...

South St Vrain near Ward, CO...(CDWR SSVWARCO): 11.9 kac-ft (New forecast site...needs adjustment...no observation data available prior to May 15)

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

Middle Fork St. Vrain at Peaceful Valley (CDWR MIDSTECO): 17.3 kac-ft (New forecast site)

St. Vrain at Lyons (CDWR SVCLYCO): 69.1 kac-ft (New forecast site...considerable anthropogenics upstream...using naturalized flow from Northern WCD of 38 kac-ft yields total of 87 kac-ft)

Boulder Creek Sub-basin forecast flow, (initialized on 6/4/2023):

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

Boulder Cr. at Orodell (CDWR BOCOROCO): 42.6 kac-ft (New forecast site, considerable anthropogenics upstream...using naturalized flow from Northern WCD 13 yields total of 53 kac-ft)

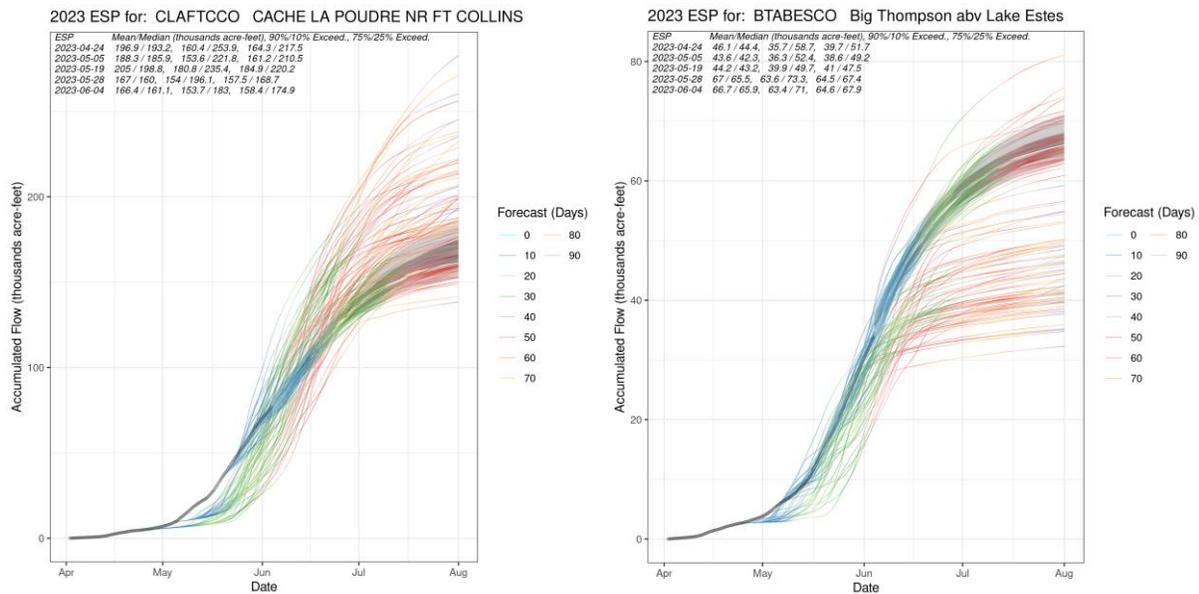
Clear Creek Sub-basin forecast flow, (initialized on 6/4/2023):

Clear Creek abv Georgetown (CDWR CLEGLKCO): 24.7 kac-ft (New forecast site)

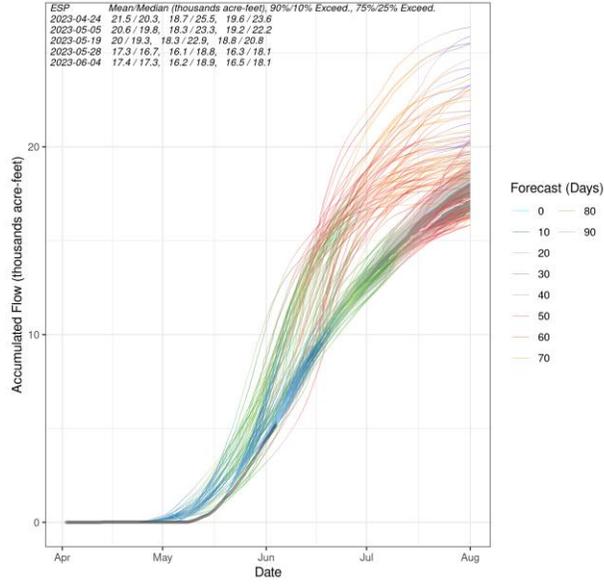
Clear Creek at Lawson (CDWR CLELAWCO): 59.6 kac-ft (New forecast site, some anthropogenics upstream, no naturalized observed flow data yet available)

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

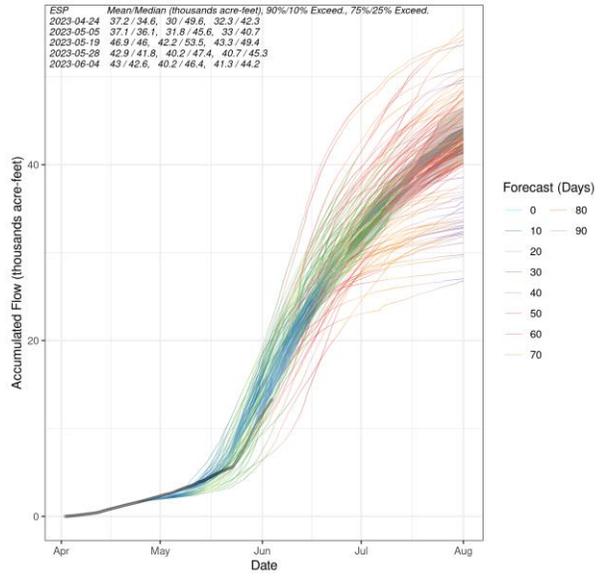
Example ensemble flow accumulation plot for Apr-Jul inflow:



2023 ESP for: MIDSTECO MIDDLE St. VRAIN AT PEACEFUL VALLEY



2023 ESP for: BOCOROCO BOULDER CREEK NEAR ORODELL



2023 ESP for: CLEGLKCO Clear Creek abv Georgetown

