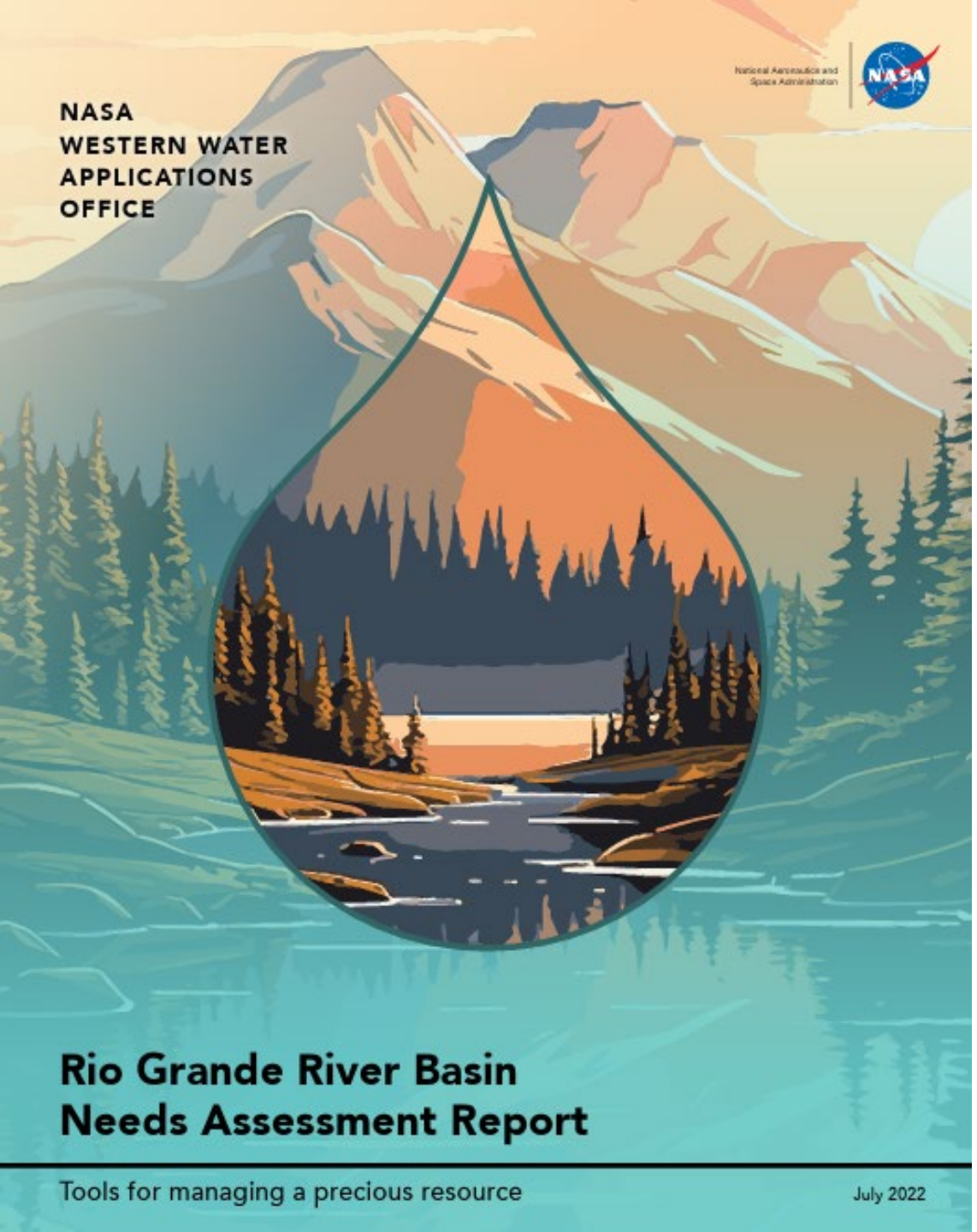
SWE Evaluation Tool (SWEET):

Ensemble-Based Spatial Snow Water Equivalent Estimates for the Rio Grande Basin

New Mexico Office of the State Engineer, Hydrology Bureau

Institute of Arctic and Alpine Research (INSTAAR), University of Colorado Boulder

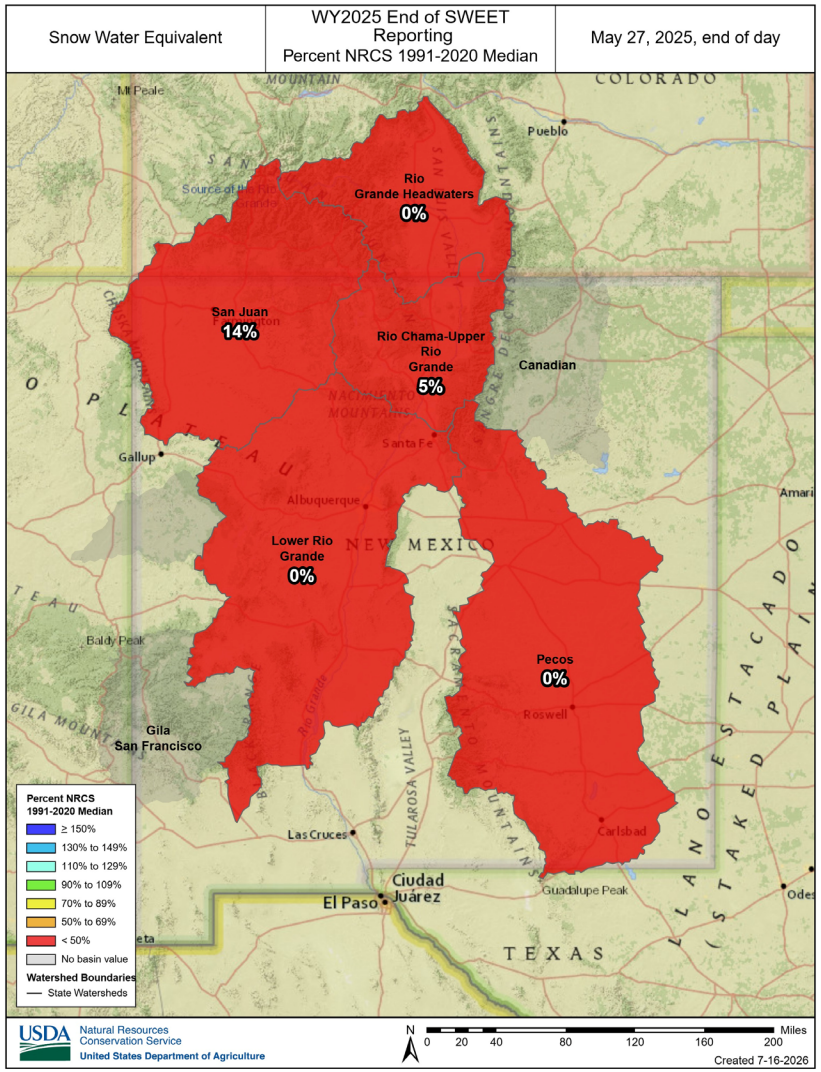
August 27, 2026

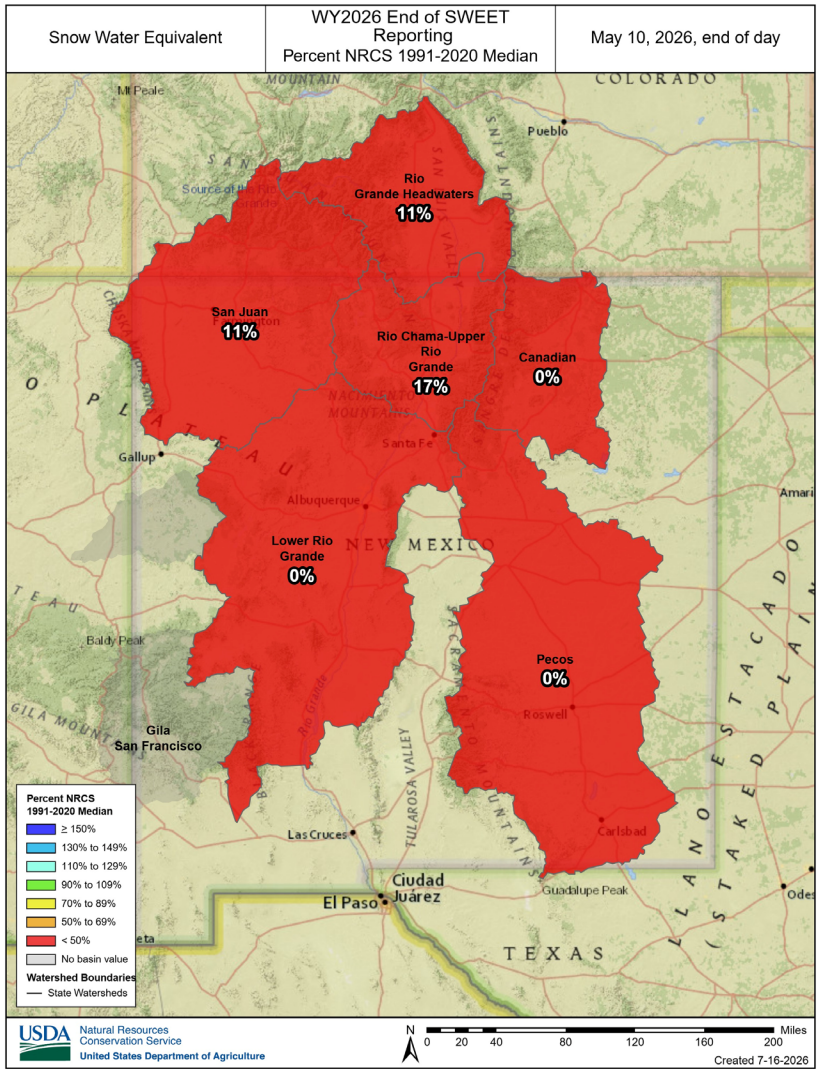


Applying NASA Remote Sensing Capabilities to Improve Water Resources Management in the Rio Grande Basin Through a Better Understanding of Supply and Demand

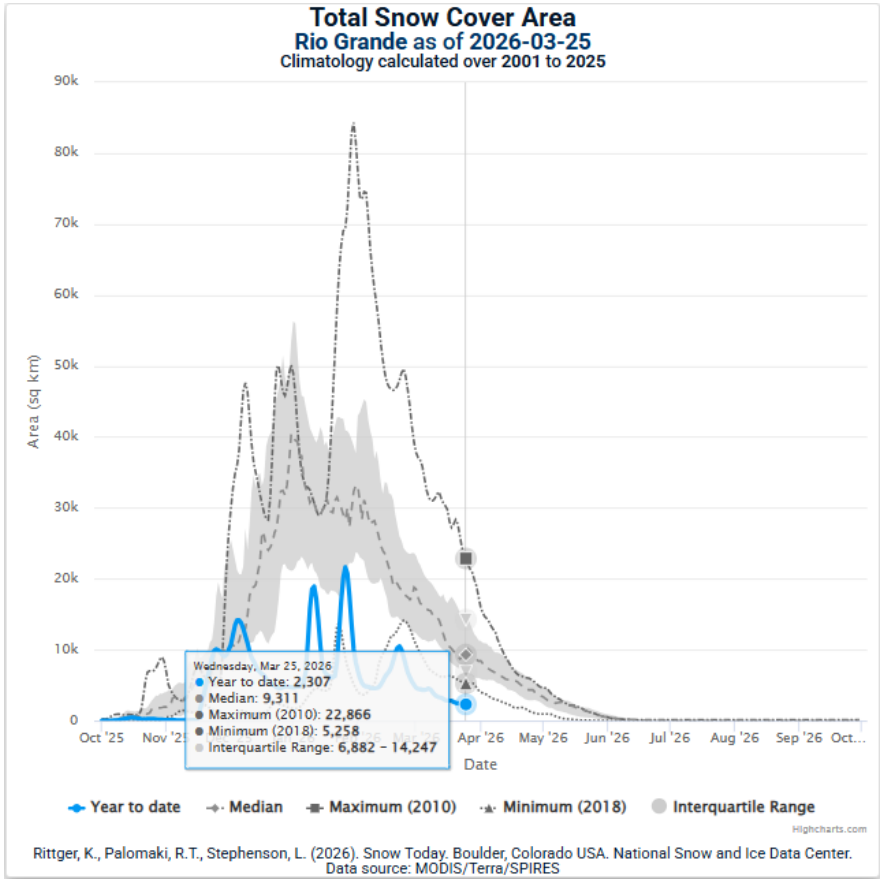
- Rio Grande Needs Assessment – July 2022
- 2-year project timeline
- WY2025 – WY2026
- Ended July 2026

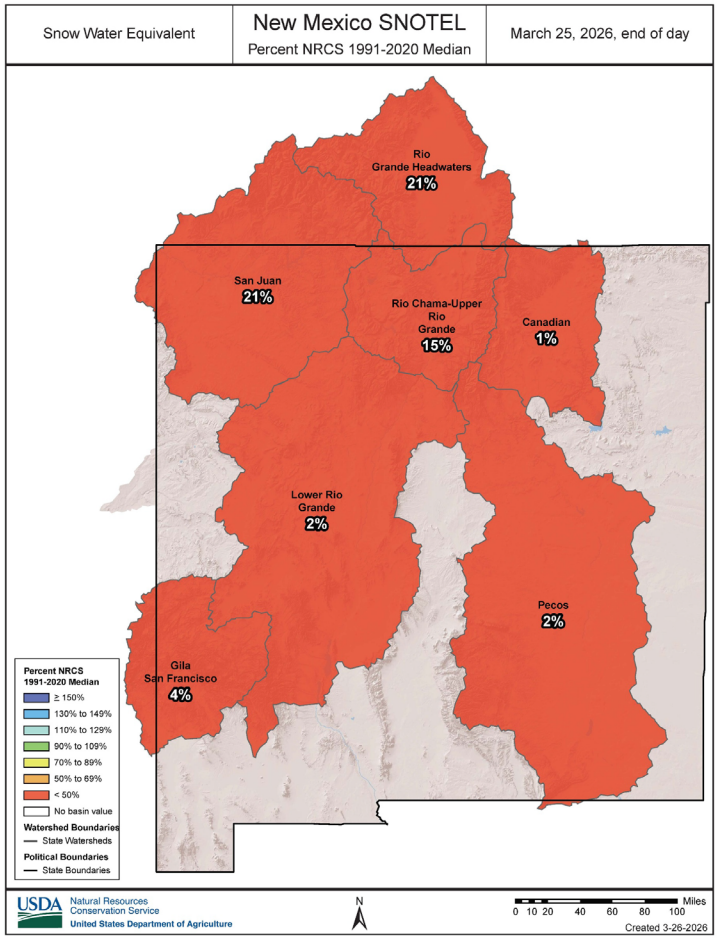
WY2025 v. WY2026

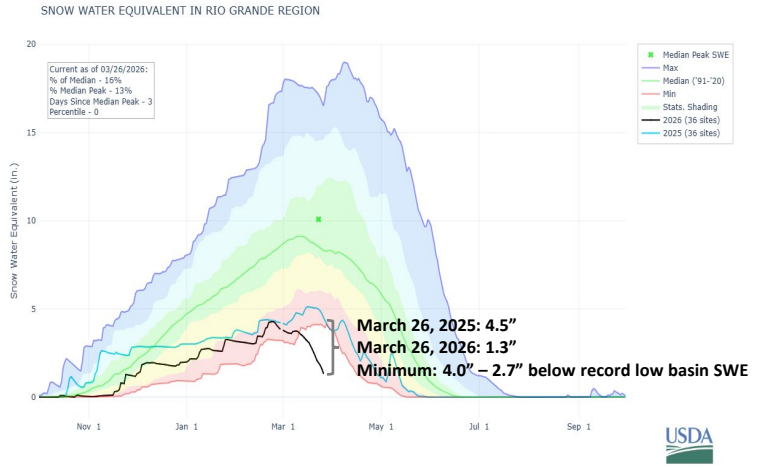


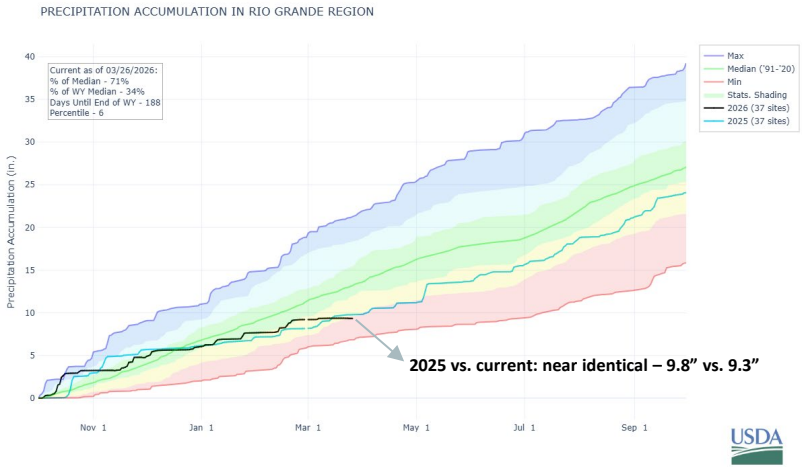


March 2026 Snowpack Conditions

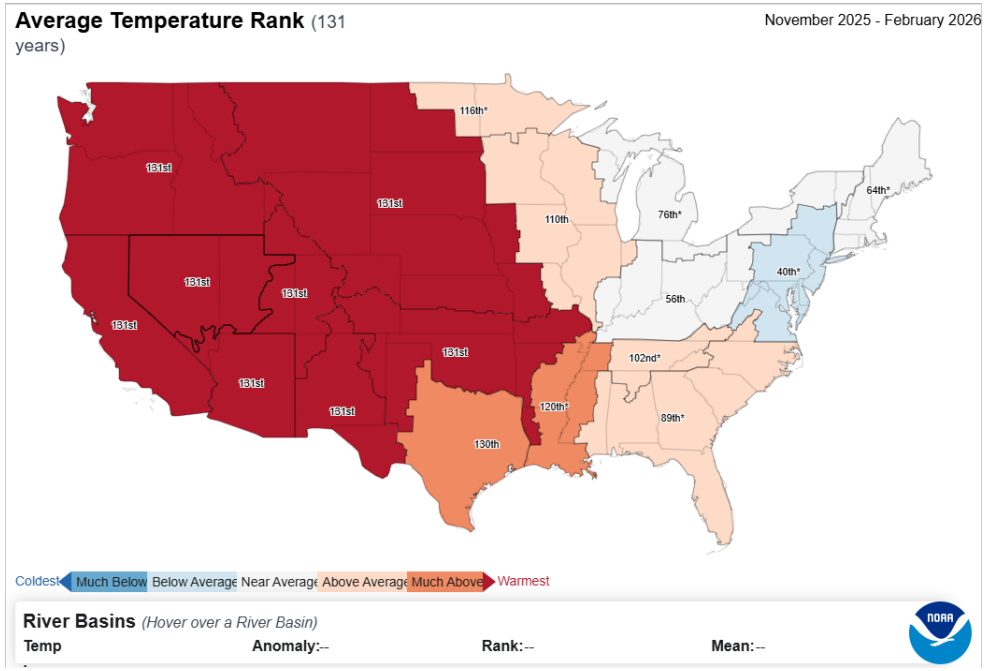


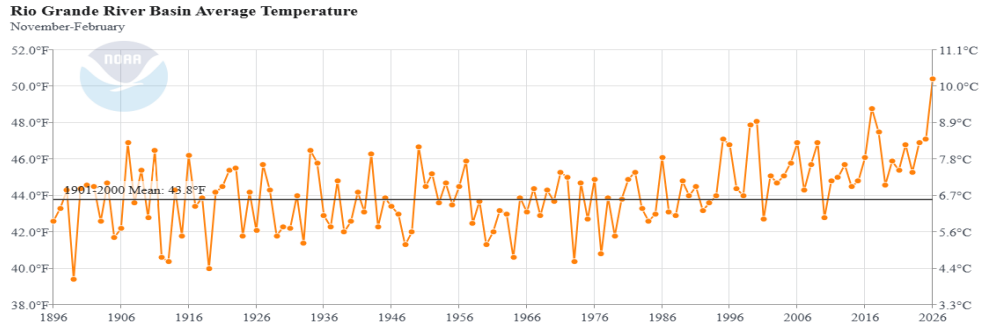






Winter 2026 Temperature Conditions



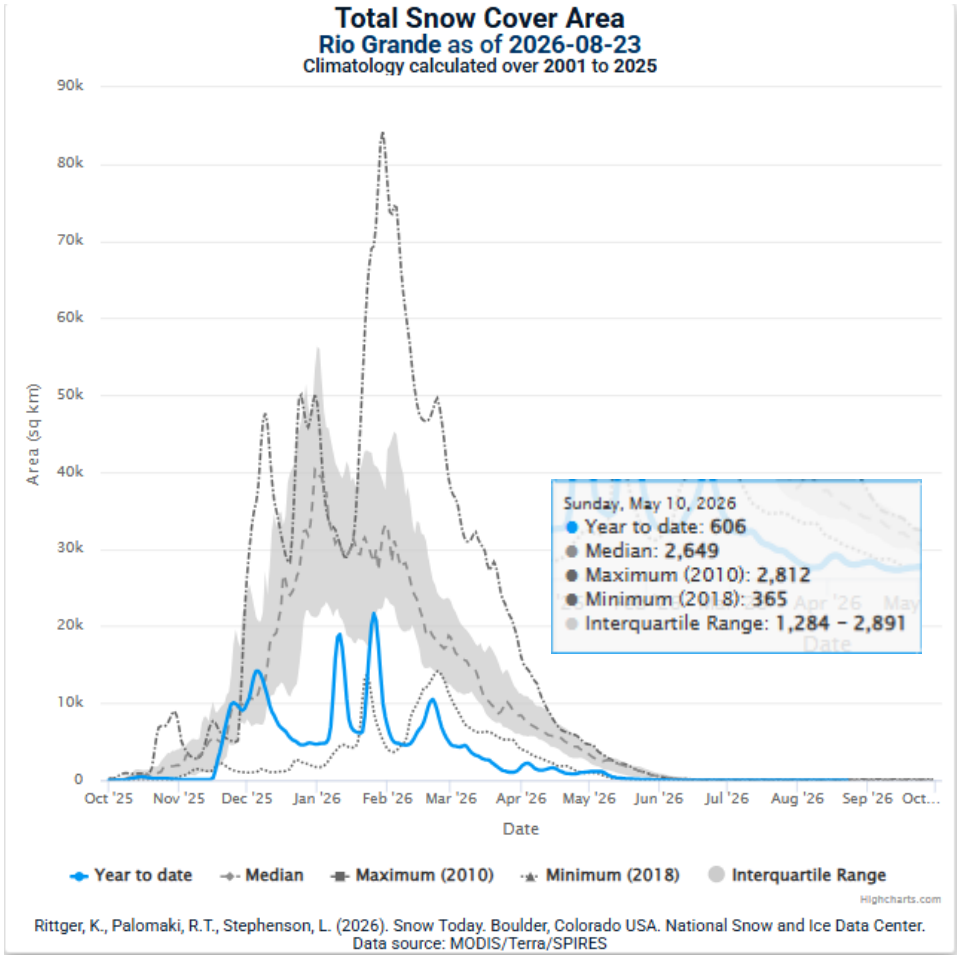


Rio Grande River Basin Average Temperature

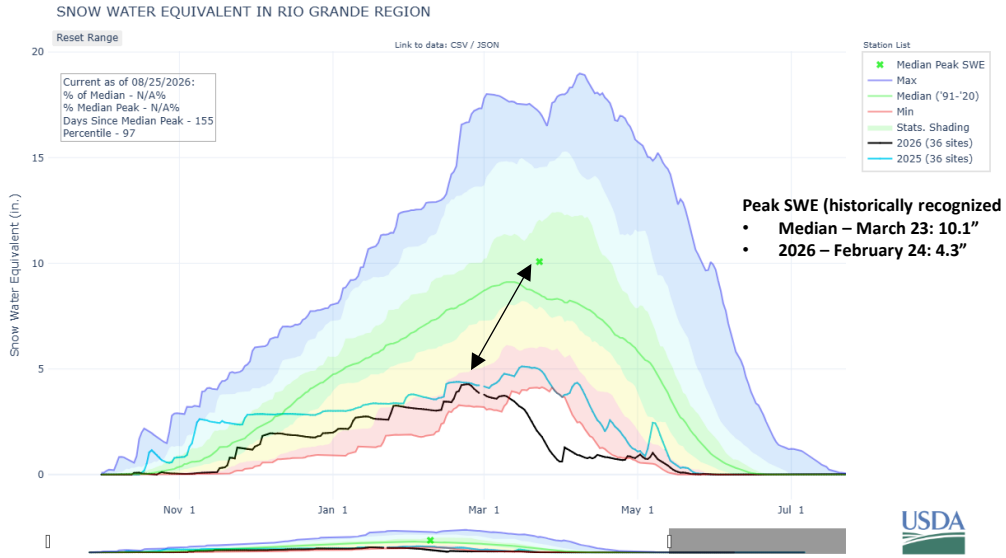
November-February

Period	Average Temperature	Rank (out of 131)	Anomaly 1901-2000 Mean: 43.8°F
November 2025-February 2026	50.4°F	131	6.6°F
November 2024-February 2025	47.1°F	126*	3.3°F
November 2023-February 2024	46.9°F	124*	3.1°F
November 2022-February 2023	45.3°F	100*	1.5°F
November 2021-February 2022	46.8°F	120*	3.0°F
November 2020-February 2021	45.4°F	103*	1.6°F
November 2019-February 2020	45.9°F	111*	2.1°F
November 2018-February 2019	44.6°F	82*	0.8°F
November 2017-February 2018	47.5°F	127	3.7°F
November 2016-February 2017	48.8°F	130	5.0°F
November 2015-February 2016	46.1°F	113*	2.3°F

WY2026 Snowpack Conditions

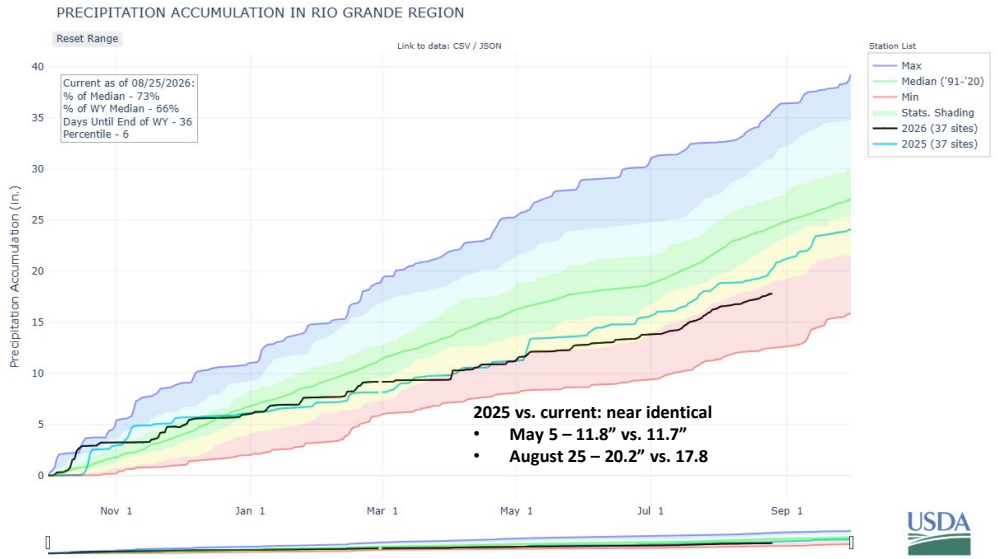


Rittger, K., Palomaki, R.T., Stephenson, L. (2026). Snow Today. Boulder, Colorado USA. National Snow and Ice Data Center. Data source: MODIS/Terra/SPIRES



Peak SWE (historically recognized on April 1)

- **Median – March 23: 10.1”**
- **2026 – February 24: 4.3”**



2025 vs. current: near identical

- **May 5 – 11.8” vs. 11.7”**
- **August 25 – 20.2” vs. 17.8**

OSE's Role as a Regulatory Agency

What OSE Does

- Administers and protects New Mexico's water resources and water rights.
- Regulates surface water and groundwater use across the state.
- Ensures compliance with interstate compacts, including the Rio Grande Compact.
- Cooperates with pueblos, tribes, and nations on shared water resource matters.

What OSE Doesn't Do

- Doesn't create streamflow or water supply forecasts – that's NRCS and NWS/WGRFC.
- Doesn't manage or operate reservoirs – that falls to Reclamation and other operators.
- Doesn't operate the SNOTEL monitoring network or USGS stream gages – OSE consumes that data, not collect it.
- Doesn't set Compact deliveries alone – allocations are negotiated through the ISC.
- Doesn't deliver water to individual users – that's irrigation districts, acequias, and conservancy districts.
- Historically, hasn't produced independent snowpack estimates – relying on whatever single outside model was available.

SWE estimates are a critical resource OSE's regulatory role has always depended on, and no ensemble-based spatial SWE product existed for the Rio Grande basin until SWEET – closing that gap without taking on the forecasting, reservoir operations, or delivery roles that belong to other agencies

Project Overview

- Project Team
  - Max Gersh (OSE), Logan Stephenson, Ross Palomaki, and Karl Rittger (INSTAAR)
- Our mission is to enhance real-time spatial estimates of SWE across the Rio Grande Basin by developing the **SWE Evaluation Tool (SWEET)**, leveraging existing NASA data products to improve the understanding of **SWE volume, distribution, and melt timing**.
- Build an operational tool that automates, analyzes, and produces an ensemble estimation of spatial SWE across the Rio Grande Basin
- Three Products:
  1. CU-SWE – 500m, weekly – Noah Molotch, INSTAAR
  2. UA (SWANN) SWE – 800m (downscaled 4km), daily – Patrick Broxton, UA
  3. SNODAS SWE – 1km, daily – NOAA NOHRSC

SWEET Reports

Spatial Estimates of SWE for the Rio Grande Basin

May 27, 2025

Max Gersh[1], Logan Stephenson[2], Ross Palomaki[2], and Karl Rittger[2]
[1] New Mexico Office of the State Engineer (NM OSE) Hydrology Bureau
[2] Institute of Arctic and Alpine Research (INSTAAR), University of Colorado Boulder
Work funded by: NASA Western Water Applications Office (WWAO)
Contact: Max.Gersh@ose.nm.gov

Overview Map – Rio Grande Basin Study Area

Figure 1. Overview map of the Rio Grande (RG) Basin study area. *The Rio Grande Headwaters, Upper Rio Grande, and Rio Grande-Elephant Butte Basins are presented as the standard HUC6 basins. HUC8 groupings (Jemez – orange, Rio Chama – green, Sangre de Cristo – yellow, and Upper Rio Grande – brown) are symbolized.*

WY2025 (left)

- 9 SWE weekly reports
- April 1 – May 27, 2025
- Only using SNODAS

WY2026 (right)

- 15 SWE weekly reports
  - Feb 1 – May 10, 2026
    - 3 SWE products

Ensemble-Based Spatial Snow Water Equivalent Estimates Using the SWE Evaluation Tool for the Rio Grande Basin

May 10, 2026

Project Team:
Max Gersh[1], Logan Stephenson[2], Ross Palomaki[2], and Karl Rittger[2]
Contributor:
Noah Molotch[2]
[1] New Mexico Office of the State Engineer (NM OSE) Hydrology Bureau
[2] Institute of Arctic and Alpine Research (INSTAAR), University of Colorado Boulder
Work funded by: NASA Western Water Actions Office (WWAO)
Contact: Max.Gersh@ose.nm.gov

Introduction

No spaceborne sensor can directly measure snow water equivalent (SWE). Therefore, the spatial distribution of SWE must be estimated from remotely sensed observations combined with modeling approaches. Existing gridded SWE products exhibit documented accuracy limitations across both mountainous and non-mountainous regions, resulting in a wide range of SWE estimates for any given location. To address this uncertainty, the New Mexico Office of the State Engineer (NM OSE), in collaboration with the Institute of Arctic and Alpine Research (INSTAAR), developed the SWE Evaluation Tool (SWEET). SWEET integrates multiple suitable SWE data products into an ensemble framework, with the objective of producing near-real-time spatial SWE estimates for the Rio Grande Basin that are, on average, as accurate as or more accurate than any individual product alone.

Figure 1 shows the near-real-time (May 10, 2026) ensemble SWE estimates for the Rio Grande Basin. Subsequent sections of this report present detailed ensemble-based SWE maps, along with summaries by subbasin and elevation band. In addition to the ensemble results highlighted in this report, figures and tables for each individual SWE product are also provided for download to support transparency and further analysis. These data sets and visualizations are available on the GitHub repository.

For ease of navigation, hyperlinks are provided throughout this report to help readers quickly access basin-specific sections and supporting data tables.

HUC6 Ensembles

Rio Grande Headwaters

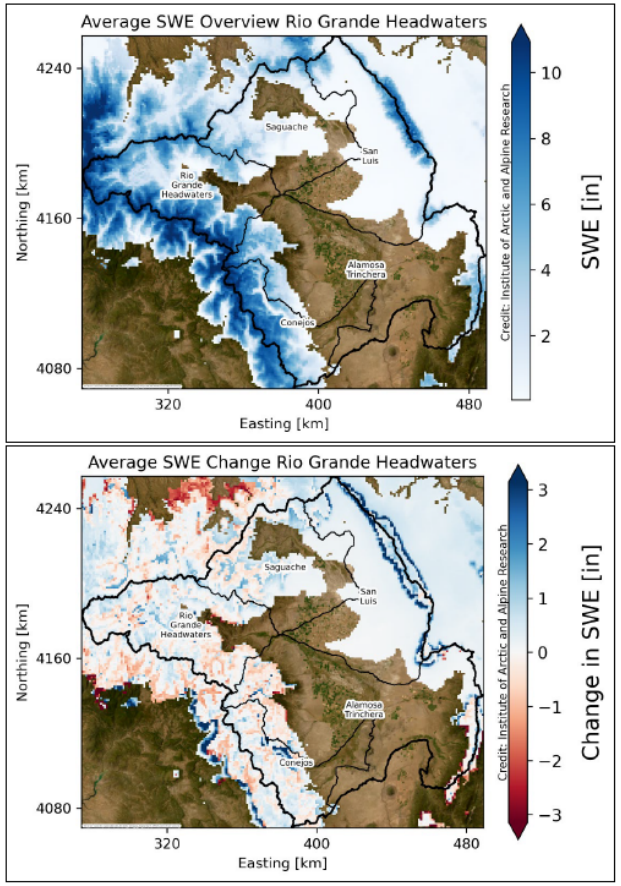


Figure 2. Estimated ensemble SWE (in.) and change in estimated ensemble SWE (in.) across the Rio Grande Headwaters HUC6 Basin for March 08, 2026, derived from the SWE Evaluation Tool (SWEET). Ensemble SWE amount across the Rio Grande Headwaters Basin, showing spatial patterns of SWE across subbasins including Rio Grande Headwaters, Alamosa-Trinchera, San Luis, Saguache, and Conejos (top); dark blue pixels denote greater SWE amounts. Change in SWE amounts (in.) across the Rio Grande Headwaters from March 01, 2026, to March 08, 2026 (bottom); blue pixels denote an increase in SWE amounts whereas red pixels denote a decrease in SWE amounts. Basin and subbasin boundaries are shown in black.

Upper Rio Grande

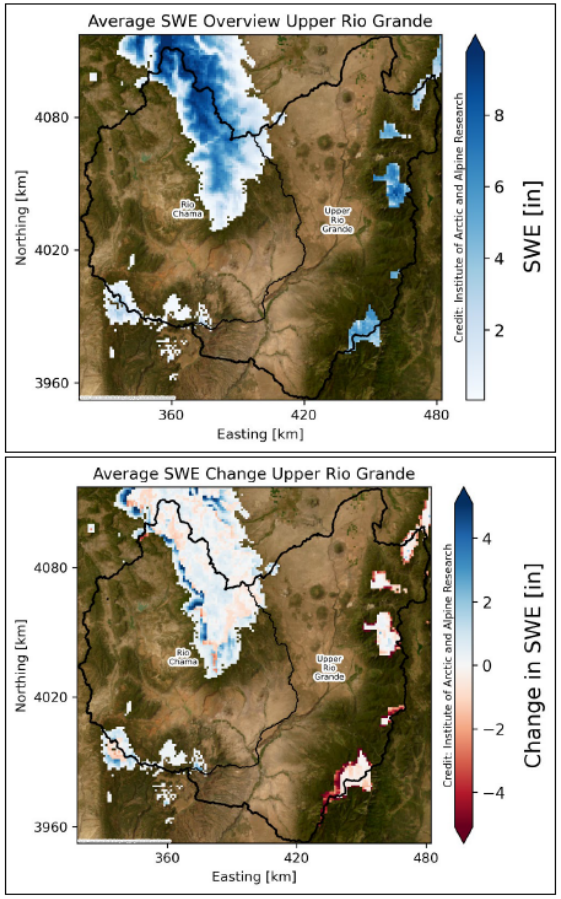


Figure 4. Estimated ensemble SWE (in.) and change in estimated ensemble SWE (in.) across the Upper Rio Grande HUC6 Basin for March 08, 2026, derived from the SWE Evaluation Tool (SWEET). Ensemble SWE amount across the Upper Rio Grande Basin, showing spatial patterns of SWE across subbasins including Rio Chama and Upper Rio Grande (top); dark blue pixels denote greater SWE amounts. Change in SWE amounts (in.) across the Upper Rio Grande Basin from March 01, 2026, to March 08, 2026 (bottom); blue pixels denote an increase in SWE amounts whereas red pixels denote a decrease in SWE amounts. Basin and subbasin boundaries are shown in black.

Rio Grande-Elephant Butte (Middle Rio Grande)

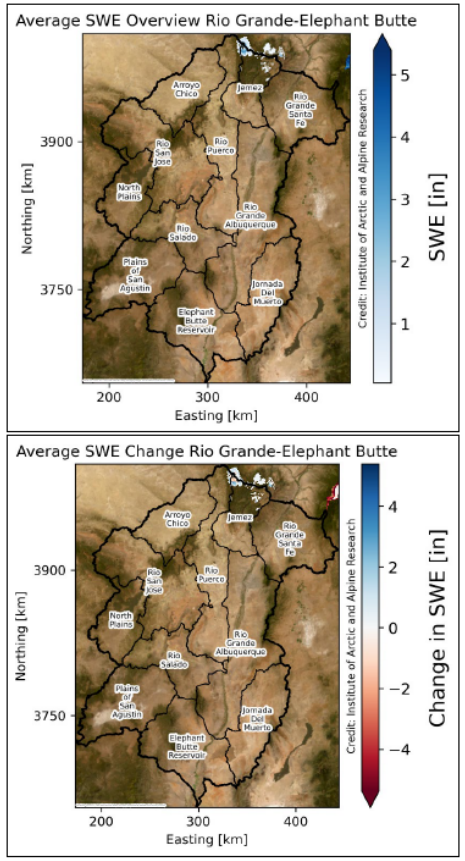


Figure 6. Estimated ensemble SWE (in.) and change in estimated ensemble SWE (in.) across the Rio Grande-Elephant Butte HUC6 Basin for March 08, 2026, derived from the SWE Evaluation Tool (SWEET). Ensemble SWE amount across the Rio Grande-Elephant Butte Basin, showing spatial patterns of SWE across subbasins including Rio Grande-Santa Fe, Jemez, Arroyo Chico, Rio San Jose, Rio Puerco, Rio Grande-Albuquerque, Rio Salado, North Plains, Plains of San Agustin, Elephant Butte Reservoir, and Jornada Del Muerto (top); dark blue pixels denote greater SWE amounts. Change in SWE amounts (in.) across the Rio Grande-Elephant Butte Basin from March 01, 2026, to March 08, 2026 (bottom); blue pixels denote an increase in SWE amounts whereas red pixels denote a decrease in SWE amounts. Basin and subbasin boundaries are shown in black.

Elevation Band Maps

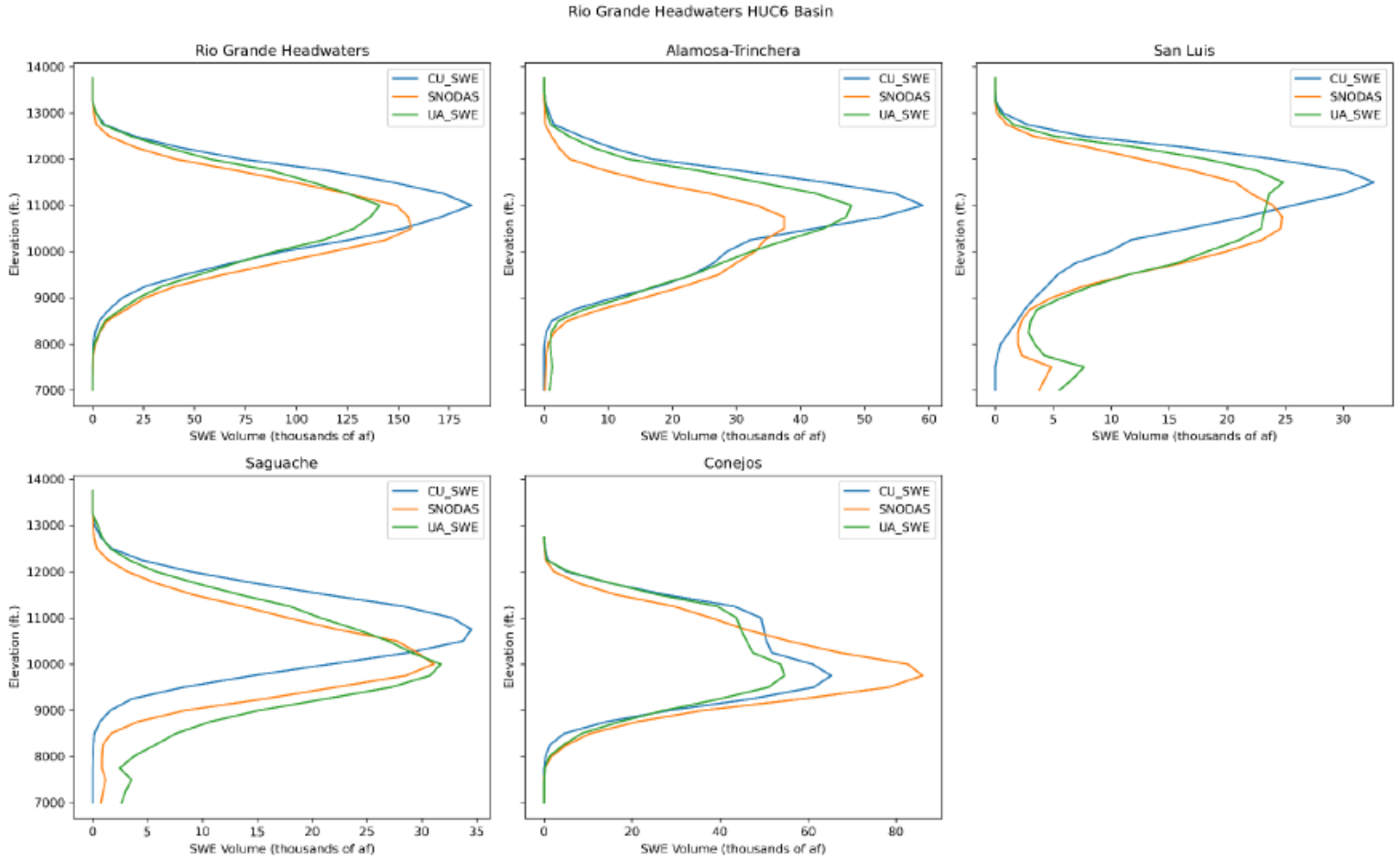


Figure 3. Estimated SWE volume (thousands of af) by subbasin and elevation band across the Rio Grande Headwaters HUC6 Basin for March 08, 2026. Elevation-distributed SWE volume for the Rio Grande Headwaters HUC6 Basin and associated subbasins (Rio Grande Headwaters, Alamosa–Trinchera, San Luis, Saguache, and Conejos), comparing three spatial SWE products (CU_SWE, SNODAS, and UA_SWE). Curves show SWE volume summarized by elevation band, illustrating differences in both magnitude and vertical distribution among products across each subbasin.

Elevation Band Maps

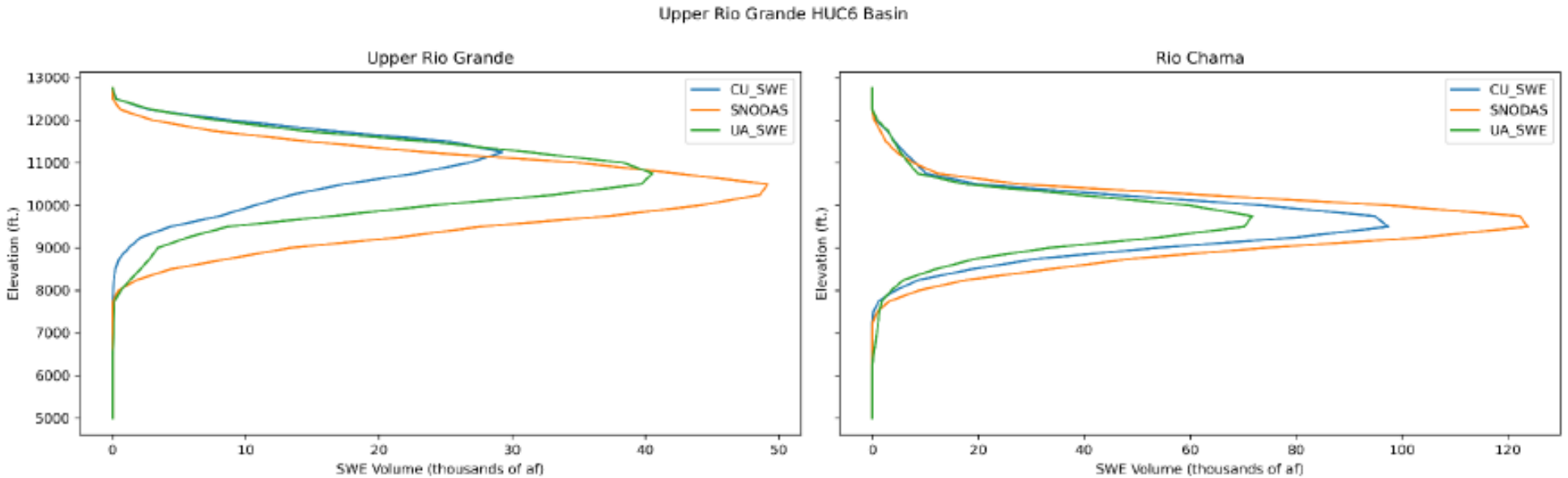
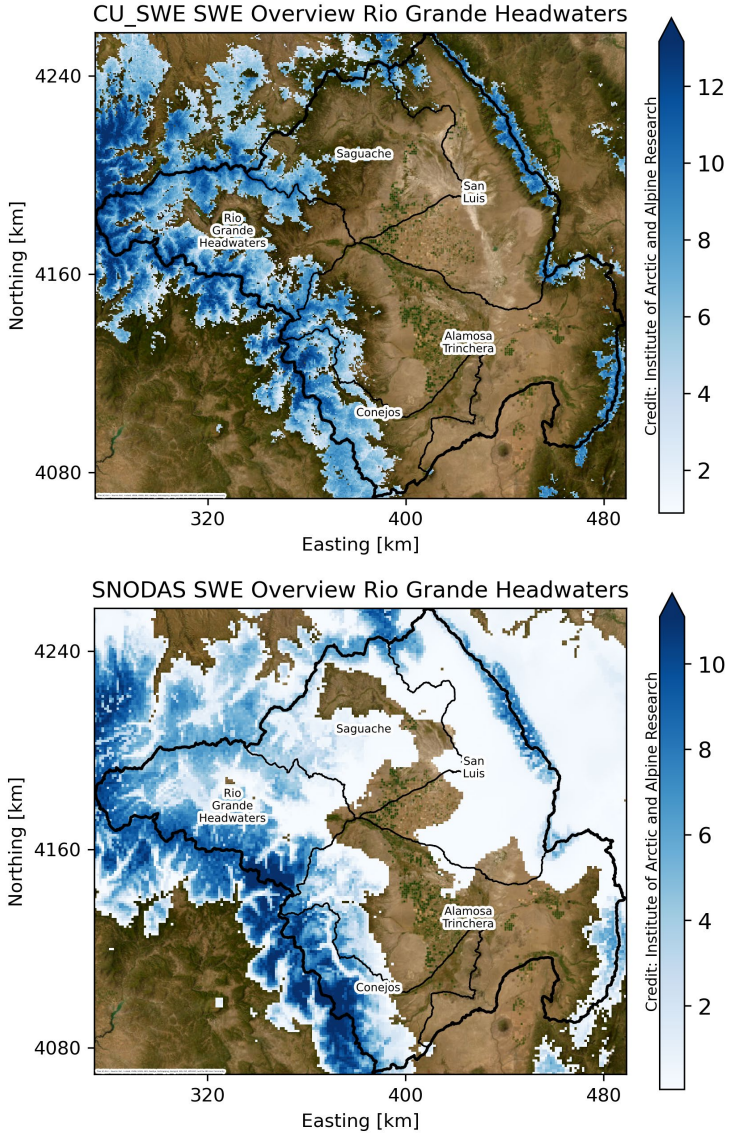
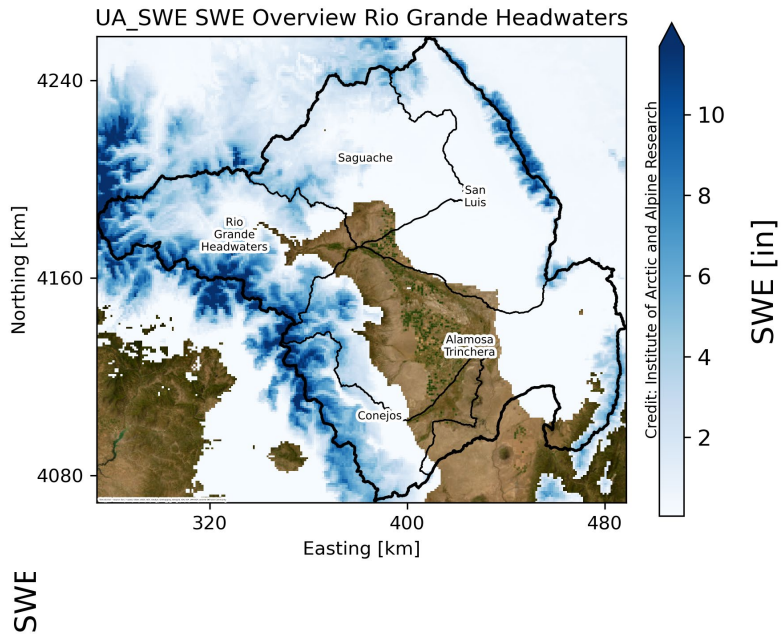


Figure 5. Estimated SWE volume (thousands of af) by subbasin and elevation band across the Upper Rio Grande HUC6 Basin for March 08, 2026. Elevation-distributed SWE volume for the Upper Rio Grande HUC6 Basin and associated subbasins (Rio Chama and Upper Rio Grande), comparing three spatial SWE products (CU_SWE, SNODAS, and UA_SWE). Curves show SWE volume summarized by elevation band, illustrating differences in both magnitude and vertical distribution among products across each subbasin.

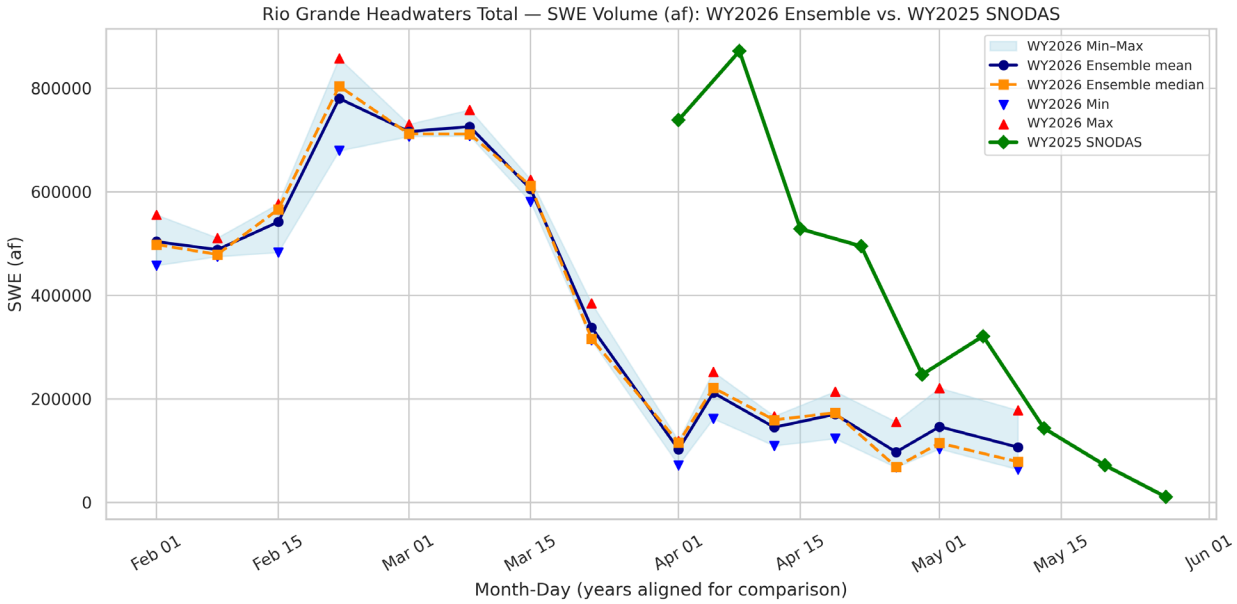
SWE Model Discrepancy

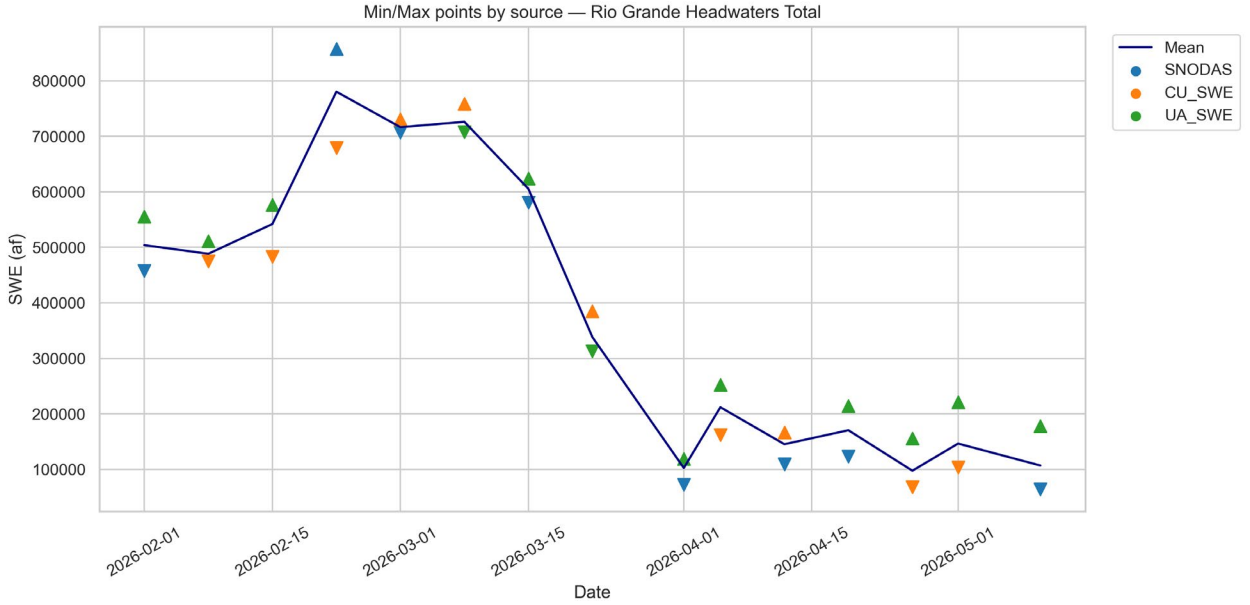
- **Lower elevation SWE coverage**
  - CU SWE: discontinuous, speckled snow cover
  - SNODAS/UA SWE: more continuous – may overestimate low-elevation snow
- **Mid-elevation disagreement**
  - Largest discrepancies where forest cover and terrain complicate snow distribution
  - SNODAS/UA SWE smooth these variations more than CU SWE
- **Terrain and physiographic sensitivity**
  - CU SWE reasonably captures localized variability (terrain, aspect, vegetation) – shows pockets of low/absent SWE that SNODAS and UA SWE miss
- **High-elevation agreement**
  - All three products agree most above the tree line
  - Continuous snow cover is easier to model or observe at high elevations

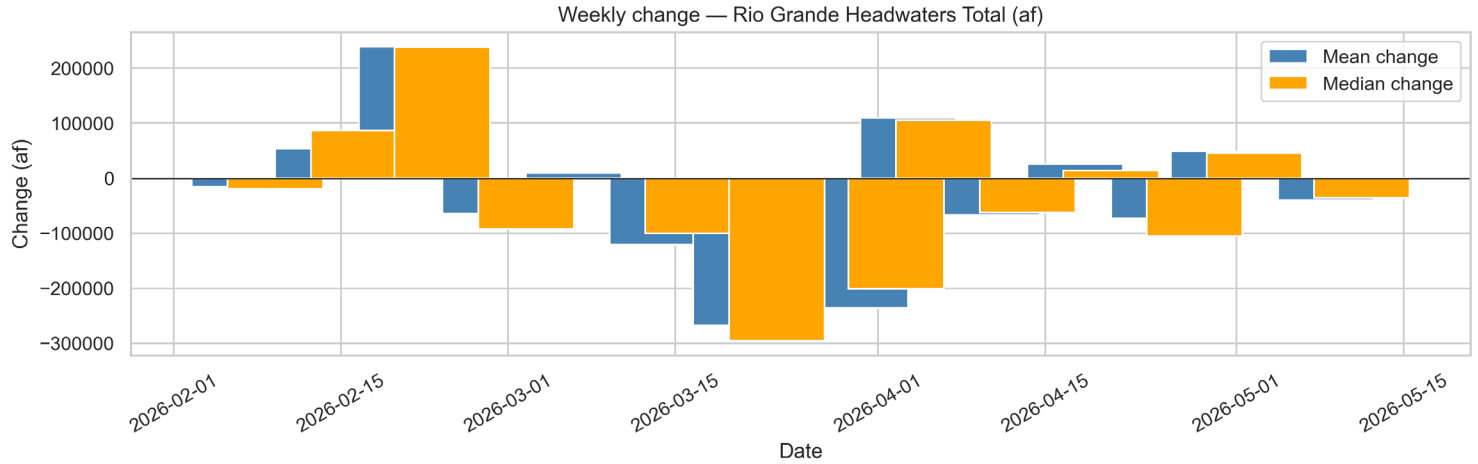




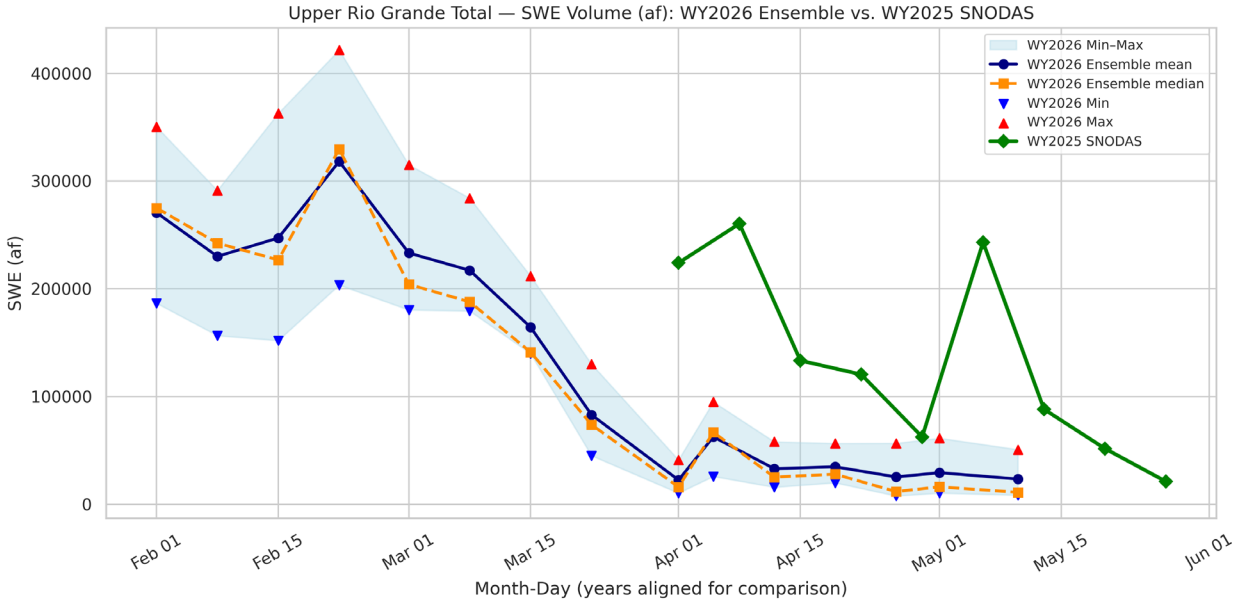
WY Summary – RG Headwaters

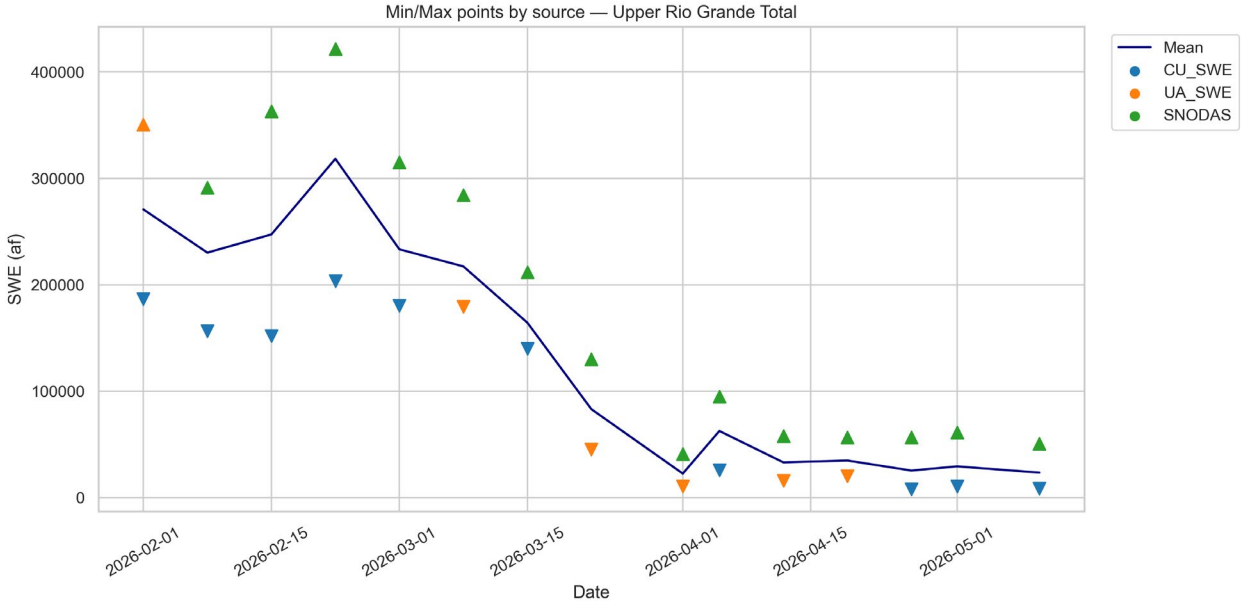


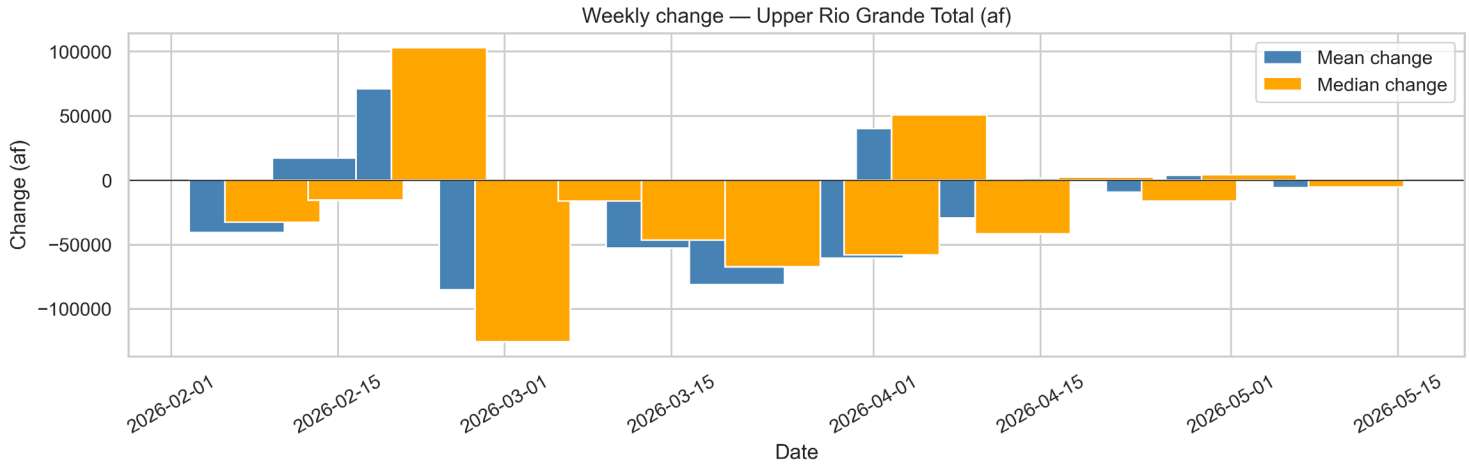




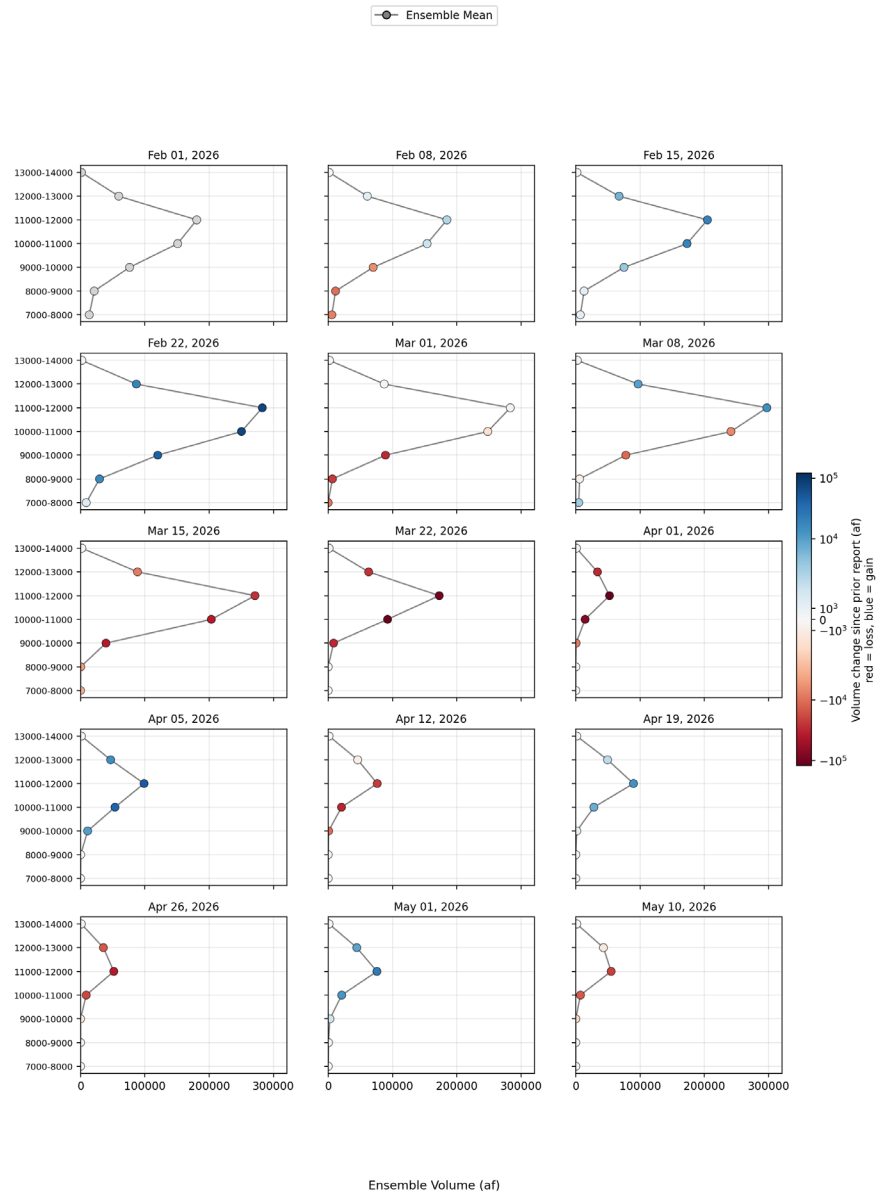
WY Summary – Upper RG

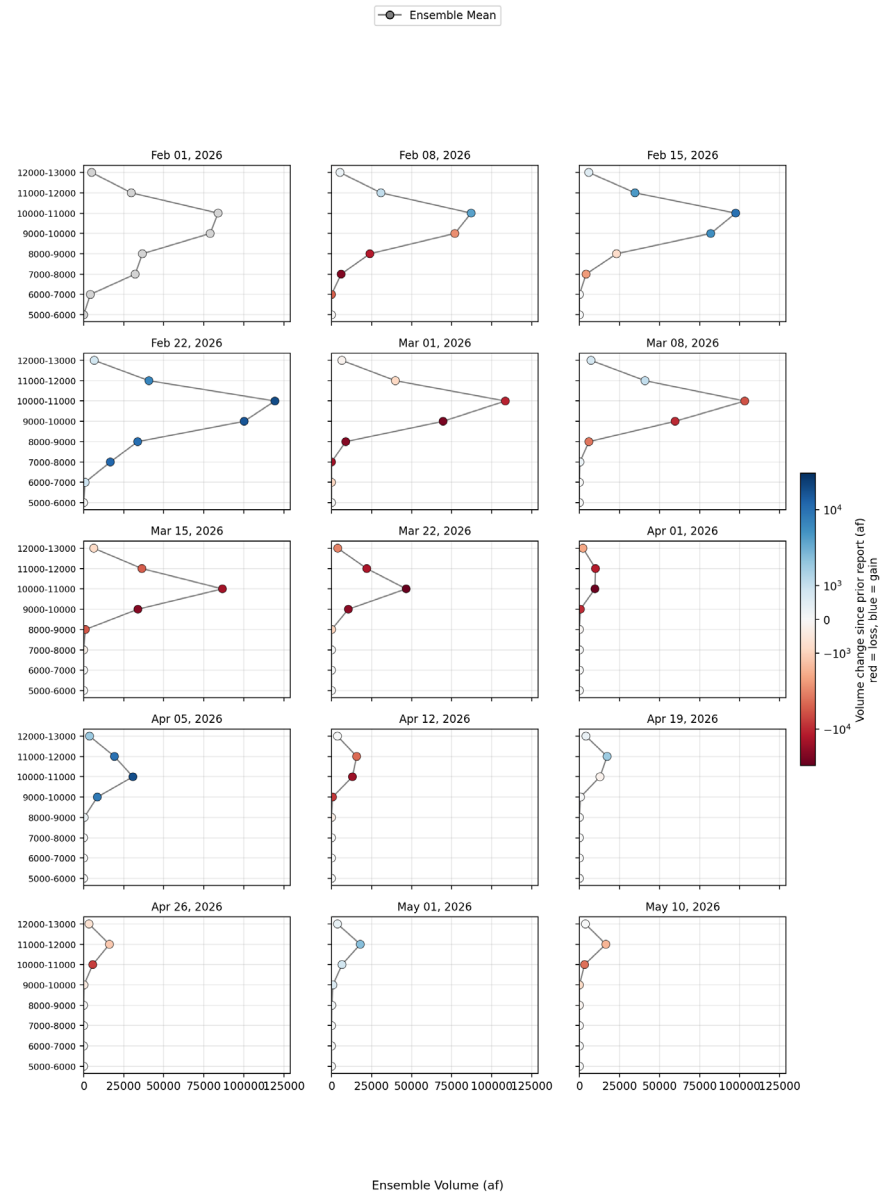






WY Summary – Elevation Bands





WY2026 Summary

Rio Grande Headwaters

- No significant outlier product across the whole HUC6.
- UA_SWE tends to run high (10/15 weeks), especially in San Luis
- SNODAS/CU_SWE split the low end.
- Spread as % of mean stays modest during peak snowpack (2–10% in Feb–Mar) and only widens late-season (up to ~60–66% by May).

Upper Rio Grande

- Clear, consistent SNODAS high bias (14/15 weeks)
- CU_SWE was consistent low (10/15 weeks; 14/15 weeks for URG subbasin)
- SNODAS ran **25–50% above the ensemble mean** during peak accumulation (Feb–Mar), and that widened to **100–150% above the mean** during the April–May melt-out tail.

Rio Grande-Elephant Butte (MRG)

- Most subbasins sit at lower elevation/more arid terrain – near-zero or zero SWE for most of the season.
- The only subbasins with measurable show no consistent single-model tendency either.

Benefits to OSE & Water Users

OSE / Rio Grande Compact Administration

- Ensemble-based, uncertainty-aware SWE estimates have the potential to give a more defensible basis for streamflow and delivery forecasting tied to Compact obligations.
- Weekly updates let forecasts be revised as conditions change, rather than waiting on a less frequent update cycle.

Irrigation Districts

- HUC8-level detail shows subbasin-specific conditions instead of a single basin-wide average (with potential to go even smaller).
- Supports earlier, more confident decisions on ditch opening dates and allocation planning, including early curtailment in low-snow years.

Municipalities & Reservoir Operators

- Ensemble mean/min/max range can be used to give a probabilistic view of expected spring runoff into storage, not one deterministic number.
- Potential for better basis for operations planning at reservoirs of all sizes.

All Users

- Fills spatial gaps between SNOTEL point sites and reduces the risk of any single model's bias driving a decision.
- A growing historical record supports year-over-year and drought-severity comparison for longer-range planning.

Case Study: March 2026

What happened

- **Lack of storm events/snow accumulation and unprecedented temperatures decimated the snowpack across the basin at all elevation bands**
- **Snowpack never really recovered for the remainder of the year**

Where the SWE models disagreed

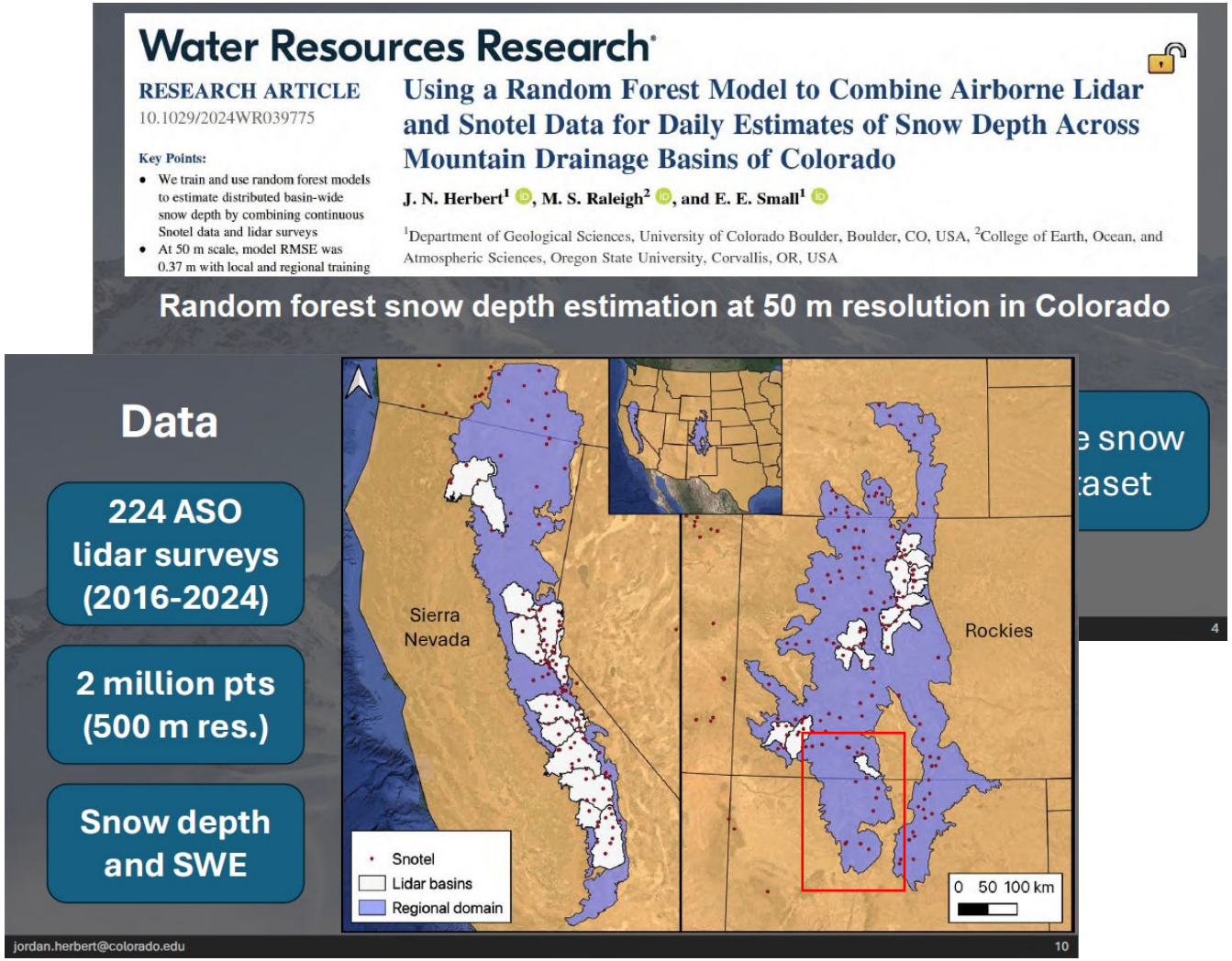
- **In the Upper Rio Grande** – the subbasin most tied to early-season runoff planning – SNODAS ran 25–50% above the ensemble mean during peak accumulation, widening to 100–150% above the mean during the April–May melt-out tail.
- **A manager relying on SNODAS alone** may have overstated available snowpack by up to 150% during exactly the weeks water managers evaluate runoff potential.

Why the ensemble mattered

- The ensemble mean and min/max range flagged this divergence in real time, rather than presenting a single, silently biased number.
- This is the actionable signal SWEET is built to surface: not any one product's estimate, but the spread and agreement across all three.

Future Work

- More comprehensive SWEET ensemble and individual SWE model validation.
- Addition of Airborne Snow Observatory data (RG Headwaters ‘25/’26, Conejos ‘22-’26).
- Add SWE products – more focus on ML models like Snotel Lidar ML (SnoLimits)
- Expand historical SWE data
- Expand scalability across state
- Improve spatial and temporal resolution scalability
- OSE/ISC webpage – reports to dashboards
  - Data Information Systems – CCSS SnowTrax



Closing Remarks & Contact Info

Thank you to the WWAO team

Thank you to our partners at INSTAAR

- **Karl Rittger, Ross Palomaki, and Logan Stephenson**

- More work to do – here's how to follow along or get in touch:
- Contact Max Gersh – max.gersh@ose.nm.gov
- Links for the project:
  - GitHub – SWE-Evaluation-Tool – repository used to generate weekly SWE reports
  - GitHub – SWE-Evaluation-Tool_REPORTS – archived reports, figures, and tables
- We will transfer everything to an OSE webpage for easy access to current and archived material
- https://drought.nm.gov/ - check out NM's new drought page