Spatial Estimates of Snow-Water Equivalent (SWE)

Intermountain West Region

February 1, 2023

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Summary of current conditions (as of 2/1/23)

As of February 1st, the modeled snow water equivalent (SWE) was in the range of 93% to 195% of the 2001-21 average across the Intermountain West (Figures 1 & 3). This is a time of year when percent of average values can be especially high in low-elevation areas as these values are quite sensitive to recent snowfall. Please note that the basin-wide percent of long-term average from the spatial SWE estimates is not directly comparable with the SNOTEL basin-wide percent of average. A better comparison might be made with the % average in the elevation bands (Table 2) that contain SNOTEL sites. Detailed SWE maps (in JPG format) and summaries of SWE (in Excel format) by individual basin and elevation band accompany the report and are publicly available on our website. An additional table (not shown in this text report) containing summaries of SWE for the Colorado Basin River Forecast Center's basin zones is also available.

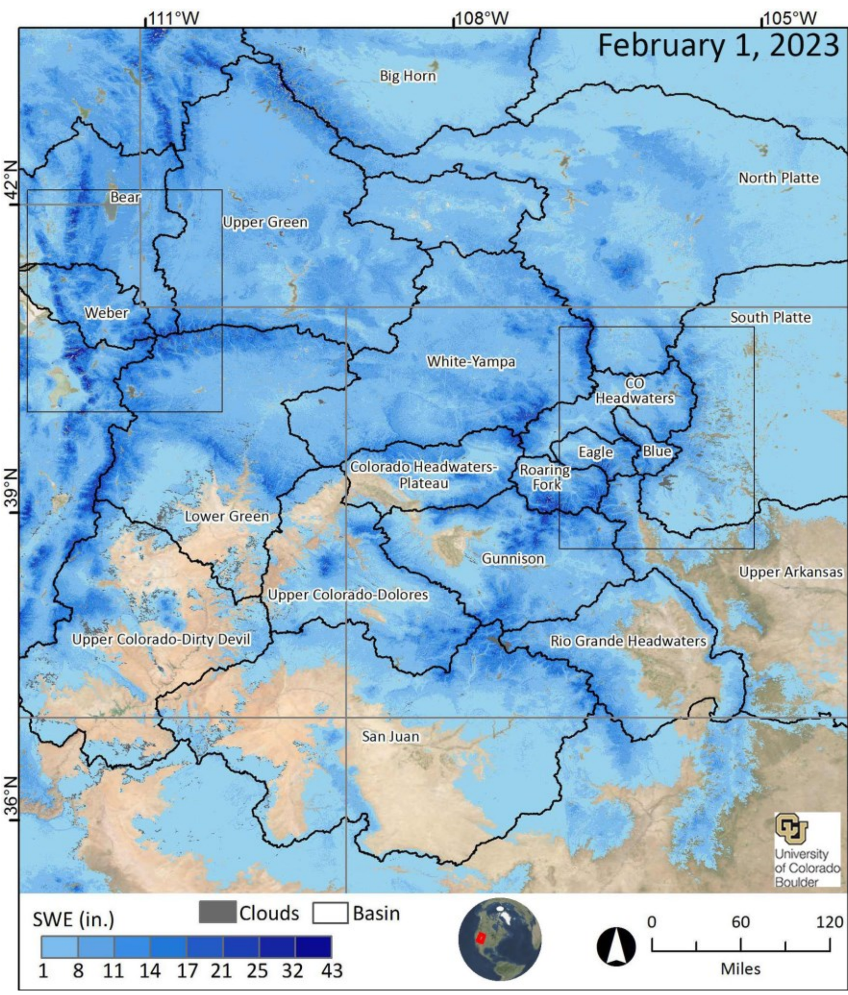

Figure 1. Estimated SWE amounts across the Intermountain West, February 1st.

Data Issues/Caveats for **February 1, 2023**

- DENSE FOREST COVER – Dense forest cover at lower elevations where snow-cover is discontinuous can cause the satellite to underestimate the snow-cover extent, leading to underestimation of SWE.
- CLOUD COVER – Cloud cover can obscure satellite measurements of snow-cover. While careful checks are made, occasionally the misclassification of clouds as snow or *vice versa* may result in the mischaracterization of SWE or bare-ground.
- PERCENT OF AVERAGE CALCULATIONS - Data utilized to generate this report change to optimize model performance. To maintain consistency across the historical record, the percent of average values are based on our baseline algorithm and therefore there can be discrepancies between absolute SWE values and corresponding percent of averages.
- RECENT SNOWFALL – There are occasionally problems with lower-elevation SWE estimates due to recent snowfall events that result in extensive snow-cover extending to valley locations where measurements are not available. This scenario results in an over-estimation of lower- elevation SWE.

About this report

This is an experimental research product that provides near-real-time estimates of snow-water equivalent (SWE) at a spatial resolution of 500 m for the Intermountain West region (Colorado, Utah, and Wyoming) from mid-winter through the melt season. The report is typically released within a week of the date of data acquisition at the top of the report. A similar report covering the Sierra Nevada has been distributed to water managers in California since 2013-14.

The spatial SWE analysis method for the Intermountain West uses the following data as inputs:

- In-situ SWE from all operational NRCS SNOTEL sites and the CoCoRaHS network
- MODSCAG fractional snow-covered area (fSCA) data from recent cloud-free MODIS satellite images
- Physiographic information (elevation, latitude, upwind mountain barriers, slope, etc.)
- Historical daily SWE patterns (1985-2021) retrospectively generated using historical MODSCAG data and an energy-balance model that back-calculates SWE given the fSCA time-series and meltout date for each pixel
- Satellite-observed daily mean fractional snow-covered area (DMFSCA)

For more details on the estimation method see the *Methods* section below. Please be sure to read the *Data Issues / Caveats* section for a discussion of persistent challenges or flagged uncertainties of the SWE product.

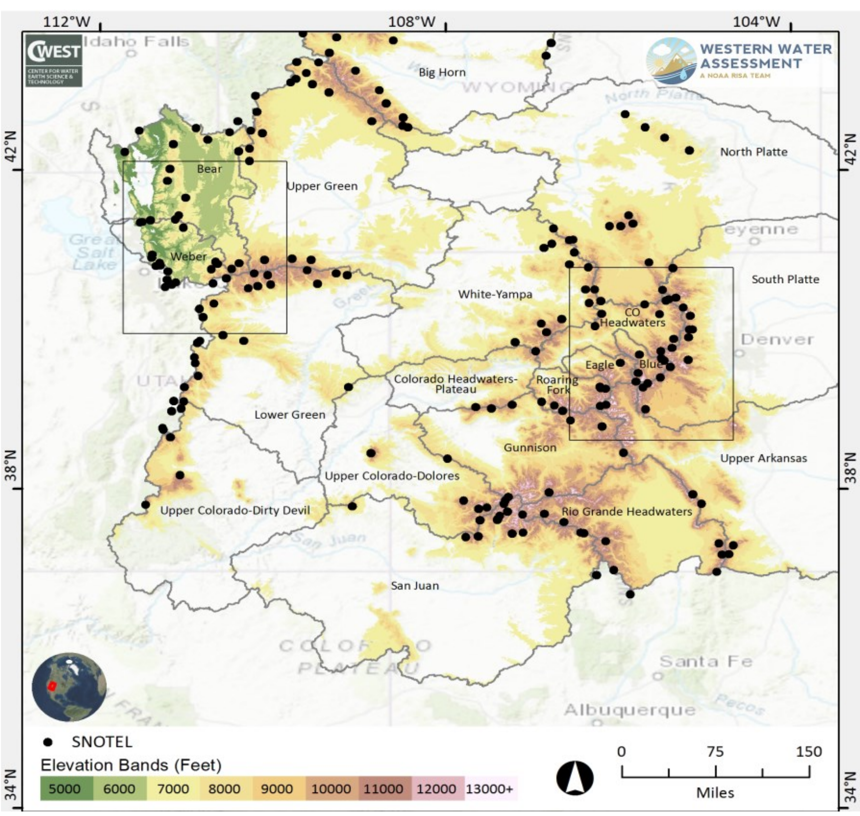

Figure 2. Intermountain West region. Location map identifies basins used in this report (gray boundaries), SNOTEL sites (black dots), and 1000' elevation bands (colored shading) that match those used in Table 1 and Table 2. The elevation bands below 7000' are shown only in the Bear and Weber basins. The Wasatch Front and Colorado Headwaters sub-regions are indicated by the small boxes.

Data availability for this report

311 SNOTEL sites in the Intermountain West network were recording SWE values out of a total of 313 sites; 0 were offline and 2 were recording zero SWE. 371 CoCoRaHs sites were also used for this report.

The value of spatially explicit estimates of SWE

Snowmelt makes up the large majority (~60-85%) of the annual streamflow in the Intermountain West. The spatial distribution of snow-water equivalent (SWE) across the landscape is complex. While broad aspects of this spatial pattern (e.g., more SWE at higher elevations and on north-facing exposures) are fairly consistent, the details vary a lot from year to year, influencing the magnitude and timing of snowmelt-driven runoff.

SWE is operationally monitored at hundreds of NRCS SNOTEL sites spread across the Intermountain West, providing a critical first-order snapshot of conditions, and the basis for runoff forecasts from NRCS and NOAA.
However, conditions at SNOTEL sites (e.g., percent of normal SWE) may not be representative of conditions in the large areas between these point measurements, and at elevations above and below the range of the SNOTEL sites. The spatial snow analysis creates a detailed picture of the spatial pattern of SWE using SNOTEL, satellite, and other data, extending beyond the SNOTEL sites to unmonitored areas.

Interpreting the spatial SWE estimates in the context of SNOTEL The spatial product estimates SWE for every pixel where the MODSCAG product identifies snow-cover. Comparatively, SNOTEL samples 8-20 points per basin within a narrower elevation range (Figure 2). Thus, the basin-wide percent of long-term average from the spatial SWE estimates is not directly comparable with the SNOTEL basin-wide percent of average. A better comparison might be made with the % average in the elevation bands (Table 2) that contain SNOTEL sites.

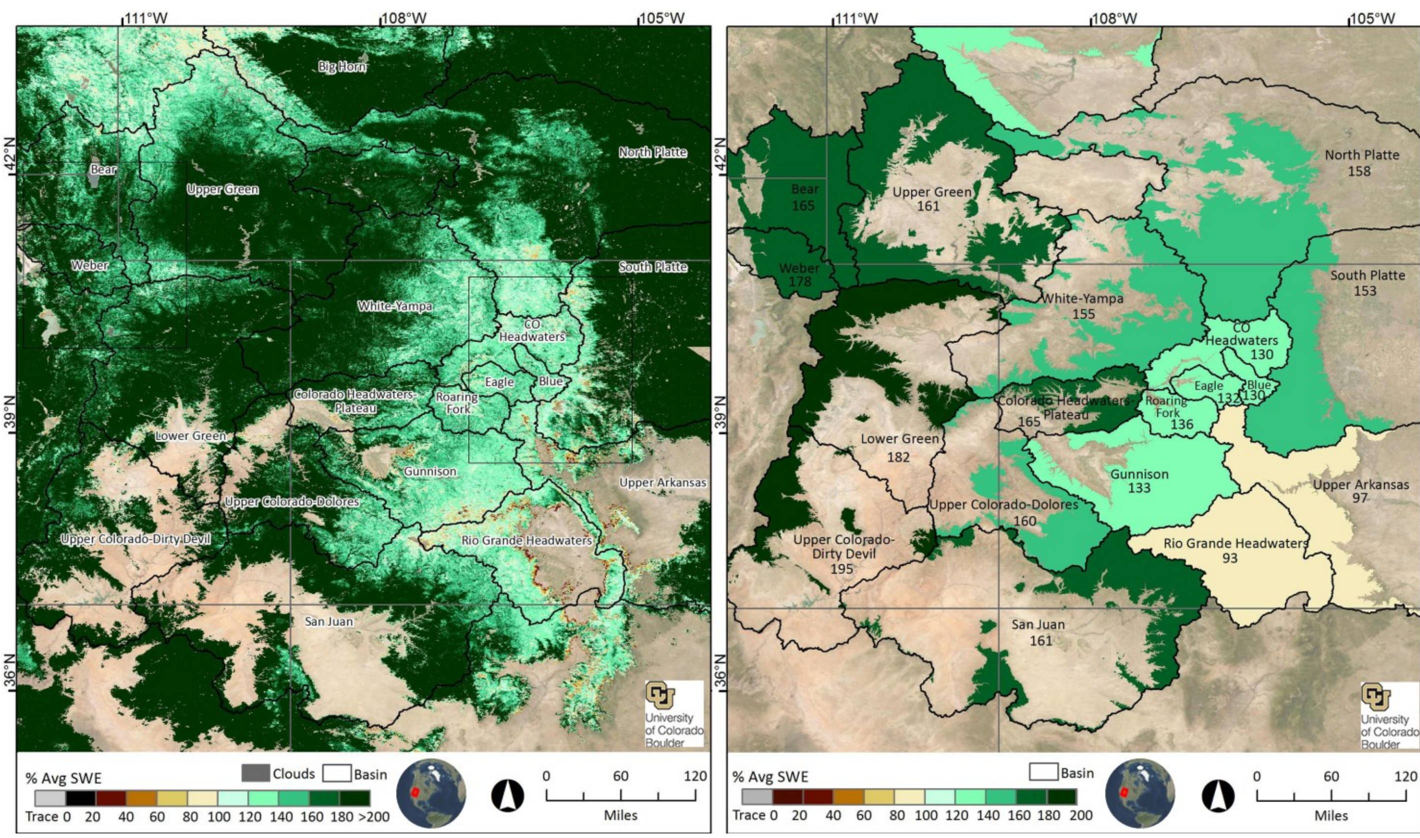

Figure 3*. *Estimated % of average SWE across the Intermountain West, February 1, 2023. Percent of long-term average (2001-2021) SWE for February 1, 2023 for the Intermountain West, calculated for each pixel (left) and basin-wide (right). Note that the basin-wide averages may reflect variable conditions across the elevation bands; see Table 2. Basin-wide percent of average is calculated across all model pixels >7000' elevation (>5000' elevation in the Bear River/Weber basins). This is a time of year when sporadic percent of average especially in low-elevation areas will be higher than historical averages.

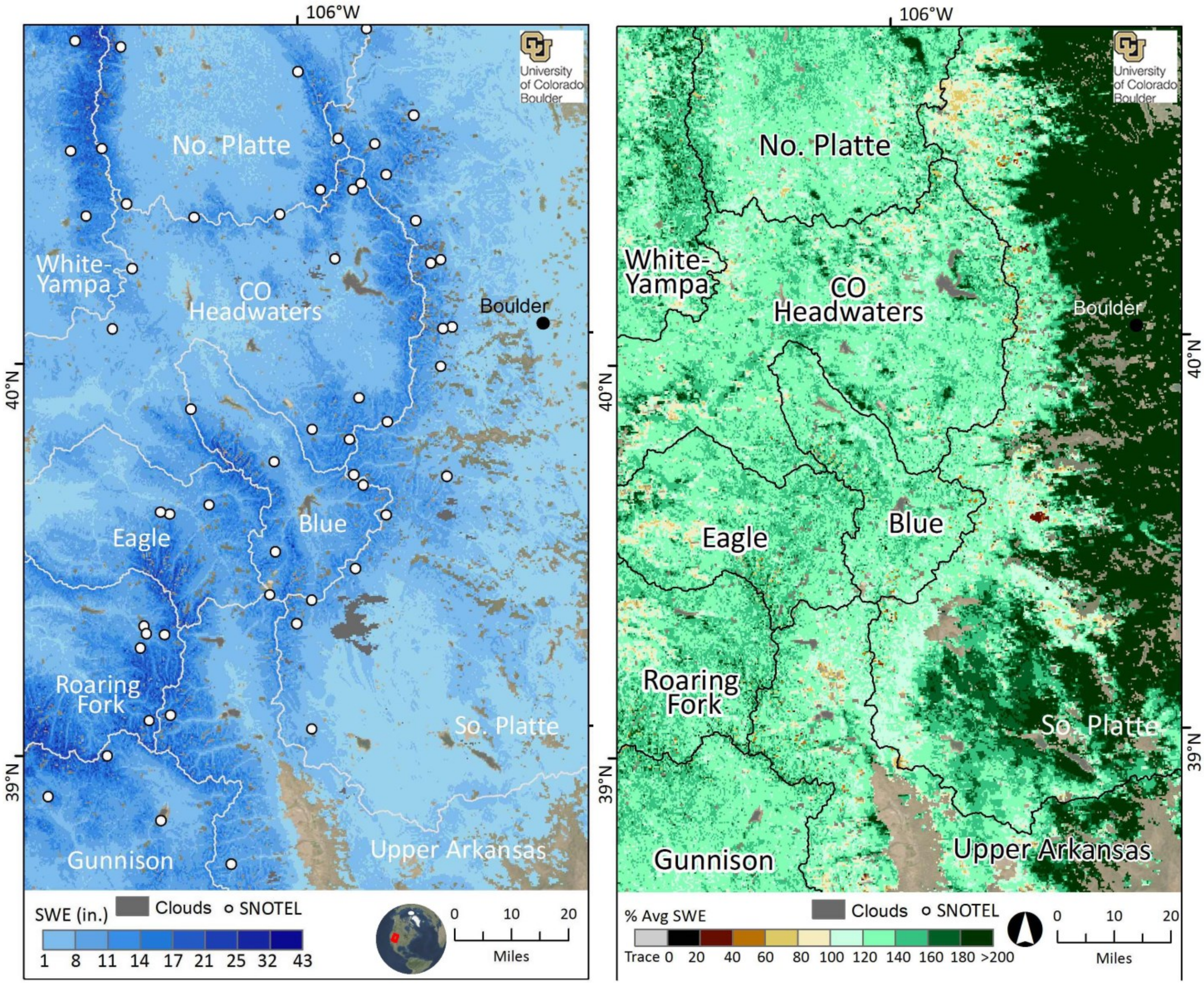

Figure 4. Estimated SWE across the Colorado Headwaters Sub-region, February 1, 2023. SWE amounts for February 1, 2023 (left), and the % of long-term average (2001-20201 SWE for February 1, 2023 for the snow-covered area (right). This is a time of year when sporadic percent of average especially in low-elevation areas will be higher than historical averages, hence the dark green shaded areas in the right map.

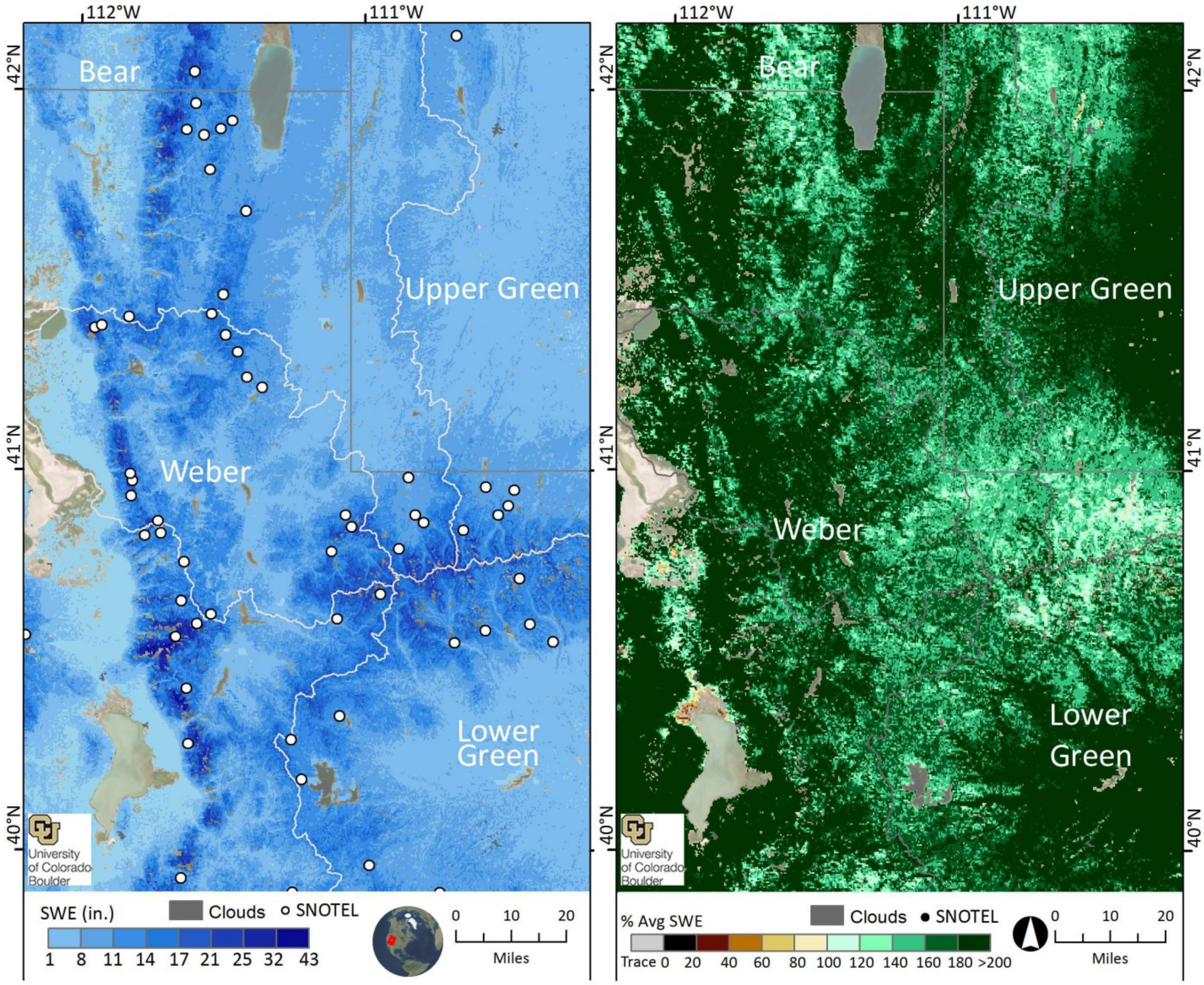

Figure 5. Estimated SWE across the Wasatch Front Sub-region, February 1, 2023. SWE amounts for February 1, 2023 (left), and the % of long-term average (2000-2020) SWE on February 1, 2023 for the snow-covered area. This is a time of year when sporadic percent of average especially in low-elevation areas will be higher than historical averages, hence the dark green shaded areas in the right map.

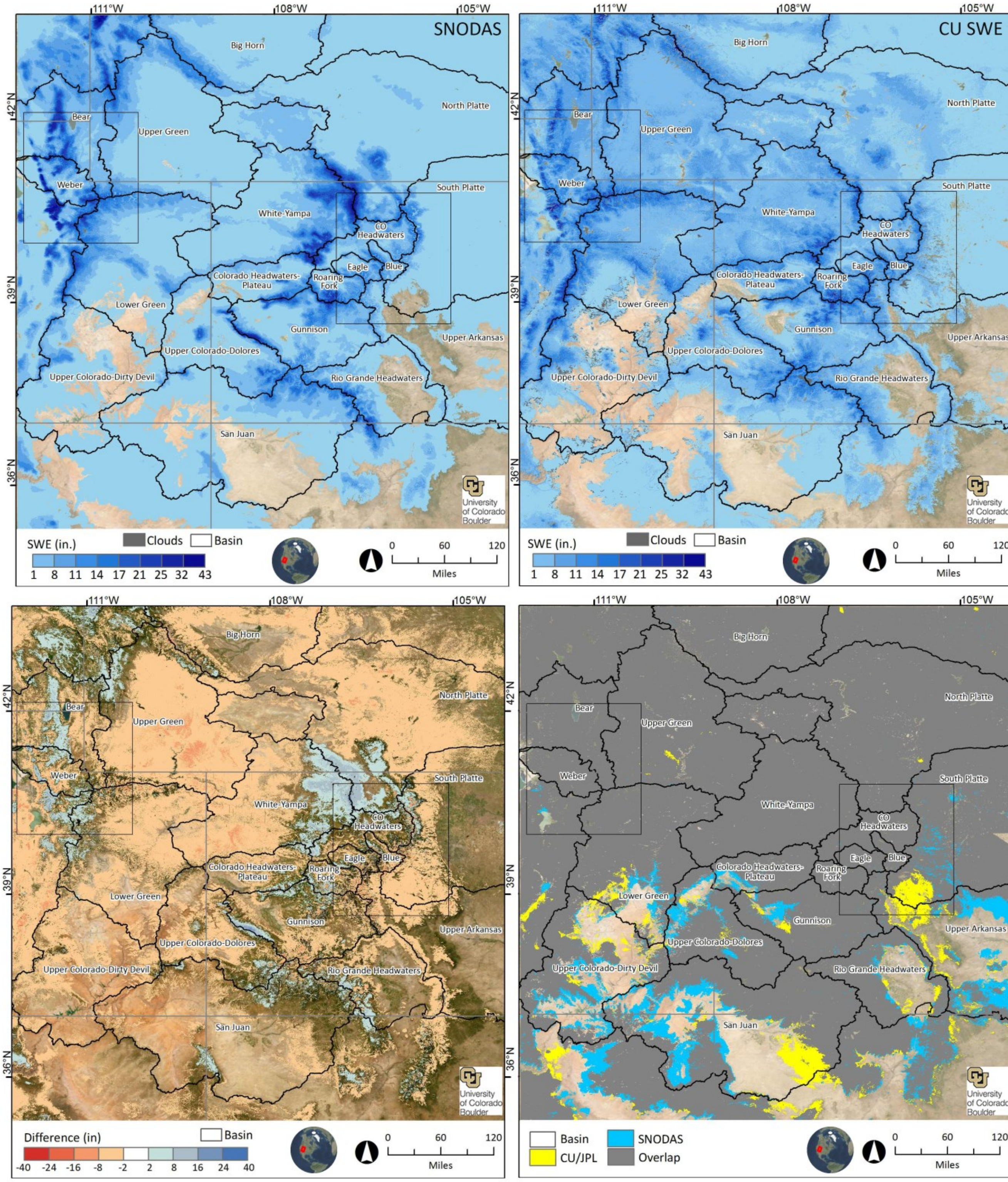

Figure 6. Comparison of the experimental CU SWE product and SNODAS SWE for the Intermountain West. The map in the upper left shows estimated SWE for February 1st from the NOAA National Weather Service's National Operational Hydrologic Remote Sensing Center (NOHRSC) SNOw Data Assimilation System (SNODAS). The upper right map shows experimental CU SWE estimated SWE amounts. The lower left map shows the difference between the February 1st SNODAS SWE estimate and the experimental CU SWE estimate. Red pixels denote areas where SNODAS SWE is less than CU SWE and blue pixels show areas where SNODAS SWE is higher than CU SWE. The map in the lower left shows the snow-cover extent of SNODAS and CU SWE estimates. Yellow pixels show where the location of CU snow extends beyond the location of the SNODAS snow extent. Blue pixels show where the SNODAS snow extends beyond the CU snow extent. Gray areas indicate regions where both products agree on the snow-cover extent.

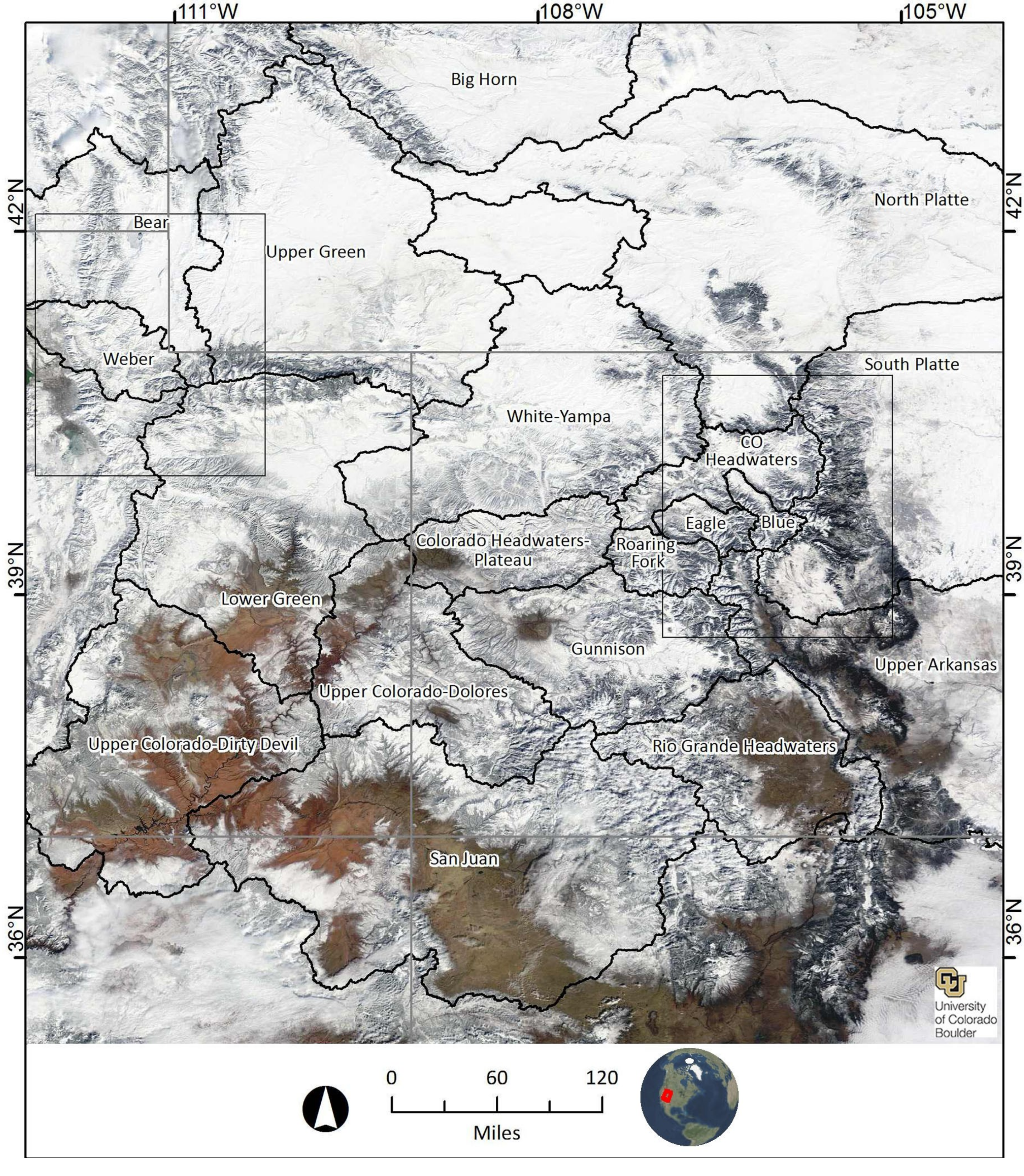

Figure 7. MODIS Image, Intermountain West. The February 1, 2023 cloud-free true color composited MODIS image showing the area that was used for the February 1, 2023 regression model run. 2 MODSCAG (MODIS Snow Covered Area and Grain-size) images were composited to create the model input fractional snow-covered area image.

Table 1. Estimated SWE by basin. The basin-wide SWE values and averages, and areas, for all pixels at elevations >7000', except for the Bear and Weber basins, which are >5000'. Shown are February 1st percent of February 1st average SWE (2001-21 as derived from the regression model), February 1st mean SWE, February 1st percent of snow-covered area, February 1st SWE volume (acre-feet), the area (mi²) inside each basin that contains data pixels (not including cloud-covered pixels, lakes or other satellite no data pixels), February 1st snow surveys, and February 1st SNOTEL sensors (the number of stations are in parentheses), for those areas collected, summarized for each basin. For comparison, the last column shows February 1st basin-wide mean SWE from SNODAS*.

Basin	2/1/23 % 2/1 Avg.	2/1/23 SWE (in)	2/1/23 % SCA	2/1/23 SWE Vol (af)	2/1/23 Area (mi^2)	2/1/23 Surveys (in)	2/1/23 Sensors (in)	2/1/23 SNODAS* (in)
Bear	165	10.2	96.5	3,526,470	6,510	15.8 (2)	15.5 (19)	9.5
Blue	130	10.0	97.9	376,399	707	6.9 (3)	11.5 (5)	7.7
Colorado Headwaters	130	8.2	97.3	1,316,600	3,006	10.2 (10)	12.4 (12)	8.3
Colorado Headwaters-Plateau	165	11.1	98.7	1,142,218	1,935	14.9 (1)	12.8 (1)	9.2
Eagle	132	9.6	99.0	501,387	982	6.0 (1)	11.6 (3)	8.3
Gunnison	133	8.7	98.3	3,173,224	6,827	10.2 (4)	13.2 (11)	7.8
Lower Green	182	11.4	98.5	3,714,095	6,120	NA	13.4 (20)	9.5
North Platte	158	6.5	94.1	3,978,487	11,407	12.7 (13)	14.7 (20)	5.1
Rio Grande Headwaters	93	4.1	58.2	1,729,926	7,852	8.7 (7)	6.7 (13)	3.1
Roaring Fork	136	11.7	99.0	904,419	1,446	8.4 (4)	12.3 (7)	10.4
San Juan	161	6.6	95.1	2,328,290	6,655	18.4 (3)	15.0 (16)	6.5
South Platte	153	5.0	91.3	1,581,957	5,985	6.0 (25)	8.7 (20)	2.3
Upper Arkansas	97	3.4	56.7	1,121,608	6,209	6.6 (5)	4.8 (6)	1.3
Upper Colorado-Dirty Devil	195	8.6	94.1	1,247,285	2,722	NA	9.6 (4)	5.4
Upper Colorado-Dolores	160	8.6	98.7	1,657,594	3,628	10.2 (1)	13.2 (7)	7.9
Upper Green	161	8.8	94.9	4,966,503	10,640	10.1 (2)	10.3 (21)	5.5
Weber	178	11.1	98.3	1,347,130	2,266	NA	20.7 (14)	10.7
White-Yampa	155	9.8	97.3	3,398,956	6,512	18.5 (3)	18.7 (14)	10.5

* This is a comparison to the SNODAS (SNOw Data Assimilation System) nationwide product from the National Weather Service.

Table 2. Estimated SWE by basin and elevation band. Elevation bands begin at 7000' and extend past the highest point in the basin, except for the Bear and Weber basins, which begin at 5000'. Note that the area of the highest 2-5 bands is typically much smaller than the lower bands. Shown are February 1st percent of February 1st average SWE (2001-21 as derived from the regression model), February 1st mean SWE, February 1st percent of snow-covered area, February 1st SWE volume (acre-feet), the area (mi^2) inside each basin that contains data pixels (not including cloud-covered pixels, lakes or other satellite no data pixels), February 1st snow surveys, and February 1st SNOTEL sensors (the number of stations are in parentheses), for those areas collected, summarized for each 1000' elevation band within each basin. For comparison, the last column shows February 1st mean SWE for each 1000' elevation band from SNODAS*.

Basin	Elevation Band	2/1/23 % 2/1 Avg.	2/1/23 SWE (in)	2/1/23 % SCA	2/1/23 SWE Vol (af)	2/1/23 Area (mi^2)	2/1/23 Surveys (in)	2/1/23 Sensors (in)	2/1/23 SNODAS* (in)
Bear	5000-6000'	193.8	8.3	96.2	375,578	843.4	NA	NA	6.3
	6000-7000'	173.1	9.1	95.2	1,366,194	2802.0	NA	11.8 (3)	7.2
	7000-8000'	155.4	10.4	97.2	1,095,068	1981.7	13.2 (1)	14.2 (8)	11.0
	8000-9000'	148.9	14.1	99.2	482,427	641.5	18.4 (1)	20.5 (6)	17.4
	9000-10,000'	147.1	14.7	99.6	114,039	145.3	NA	11.6 (2)	15.9
	10,000-11,000'	154.7	17.8	99.0	78,564	82.9	NA	NA	15.7
	11,000-12,000'	156.1	19.9	96.3	13,463	12.7	NA	NA	13.7
	12,000-13,000'	150.6	19.1	93.6	1,137	1.1	NA	NA	10.8
Blue	7000-8000'	132.4	4.4	97.8	8,523	36.0	NA	NA	4.6
	8000-9000'	130.8	6.3	99.3	36,137	107.0	NA	NA	4.7
	9000-10,000'	134.9	8.0	98.6	54,771	128.0	NA	8.2 (1)	6.3
	10,000-11,000'	133.0	10.3	99.3	105,937	193.3	6.9 (3)	14.4 (2)	8.9
	11,000-12,000'	129.4	13.1	97.8	121,910	174.8	NA	10.2 (2)	9.9
	12,000-13,000'	119.5	13.6	91.9	45,277	62.3	NA	NA	8.1
	13,000+	98.2	12.8	79.4	3,844	5.6	NA	NA	3.9
Colorado Headwaters-Plateau	7000-8000'	174.1	8.6	97.3	334,993	732.8	NA	NA	5.5
	8000-9000'	167.4	11.5	99.2	439,264	713.6	NA	NA	8.2
	9000-10,000'	149.4	12.7	99.9	172,846	255.9	NA	NA	13.8
	10,000+	157.6	15.6	99.9	187,716	225.7	14.9 (1)	12.8 (1)	18.2
Colorado Headwaters	7000-8000'	128.8	4.7	96.0	116,230	468.0	NA	NA	4.3
	8000-9000'	127.3	6.4	96.7	307,159	899.5	8.6 (1)	8.2 (3)	5.7
	9000-10,000'	129.8	8.1	98.4	333,070	775.4	9.0 (4)	10.1 (3)	8.7
	10,000-11,000'	134.5	11.5	98.8	370,846	607.2	11.8 (4)	16.2 (5)	13.7
	11,000-12,000'	130.8	14.0	95.9	168,587	225.1	11.1 (2)	12.8 (1)	12.3
	12,000+	112.8	12.8	89.1	20,618	30.3	NA	NA	7.5
Eagle	7000-8000'	125.6	4.6	99.6	42,291	172.0	NA	NA	2.7
	8000-9000'	129.4	7.4	99.6	76,833	195.4	6.0 (1)	9.7 (1)	5.3
	9000-10,000'	135.1	9.2	99.4	89,844	182.3	NA	11.3 (1)	8.7
	10,000-11,000'	134.3	11.2	98.8	156,506	261.7	NA	13.7 (1)	11.4
	11,000-12,000'	137.5	14.7	99.1	107,350	137.2	NA	NA	12.6
	12,000-13,000'	128.5	15.9	93.3	27,263	32.1	NA	NA	10.5
	13,000+	108.9	15.2	84.7	1,300	1.6	NA	NA	7.8
Gunnison	7000-8000'	142.2	5.2	97.5	305,405	1091.1	NA	NA	4.4
	8000-9000'	135.1	7.2	98.7	701,704	1828.6	NA	16.0 (1)	7.0
	9000-10,000'	133.3	8.7	98.9	652,177	1411.0	11.0 (1)	17.4 (2)	8.2
	10,000-11,000'	131.3	10.3	98.5	837,226	1529.0	9.9 (3)	14.0 (5)	9.3
	11,000-12,000'	128.2	12.6	98.4	454,824	674.7	NA	8.4 (3)	10.3
	12,000-13,000'	126.8	14.2	95.6	203,080	268.4	NA	NA	9.4
	13,000+	119.3	14.4	90.3	18,808	24.5	NA	NA	7.3

Basin	Elevation Band	2/1/23 % 2/1 Avg.	2/1/23 SWE (in)	2/1/23 % SCA	2/1/23 SWE Vol (af)	2/1/23 Area (mi^2)	2/1/23 Surveys (in)	2/1/23 Sensors (in)	2/1/23 SNODAS* (in)
Lower Green	7000-8000'	199.0	8.8	97.5	1,151,067	2442.3	NA	8.4 (1)	6.4
	8000-9000'	182.2	11.5	99.3	1,166,350	1899.4	NA	12.8 (9)	10.4
	9000-10,000'	172.9	13.8	99.7	646,393	878.2	NA	15.4 (5)	13.1
	10,000-11,000'	164.3	15.5	99.0	551,844	668.2	NA	13.1 (4)	13.1
	11,000-12,000'	157.0	16.0	96.0	169,655	198.2	NA	15.2 (1)	11.2
	12,000-13,000'	150.2	16.3	95.1	27,992	32.3	NA	NA	8.5
	13,000+	140.9	16.4	91.9	795	0.9	NA	NA	4.9
North Platte	7000-8000'	176.2	5.7	92.4	2,145,471	7090.0	NA	10.1 (3)	2.1
	8000-9000'	136.1	6.5	95.9	942,493	2716.0	10.7 (4)	10.3 (5)	7.5
	9000-10,000'	135.8	8.8	99.3	455,273	966.0	11.6 (7)	17.0 (7)	12.5
	10,000-11,000'	139.5	12.6	99.2	382,134	568.6	20.9 (2)	18.7 (5)	17.2
	11,000-12,000'	129.0	15.3	92.7	50,722	62.3	NA	NA	15.7
	12,000-13,000'	107.7	12.6	86.1	2,394	3.6	NA	NA	8.0
Rio Grande Headwaters	7000-8000'	11.1	0.2	5.8	25,332	2690.4	NA	NA	0.0
	8000-9000'	97.3	2.7	68.6	216,660	1495.0	NA	NA	1.0
	9000-10,000'	118.5	5.4	92.0	318,049	1111.0	7.4 (4)	5.7 (1)	3.4
	10,000-11,000'	116.5	7.5	95.6	566,683	1423.0	12.3 (4)	4.7 (7)	7.1
	11,000-12,000'	113.7	9.7	96.3	445,690	861.3	NA	9.7 (5)	8.6
	12,000-13,000'	108.0	10.9	90.4	147,310	253.7	NA	NA	7.9
	13,000+	94.3	11.0	78.9	10,201	17.4	NA	NA	5.1
Roaring Fork	7000-8000'	119.9	5.4	98.8	61,458	215.1	NA	NA	3.2
	8000-9000'	129.6	8.3	99.4	122,585	276.7	4.9 (1)	7.0 (1)	6.6
	9000-10,000'	140.7	10.8	99.4	141,712	245.1	4.9 (1)	11.5 (2)	10.5
	10,000-11,000'	140.4	13.1	99.6	230,647	329.8	9.3 (1)	15.0 (3)	13.2
	11,000-12,000'	141.9	16.8	99.0	237,035	264.6	9.8 (2)	11.0 (1)	15.2
	12,000-13,000'	136.8	18.0	96.0	102,876	106.9	NA	NA	14.2
	13,000+	128.0	19.5	91.2	8,107	7.8	NA	NA	13.0
San Juan	7000-8000'	189.4	4.0	93.7	831,306	3867.1	6.4 (1)	NA	3.6
	8000-9000'	153.7	6.9	98.0	407,549	1106.6	NA	14.6 (2)	7.6
	9000-10,000'	145.9	9.3	98.6	267,985	539.6	26.3 (1)	10.6 (4)	10.2
	10,000-11,000'	140.1	12.3	98.1	350,614	535.1	22.6 (1)	15.5 (5)	13.3
	11,000-12,000'	129.0	14.2	95.3	322,135	424.1	NA	18.2 (5)	14.5
	12,000-13,000'	115.8	15.2	86.8	136,908	169.3	NA	NA	13.1
	13,000+	112.8	16.5	82.9	11,793	13.4	NA	NA	10.7
South Platte	7000-8000'	>200†	3.3	90.0	269,114	1549.1	NA	NA	0.6
	8000-9000'	168.4	3.8	90.3	319,630	1579.3	4.1 (7)	5.9 (3)	0.9
	9000-10,000'	136.1	4.3	91.4	309,921	1358.4	4.6 (6)	10.4 (4)	1.6
	10,000-11,000'	118.2	7.2	93.4	330,106	857.3	7.1 (9)	9.3 (9)	5.6
	11,000-12,000'	118.0	10.1	96.1	247,243	460.5	8.6 (4)	7.6 (4)	6.6
	12,000-13,000'	111.5	11.0	90.6	92,045	157.1	NA	NA	6.3
	13,000+	99.0	11.4	80.3	13,897	22.9	NA	NA	3.9

Basin	Elevation Band	2/1/23 % 2/1 Avg.	2/1/23 SWE (in)	2/1/23 % SCA	2/1/23 SWE Vol (af)	2/1/23 Area (mi^2)	2/1/23 Surveys (in)	2/1/23 Sensors (in)	2/1/23 SNODAS* (in)
Upper Arkansas	7000-8000'	71.3	0.6	28.7	57,341	1857.0	NA	NA	0.1
	8000-9000'	70.4	1.6	42.4	136,211	1590.1	NA	NA	0.1
	9000-10,000'	102.3	3.6	73.5	237,795	1236.8	2.0 (1)	1.4 (1)	0.4
	10,000-11,000'	110.6	6.2	88.7	257,929	782.3	7.5 (2)	5.8 (3)	2.6
	11,000-12,000'	120.3	10.1	97.1	243,691	450.7	8.0 (3)	5.1 (2)	6.3
	12,000-13,000'	120.5	12.1	92.5	161,482	250.3	NA	NA	6.6
	13,000+	106.7	12.3	83.0	27,158	41.5	NA	NA	4.6
Upper Colorado-Dirty Devil	7000-8000'	>200†	5.5	88.2	333,305	1144.3	NA	NA	2.3
	8000-9000'	190.5	8.7	97.6	384,458	828.2	NA	8.5 (1)	5.8
	9000-10,000'	180.1	12.1	99.0	255,484	396.7	NA	11.5 (2)	8.3
	10,000-11,000'	174.7	14.5	99.2	222,219	286.8	NA	7.0 (1)	11.4
	11,000-12,000'	164.4	14.6	99.9	51,818	66.3	NA	NA	11.6
Upper Colorado-Dolores	7000-8000'	176.7	6.0	98.5	473,192	1489.8	NA	NA	4.6
	8000-9000'	157.9	8.8	99.0	538,752	1141.8	10.2 (1)	11.8 (1)	7.8
	9000-10,000'	154.8	10.8	99.5	279,251	485.9	10.2 (1)	13.3 (3)	11.7
	10,000-11,000'	142.7	12.3	99.5	226,232	345.9	NA	13.6 (3)	14.1
	11,000-12,000'	138.5	15.2	97.3	100,044	123.6	NA	NA	15.2
	12,000-13,000'	132.9	18.2	90.9	34,550	35.6	NA	NA	11.2
	13,000+	128.5	20.0	87.4	5,574	5.2	NA	NA	9.8
Upper Green	7000-8000'	176.1	7.6	93.5	2,906,932	7163.5	NA	7.3 (1)	3.4
	8000-9000'	146.5	9.4	97.8	890,348	1774.2	11.1 (1)	10.9 (10)	7.6
	9000-10,000'	134.7	11.2	99.3	512,564	861.7	9.0 (1)	9.5 (8)	11.0
	10,000-11,000'	132.2	13.7	98.0	449,977	614.5	NA	12.2 (2)	12.1
	11,000-12,000'	129.6	16.8	92.8	172,876	193.5	NA	NA	11.9
	12,000+	124.2	19.2	88.5	32,446	31.7	NA	NA	9.9
Weber	5000-6000'	>200†	8.3	96.7	131,934	297.7	NA	NA	5.5
	6000-7000'	189.1	9.5	97.8	416,193	825.4	NA	13.8 (2)	6.9
	7000-8000'	167.2	11.6	98.8	462,773	746.8	NA	24.6 (7)	12.6
	8000-9000'	162.9	15.0	99.5	206,876	259.2	NA	16.1 (3)	18.5
	9000-10,000'	159.0	17.1	99.6	80,478	88.4	NA	20.7 (2)	19.3
	10,000+	159.2	18.8	99.2	48,186	48.0	NA	NA	19.7
White-Yampa	7000-8000'	164.6	8.3	96.1	1,656,403	3723.3	13.4 (1)	12.3 (1)	6.7
	8000-9000'	143.7	9.9	98.6	827,471	1561.6	21.1 (2)	18.6 (5)	12.4
	9000-10,000'	143.8	12.4	99.4	434,534	659.2	26.2 (1)	16.1 (6)	17.2
	10,000-11,000'	149.1	15.5	99.1	399,614	484.5	NA	30.0 (2)	22.0
	11,000-12,000'	151.6	18.3	97.5	80,826	83.0	NA	NA	21.0
	12,000-13,000'	128.6	14.6	93.5	109	0.1	NA	NA	17.5

† Deep, and particularly low-elevation snow in areas that typically are snow-free can report exceptionally high percent of average for this date because the mean 2001-2021 regression-derived SWE for that area is low or 0.

* This is a comparison to the SNODAS (SNOw Data Assimilation System) nationwide product from the National Weather Service.

Location of Reports, Excel Format Tables, and JPG Maps

https://www.colorado.edu/instaar/research/labs-groups/mountain-hydrology-group/intermountain-west-swe-reports

Methods

The spatial SWE estimation method is described in Yang, et. al. 2022 and Schneider and Molotch (2016). The method uses linear regression in which the dependent variable is derived from the operationally measured in situ SWE from all online NRCS SNOTEL sites in the domain and when applicable the CoCoRaHS SWE values. The SNOTEL SWE observations are scaled by the fractional snow-covered area (fSCA) across the 500 m pixel containing that SNOTEL site before being used in the linear regression model. The fSCA is a near-real-time cloud-free MODIS satellite image which has been processed using the MODIS Snow Cover and Grain size (MODSCAG) fractional snow-covered area algorithm program (Painter, et. al. 2009) and the Snow Today fSCA image when needed (Rittger, et. al. 2019, https://nsidc.org/snow-today).

The following independent variables (predictors) enter into the linear regression model:

- Physiographic variables that affect snow accumulation, melt, and redistribution, including elevation, latitude, upwind mountain barriers, slope, and others. See Table 1 in Yang, et. al., 2022 for the full set of these variables.
- The historical daily SWE pattern (1985-2021) retrospectively generated using historical Landsat data, and an energy-balance model that back-calculates SWE given the fractional Snow-Covered Area (fSCA) time series and meltout date for each pixel. See Fang, et. al., 2022 for details. (For computational efficiency, only one image during the 1985-2021 period that best matches the real-time SNOTEL-observed pattern is selected as an independent variable.)
- Satellite-observed daily mean fractional snow-covered area (DMFSCA) derived from Rittger, et. al., 2019 data.

The real-time regression model for this date has been validated by cross-validation, whereby 10% of the SNOTEL data are randomly removed and the model prediction is compared to the measured value at the removed SNOTEL stations. This is repeated 30 times to obtain an average R-squared value, which denotes how closely the model fits the SNOTEL data. During development of this regression method, the model was also validated against independent historical SWE data collected in snow surveys at 9 locations in Colorado, and an intensive field survey in north-central Colorado.

List of All Known Data Issues/Caveats

- RECENT SNOWFALL – There are occasionally problems with lower-elevation SWE estimates due to recent snowfall events that result in extensive snow-cover extending to valley locations where measurements are not available. This scenario results in an over-estimation of lower- elevation SWE.
- LIMITED SNOW PILLOW DATA – When snow at the snow pillow sites melts out, but remains at higher elevations, the model tends to overestimate SWE at the under-monitored upper elevations. This issue typically occurs late in the melt season, resulting in less accurate SWE prediction at higher elevations compared to earlier in the snow season.
- CLOUD COVER – Cloud cover can obscure satellite measurements of snow-cover. While careful checks are made, occasionally the misclassification of clouds as snow or *vice versa* may result in the mischaracterization of SWE or bare-ground.
- LOW LOOK ANGLE – When a satellite does not pass directly over a region but the area is still included within the satellite sensor's field of view, this is referred to as a low "look angle". The resulting image has lower effective resolution – this "blurry" MODSCAG data still contains useful information but may lead to overestimation of SWE near the margins of the snow-cover extent.
- POOR QUALITY SNOTEL DATA – Although data QA/QC is performed, occasional SNOTEL sensor malfunction may result in localized SWE errors.
- ANOMALOUS SNOW PATTERNS – Anomalous snow years or snow distributions may cause SWE error due to the model design to search for similar SWE distributions from previous years. If no close seasonal analogue exists, the model is forced to find the most similar year, which may result in error.
- DENSE FOREST COVER – Dense forest cover at lower elevations where snow-cover is discontinuous can cause the satellite to underestimate the snow-cover extent, leading to underestimation of SWE.
- PERCENT OF AVERAGE CALCULATIONS - Data utilized to generate this report change to optimize model performance. To maintain consistency across the historical record, the percent of average values are based on our baseline algorithm and therefore there can be discrepancies between absolute SWE values and corresponding percent of averages.

- MODELING METHODS - We work to generate the best SWE estimates for each reporting date. Our methods can change from one report to another. Sometimes data changes between reports is an artifact of method changes.

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