Spatial Estimates of Snow-Water Equivalent (SWE)

Intermountain West Region

March 1, 2022

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Summary of current conditions (as of 3/1/22)

As of March 1st, the modeled snow water equivalent (SWE) was in the range of 67% to 119% of the 2000-20 average across the Intermountain West (Figures 1 & 3). There remains a mostly an east-west gradient with the western half of the domain, including the Bear, Weber and Upper Green, exhibiting below average SWE (67% to 75%) and the eastern basins close to or just above average (Figure 3). 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; however, values from this report are generally in close agreement. 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.

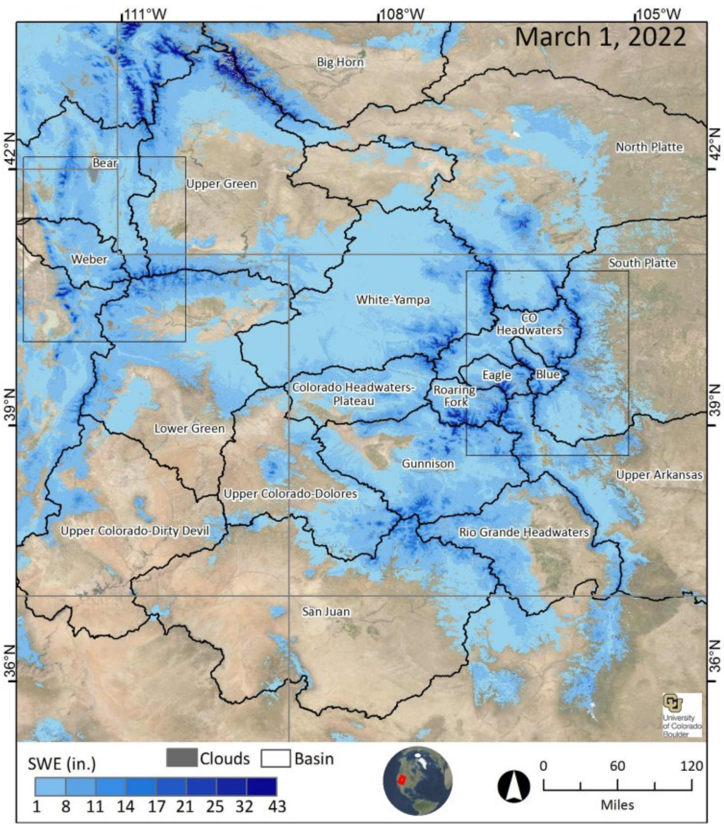

Figure 1. Estimated SWE amounts across the Intermountain West, March 1st.

Data Issues/Caveats for March 1, 2022

- 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.
- 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.
- 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.
- 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

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 (2000-2012) 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

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.

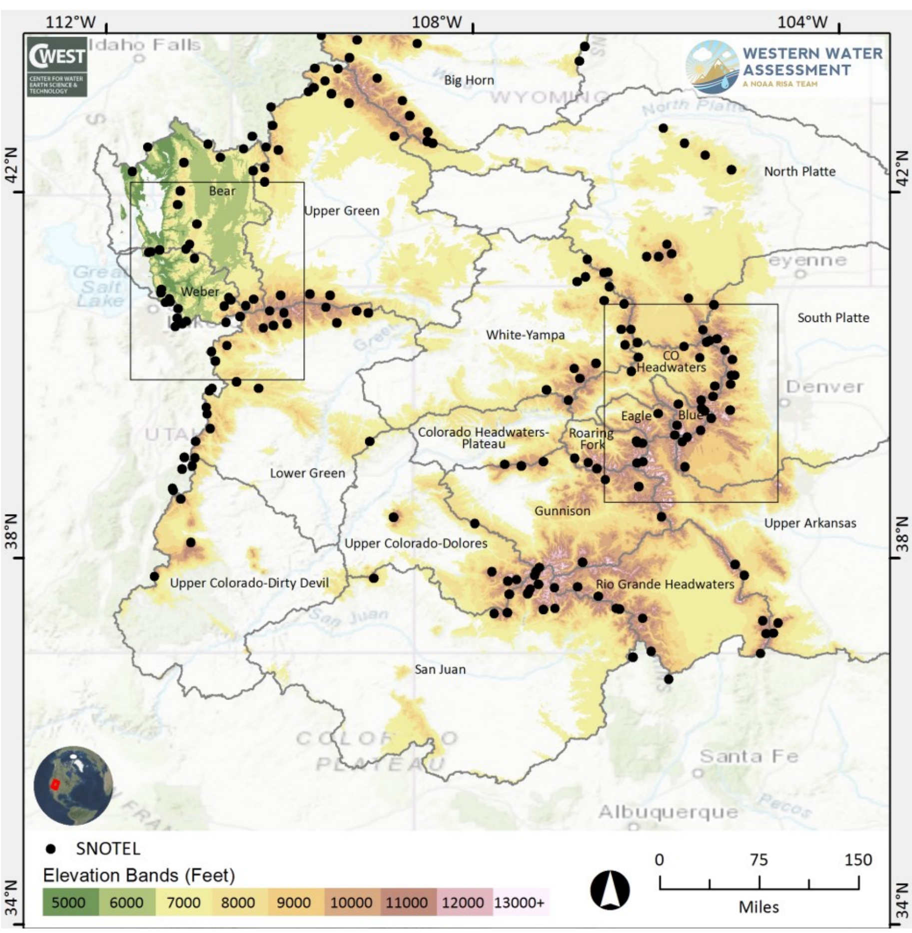

Figure 2. Intermountain West region. Location map identifies basins used in this report (gray boundaries), SNOTEL sites (black dots), and 1000' elevation bands (colored shading) that match those used in Table 1 and Table 2. The elevation bands below 7000' are shown only in the Bear and Weber basins.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

Data availability for this report

313 SNOTEL sites in the Intermountain West network were recording SWE values out of a total of 313 sites; 0 were offline and 4 were recording zero SWE. 1592 CoCoRaHS measurements were also used for this report. 178 snow course measurements were used to vet the model results.

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.

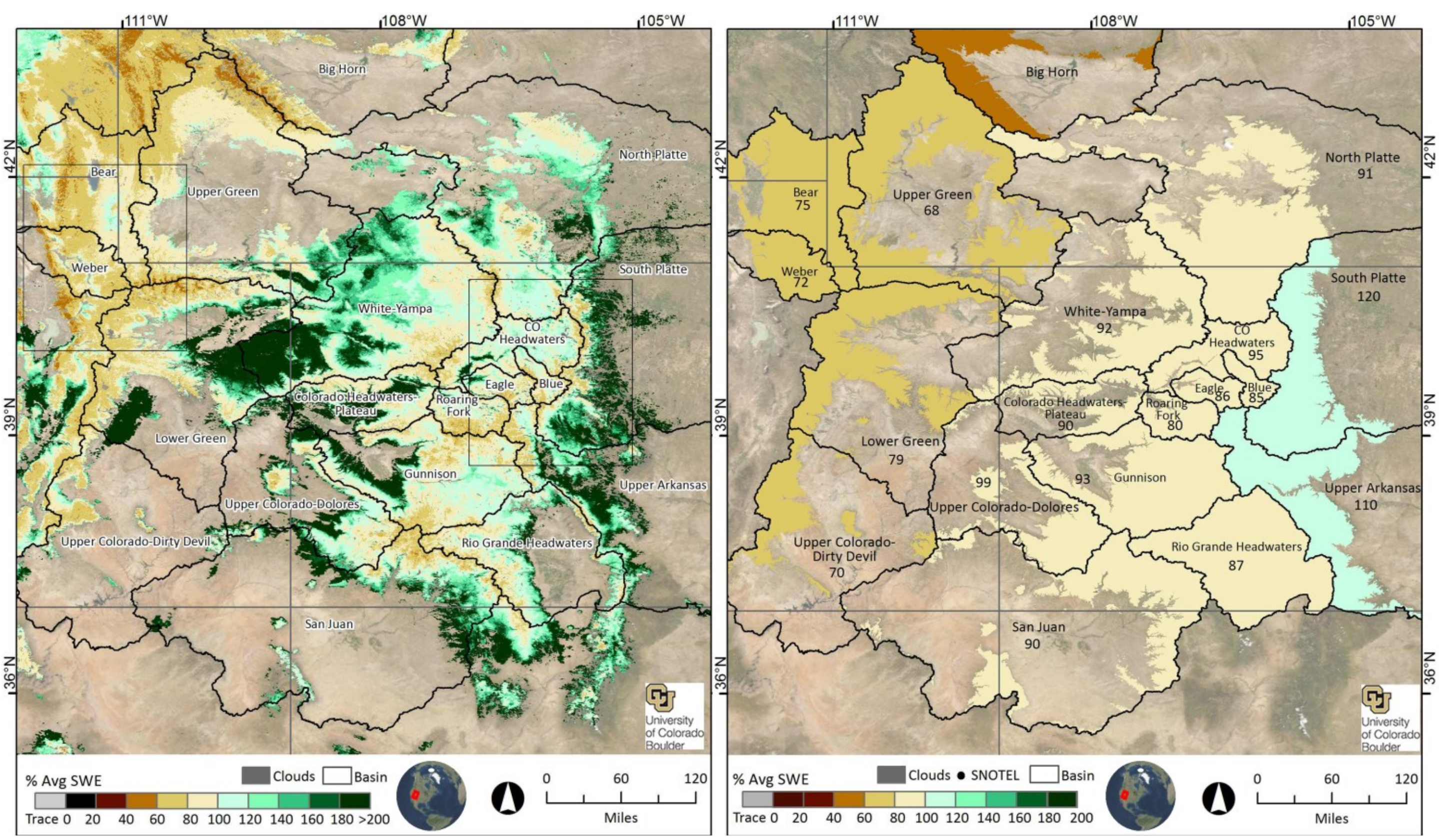

Figure 3. Estimated % of average SWE across the Intermountain West, March 1, 2022. Percent of long-term average (2000-2020) SWE for March 1, 2022 for the Intermountain West, calculated for each pixel (left) and basin-wide (right). Some pixels at lower elevations are showing as dark green (>180% of average) due to persistent snow cover that greatly exceeds the average amount at these elevations (near-zero) for this time of year. 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).

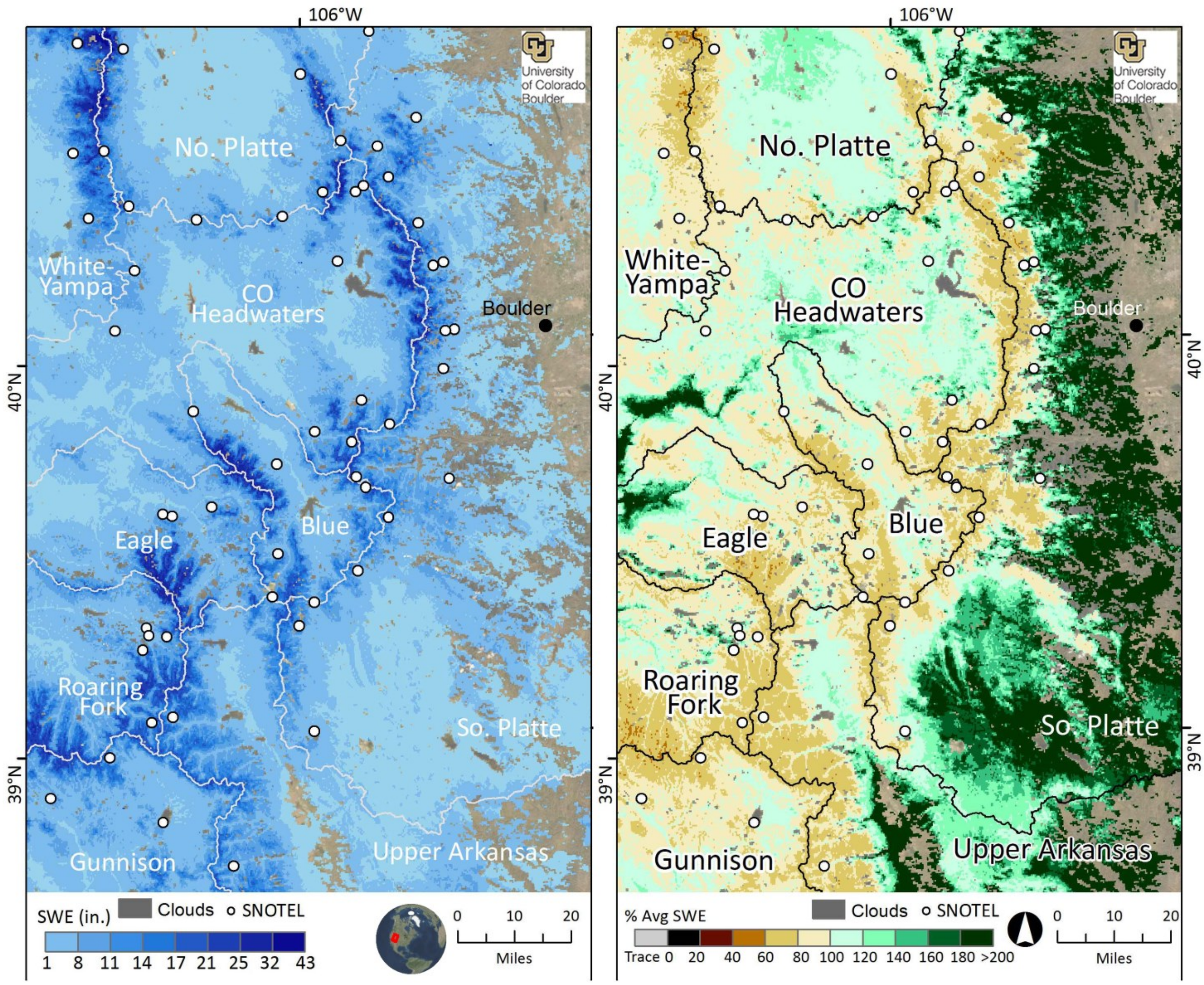

Figure 4. Estimated SWE across the Colorado Headwaters Sub-region, March 1, 2022. SWE amounts for March 1, 2022 (left), and the % of long-term average (2000-2020) SWE for March 1, 2022 for the snow-covered area (right).

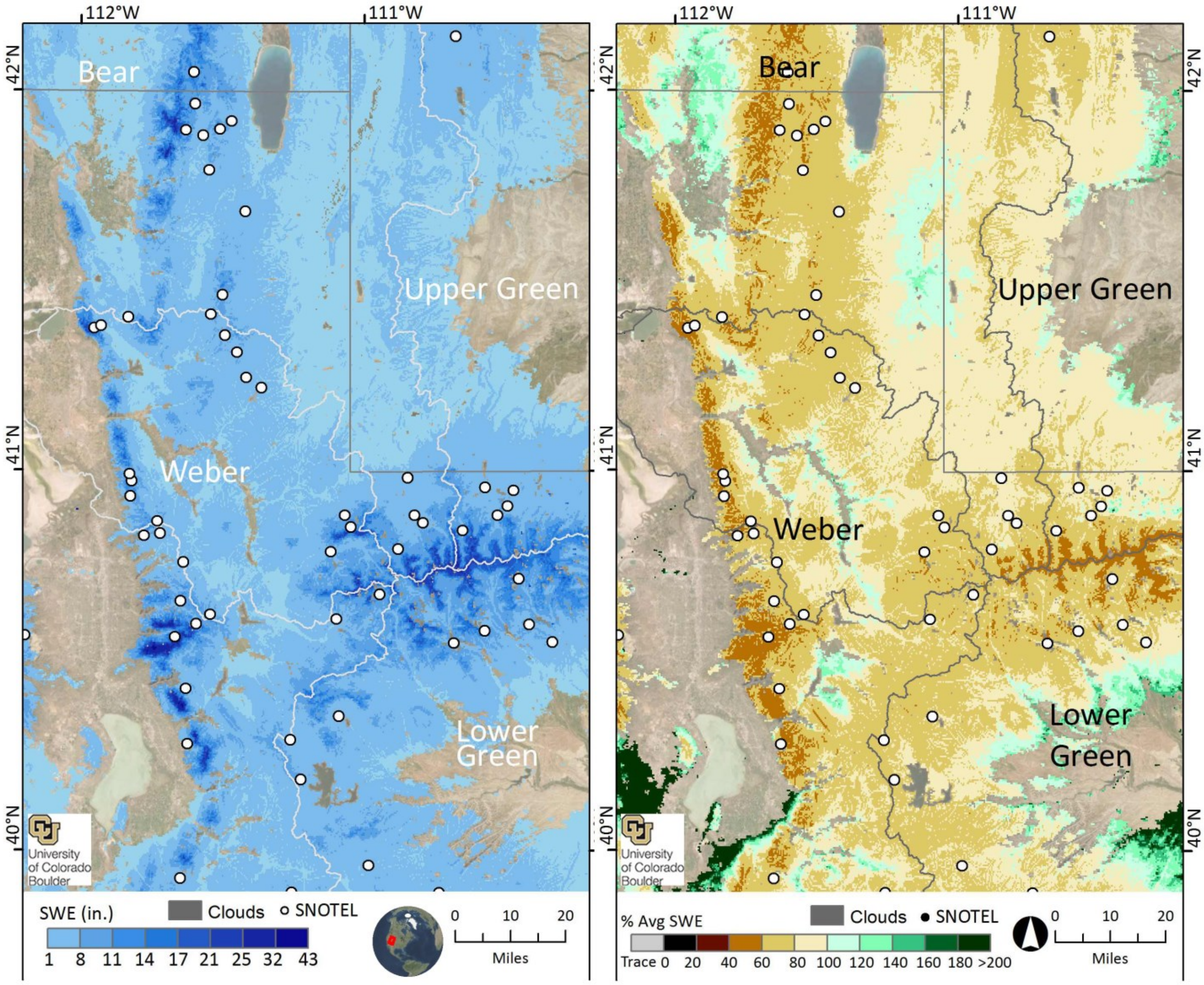

Figure 5. Estimated SWE across the Wasatch Front Sub-region, March 1, 2022. SWE amounts for March 1, 2022 (left), and the % of long-term average (2000-2020) SWE on March 1, 2022 for the snow-covered area.

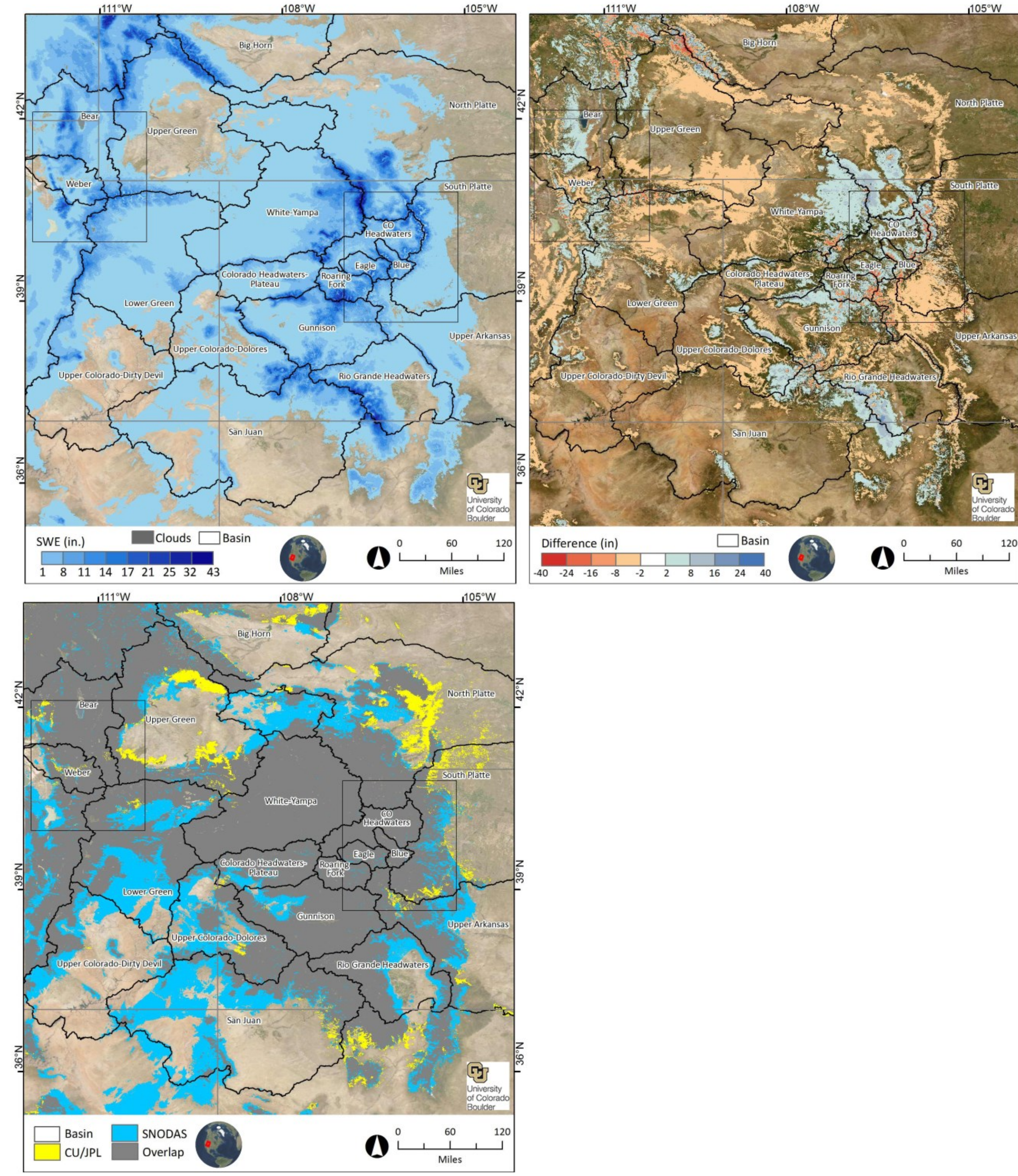

Figure 6. Comparison of the experimental CU SWE product and SNODAS SWE for the Intermountain West. The map in the upper left shows estimated SWE for March 1st from the NOAA National Weather Service's National Operational Hydrologic Remote Sensing Center (NOHRSC) SNOw Data Assimilation System (SNODAS). The upper right map shows the difference between the March 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.

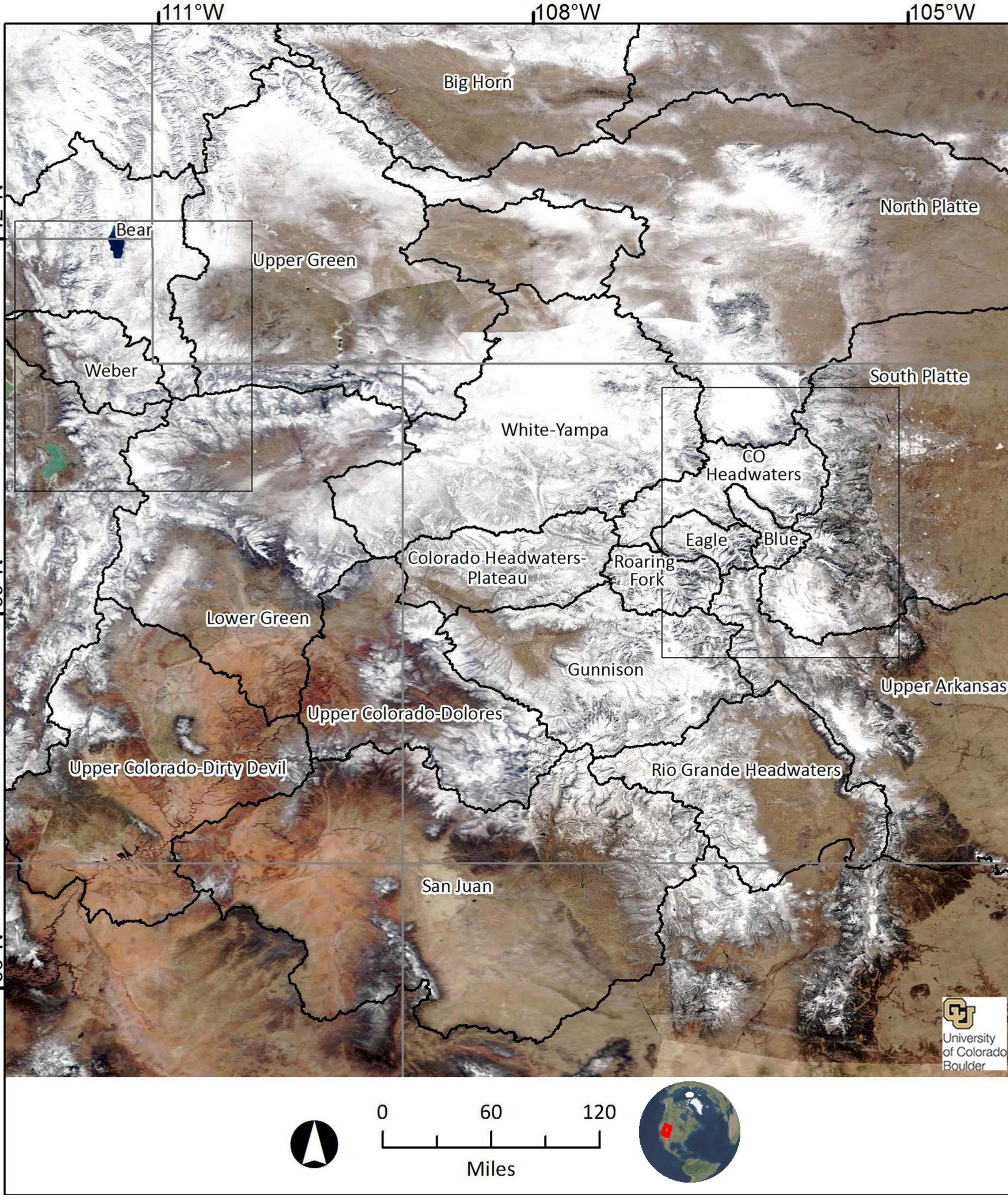

Figure 7. MODIS Image, Intermountain West. The March 1, 2022 cloud-free true color MODIS image showing the composited image that was used for the March 1, 2022 regression model run. 2 MODSCAG images and 1 Snow Today image were composited to create the input MODSCAG image.

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 March 1st percent of March 1st average SWE (2000-20 as derived from the regression model), March 1st mean SWE, March 1st percent of snow-covered area, March 1st water 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), March 1st SNOTEL sensors (the number of stations are in parentheses), and March 1st snow courses, for those areas collected, summarized for each basin. For comparison, the last column shows March 1st basin-wide mean SWE from SNODAS*.

Basin	3/1/22 % 3/1 Avg	3/1/22 SWE (in)	3/1/22 % SCA	3/1/22 Vol (af)	3/1/22 Area (mi^2)	3/1/22 Sensors	3/1/22 Courses	3/1/22 SNODAS* (in)
Bear	75.4	5.3	96.7	1,854,874	6,530	10.2 (21)	10.7 (9)	6.0
Blue	84.9	9.1	98.6	348,925	720	7.5 (11)	7.4 (3)	8.4
Colorado Headwaters	94.8	6.9	99.3	1,115,332	3,031	9.3 (17)	9.3 (13)	8.0
Colorado Headwaters-Plateau	90.5	6.4	98.7	661,143	1,946	6.6 (2)	10.9 (1)	7.0
Eagle	85.7	8.2	96.3	431,715	990	3.8 (9)	3.3 (2)	9.0
Gunnison	92.7	6.4	99.2	2,353,160	6,855	7.2 (23)	10.5 (6)	6.9
Lower Green	79.1	6.1	92.1	2,011,193	6,144	9.0 (20)	10.5 (1)	5.9
North Platte	90.8	3.5	80.8	2,144,692	11,416	8.2 (33)	11.7 (11)	3.7
Rio Grande Headwaters	86.6	3.4	55.7	1,443,278	7,887	3.4 (31)	8.9 (7)	3.9
Roaring Fork	80.2	9.6	98.5	743,069	1,458	11.2 (10)	10.3 (4)	10.3
San Juan	90.1	3.6	66.9	1,294,956	6,692	7.0 (38)	9.3 (9)	4.3
South Platte	119.8	4.2	80.5	1,368,706	6,068	3.3 (69)	7.4 (29)	2.6
Upper Arkansas	109.5	3.9	67.6	1,311,067	6,234	1.5 (31)	9.0 (5)	2.0
Upper Colorado-Dirty Devil	69.9	3.8	63.3	564,839	2,779	5.6 (5)	6.8 (1)	3.7
Upper Colorado-Dolores	98.9	4.9	93.0	955,010	3,632	9.4 (8)	6.8 (4)	5.1
Upper Green	67.5	5.0	79.0	2,863,958	10,670	7.9 (24)	9.2 (2)	3.9
Weber	72.1	5.6	93.7	682,126	2,273	9.0 (18)	NA	5.5
White-Yampa	92.3	5.8	99.1	2,020,096	6,512	11.8 (17)	12.3 (4)	7.1

* 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 March 1st percent of March 1st average SWE (2000-20 as derived from the regression model), March 1st mean SWE, March 1st percent of snow-covered area, March 1st water 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), March 1st SNOTEL sensors (the number of stations are in parentheses), and March 1st snow courses, for those areas collected, summarized for each 1000’ elevation band within each basin. For comparison, the last column shows March 1st mean SWE for each 1000’ elevation band from SNODAS*.

Basin	Elevation Band	3/1/22 % 3/1 Avg	3/1/22 SWE (in)	3/1/22 % SCA	3/1/22 Vol (af)	3/1/22 Area (mi^2)	3/1/22 Sensors	3/1/22 Courses	3/1/22 SNODAS* (in)
Bear	5000-6000'	82.7	3.5	94.9	160,090	846.2	1.2 (2)	NA	2.8
	6000-7000'	80.1	4.1	94.6	611,400	2806.0	7.8 (3)	9.4 (5)	4.5
	7000-8000'	73.1	5.7	99.3	603,302	1987.6	9.4 (8)	11.8 (3)	7.0
	8000-9000'	66.5	9.2	99.4	316,922	646.3	15.8 (6)	14.0 (1)	12.0
	9000-10,000'	68.4	11.3	99.4	88,115	145.8	9.5 (2)	NA	12.1
	10,000-11,000'	67.0	13.5	100.0	59,645	83.1	NA	NA	13.1
	11,000-12,000'	57.4	19.0	100.0	14,026	13.8	NA	NA	11.1
	12,000-13,000'	56.2	19.4	100.0	1,374	1.3	NA	NA	7.0
Blue	7000-8000'	114.4	3.1	96.4	6,010	36.0	0.0 (1)	NA	5.5
	8000-9000'	101.1	4.4	99.9	24,889	107.2	5.5 (1)	NA	5.7
	9000-10,000'	98.0	5.6	98.1	38,283	129.0	6.3 (4)	NA	7.2
	10,000-11,000'	90.1	7.9	97.0	82,394	195.8	9.6 (3)	7.4 (3)	10.1
	11,000-12,000'	77.0	13.3	99.7	125,796	176.8	11.8 (2)	NA	10.4
	12,000-13,000'	69.6	17.9	99.9	65,327	68.4	NA	NA	7.2
	13,000+	67.8	16.9	100.0	6,227	6.9	NA	NA	2.6
Colorado Headwaters-Plateau	7000-8000'	102.8	4.8	97.5	189,847	738.9	0.0 (1)	NA	4.4
	8000-9000'	89.7	5.6	99.3	215,372	717.0	NA	NA	6.3
	9000-10,000'	83.1	8.5	99.7	116,062	256.8	NA	NA	9.3
	10,000-11,000'	79.7	10.9	99.6	132,520	227.1	13.1 (1)	10.9 (1)	14.7
	11,000-12,000'	70.2	20.8	100.0	7,343	6.6	NA	NA	13.0
Colorado Headwaters	7000-8000'	118.2	3.6	99.6	90,744	469.1	4.1 (1)	NA	4.9
	8000-9000'	101.7	4.7	98.8	227,340	906.3	5.1 (7)	9.3 (1)	5.6
	9000-10,000'	99.0	6.2	99.7	259,073	781.1	9.6 (3)	8.5 (6)	8.0
	10,000-11,000'	88.8	9.4	99.1	306,642	611.1	15.6 (5)	9.7 (5)	13.1
	11,000-12,000'	73.9	16.0	99.8	196,400	229.9	11.9 (1)	11.3 (2)	10.4
	12,000-13,000'	69.1	19.8	100.0	34,864	33.0	NA	NA	5.5
	13,000+	68.0	24.1	100.0	269	0.2	NA	NA	3.5
Eagle	7000-8000'	111.2	3.8	100.0	34,935	172.0	0.0 (3)	NA	4.9
	8000-9000'	92.7	5.3	99.8	55,569	196.1	2.5 (4)	6.5 (1)	5.7
	9000-10,000'	89.4	6.6	94.1	64,022	182.5	11.0 (1)	NA	8.5
	10,000-11,000'	85.2	8.6	91.2	121,292	264.2	12.9 (1)	0.0 (1)	12.1
	11,000-12,000'	74.4	15.1	98.4	111,723	138.5	NA	NA	13.3
	12,000-13,000'	65.5	22.8	100.0	41,631	34.2	NA	NA	8.1
	13,000+	63.6	22.0	100.0	2,542	2.2	NA	NA	4.3
Gunnison	7000-8000'	123.6	3.7	97.8	217,487	1091.9	0.3 (7)	NA	3.0
	8000-9000'	100.8	4.5	99.8	442,251	1830.2	6.0 (2)	NA	5.4
	9000-10,000'	93.7	5.8	99.5	440,800	1414.6	9.2 (6)	11.2 (2)	7.3
	10,000-11,000'	88.4	7.5	98.8	618,530	1537.2	13.6 (5)	10.8 (3)	9.1
	11,000-12,000'	78.4	10.8	99.9	390,605	681.1	9.3 (3)	8.5 (1)	10.0
	12,000-13,000'	70.5	15.2	100.0	221,651	274.3	NA	NA	9.4
	13,000+	68.2	15.9	100.0	21,836	25.7	NA	NA	7.2

Basin	Elevation Band	3/1/22 % 3/1 Avg	3/1/22 SWE (in)	3/1/22 % SCA	3/1/22 Vol (af)	3/1/22 Area (mi^2)	3/1/22 Sensors	3/1/22 Courses	3/1/22 SNODAS* (in)
Lower Green	7000-8000'	91.8	4.0	85.8	522,624	2453.2	5.0 (1)	NA	3.1
	8000-9000'	78.9	5.9	95.1	592,610	1898.7	8.4 (9)	NA	6.6
	9000-10,000'	73.7	7.6	95.6	355,698	875.1	10.1 (5)	10.5 (1)	8.4
	10,000-11,000'	72.0	9.9	99.3	352,147	669.0	9.6 (4)	NA	10.1
	11,000-12,000'	61.5	14.1	100.0	155,861	208.0	11.5 (1)	NA	8.8
	12,000-13,000'	55.6	15.0	100.0	31,097	39.0	NA	NA	5.6
	13,000+	54.7	15.5	100.0	1,155	1.4	NA	NA	1.7
North Platte	7000-8000'	88.6	2.1	70.6	780,640	7091.5	1.6 (15)	NA	0.7
	8000-9000'	98.2	4.1	97.5	600,368	2717.3	6.8 (6)	8.1 (4)	5.9
	9000-10,000'	94.6	6.7	96.7	345,088	968.9	15.8 (7)	11.1 (5)	11.6
	10,000-11,000'	82.4	11.3	98.8	342,858	569.2	18.8 (5)	20.5 (2)	17.2
	11,000-12,000'	67.5	20.5	99.5	71,507	65.3	NA	NA	13.0
	12,000-13,000'	66.0	21.5	96.4	4,231	3.7	NA	NA	5.4
Rio Grande Headwaters	7000-8000'	15.6	0.1	3.1	10,182	2690.5	0.0 (10)	NA	0.1
	8000-9000'	105.9	2.1	59.6	170,264	1495.1	0.6 (5)	NA	1.8
	9000-10,000'	104.3	4.3	88.5	256,554	1112.8	3.0 (3)	6.5 (4)	4.9
	10,000-11,000'	95.4	5.9	94.9	446,670	1428.8	5.9 (7)	9.4 (4)	8.4
	11,000-12,000'	84.5	8.3	99.0	386,001	874.8	8.9 (6)	NA	9.3
	12,000-13,000'	74.2	11.4	99.9	161,622	267.0	NA	NA	8.3
	13,000+	69.5	12.3	99.2	11,985	18.2	NA	NA	5.8
Roaring Fork	7000-8000'	104.9	4.2	99.7	47,667	215.1	3.3 (3)	NA	5.2
	8000-9000'	92.2	5.6	99.6	82,172	277.4	8.2 (1)	6.1 (1)	6.7
	9000-10,000'	86.5	7.0	96.8	92,388	246.0	13.7 (2)	6.1 (1)	9.8
	10,000-11,000'	81.9	9.3	96.6	165,146	331.7	18.0 (3)	11.1 (1)	13.6
	11,000-12,000'	70.8	15.7	99.8	223,492	267.7	12.3 (1)	12.1 (2)	14.2
	12,000-13,000'	65.5	20.5	100.0	122,500	111.9	NA	NA	11.5
	13,000+	64.0	21.4	100.0	9,704	8.5	NA	NA	10.7
San Juan	7000-8000'	101.2	1.4	48.5	290,210	3872.1	1.0 (19)	3.6 (1)	1.0
	8000-9000'	99.1	3.7	82.2	221,189	1106.8	8.8 (4)	7.9 (5)	5.1
	9000-10,000'	96.0	5.7	96.4	165,444	540.8	8.9 (5)	8.0 (4)	8.4
	10,000-11,000'	83.5	7.7	99.1	222,546	538.6	15.3 (5)	24.2 (1)	11.7
	11,000-12,000'	72.7	10.6	99.8	243,147	431.4	18.1 (5)	NA	13.7
	12,000-13,000'	65.8	14.0	99.9	140,439	188.4	NA	NA	12.5
	13,000+	63.7	15.7	100.0	11,981	14.3	NA	NA	9.5
South Platte	7000-8000'	136.4	1.6	56.7	135,884	1550.9	0.4 (26)	NA	0.5
	8000-9000'	160.3	3.0	82.3	253,807	1584.5	1.4 (22)	4.4 (8)	1.4
	9000-10,000'	144.1	3.8	90.9	282,911	1382.6	7.0 (7)	6.1 (7)	2.1
	10,000-11,000'	103.3	6.2	89.5	292,555	887.1	10.0 (10)	9.5 (11)	6.4
	11,000-12,000'	81.0	10.6	98.3	264,488	469.1	9.2 (4)	9.4 (4)	6.6
	12,000-13,000'	72.6	13.5	96.8	121,913	169.1	NA	NA	5.5
	13,000+	69.4	13.2	87.5	17,148	24.3	NA	NA	2.7

Basin	Elevation Band	3/1/22 % 3/1 Avg	3/1/22 SWE (in)	3/1/22 % SCA	3/1/22 Vol (af)	3/1/22 Area (mi^2)	3/1/22 Sensors	3/1/22 Courses	3/1/22 SNODAS* (in)
Upper Arkansas	7000-8000'	137.4	1.0	36.7	98,076	1856.8	0.2 (16)	NA	0.5
	8000-9000'	140.2	2.5	64.4	213,090	1591.5	0.2 (8)	NA	0.9
	9000-10,000'	124.8	4.2	84.0	278,836	1240.6	2.4 (2)	5.6 (1)	1.9
	10,000-11,000'	104.9	6.1	90.7	255,760	788.0	7.5 (3)	9.8 (2)	4.6
	11,000-12,000'	82.0	9.9	97.9	238,615	451.6	7.4 (2)	10.2 (3)	6.8
	12,000-13,000'	71.1	13.8	98.4	191,139	259.2	NA	NA	5.1
	13,000+	68.4	14.3	94.9	35,550	46.7	NA	NA	2.3
Upper Colorado-Dirty Devil	7000-8000'	49.0	1.3	28.1	84,806	1187.9	0.0 (1)	NA	0.8
	8000-9000'	82.6	4.3	82.2	193,033	837.7	8.7 (1)	NA	4.1
	9000-10,000'	75.8	6.3	96.6	133,706	399.5	6.8 (2)	6.8 (1)	6.3
	10,000-11,000'	70.0	7.8	97.9	119,386	288.0	5.5 (1)	NA	9.4
	11,000-12,000'	66.9	9.6	99.9	33,908	66.3	NA	NA	9.2
Upper Colorado-Dolores	7000-8000'	121.2	3.4	85.7	266,236	1488.8	NA	NA	1.6
	8000-9000'	98.7	4.6	97.8	278,165	1143.2	3.4 (2)	6.2 (3)	4.4
	9000-10,000'	90.4	6.1	99.2	158,000	486.7	10.5 (3)	8.2 (2)	8.9
	10,000-11,000'	83.7	7.7	97.0	141,509	346.7	12.5 (3)	NA	12.9
	11,000-12,000'	72.6	11.1	98.3	73,199	123.9	NA	NA	14.7
	12,000-13,000'	64.9	16.4	100.0	32,463	37.1	NA	NA	10.2
	13,000+	62.5	18.5	100.0	5,438	5.5	NA	NA	8.0
Upper Green	7000-8000'	69.6	2.9	71.7	1,110,322	7165.5	2.6 (4)	NA	1.5
	8000-9000'	73.0	6.3	94.4	596,057	1779.5	9.7 (10)	12.1 (1)	5.7
	9000-10,000'	66.4	8.6	91.5	396,623	866.0	7.6 (8)	6.2 (1)	10.3
	10,000-11,000'	59.7	14.3	93.7	471,662	619.8	10.3 (2)	NA	13.7
	11,000-12,000'	52.3	22.1	95.6	237,887	202.2	NA	NA	12.0
	12,000-13,000'	51.9	25.5	97.3	49,138	36.2	NA	NA	8.6
	13,000+	50.3	33.9	94.4	2,269	1.3	NA	NA	9.5
Weber	5000-6000'	63.7	2.5	66.8	40,259	296.3	1.9 (1)	NA	1.7
	6000-7000'	77.6	4.5	95.4	196,360	826.9	3.2 (5)	NA	2.8
	7000-8000'	72.9	5.9	99.7	236,161	749.8	11.7 (7)	NA	6.7
	8000-9000'	66.9	8.6	99.8	119,585	262.2	11.6 (3)	NA	11.0
	9000-10,000'	68.4	10.8	100.0	51,099	89.1	14.1 (2)	NA	12.4
	10,000-11,000'	67.1	14.7	100.0	37,995	48.6	NA	NA	13.2
	11,000-12,000'	63.1	19.9	100.0	666	0.6	NA	NA	13.9
White-Yampa	7000-8000'	101.9	3.7	98.9	735,042	3724.1	2.5 (3)	10.3 (1)	4.1
	8000-9000'	90.1	5.9	99.7	489,813	1563.0	11.8 (6)	13.0 (3)	8.4
	9000-10,000'	85.1	9.8	99.1	345,784	658.7	12.3 (6)	19.6 (1)	12.4
	10,000-11,000'	77.6	13.8	99.3	356,424	483.1	23.9 (2)	NA	17.0
	11,000-12,000'	67.4	21.1	99.1	92,897	82.6	NA	NA	11.3
	12,000-13,000'	67.4	18.3	100.0	136	0.1	NA	NA	10.5

* 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

http://instaar.colorado.edu/research/labs-groups/mountain-hydrology-group/page/37200/

Methods

The spatial SWE estimation method is described in 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. 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, snow.jpl.nasa.gov) 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 Figure 2 in Schneider and Molotch (2016) for the full set of these variables.
- The historical daily SWE pattern (2000-2012) retrospectively generated using historical MODSCAG 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 Guan, et. al., 2013 for details. (For computational efficiency, only one image from either the 1st or 15th of a month during the 2000-2012 period that best matches the real-time SNOTEL-observed pattern is selected as an independent variable.)

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 underestimate 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.

References and Additional Sources

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