Real-Time Spatial Estimates of Snow-Water Equivalent (SWE)

Western United States Region

March 1, 2025

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Introduction

Figure 1 below displays estimated SWE amounts across the Western United States. 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 here. 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 percent of average in the elevation banded tables (linked below) that contain SNOTEL sites.

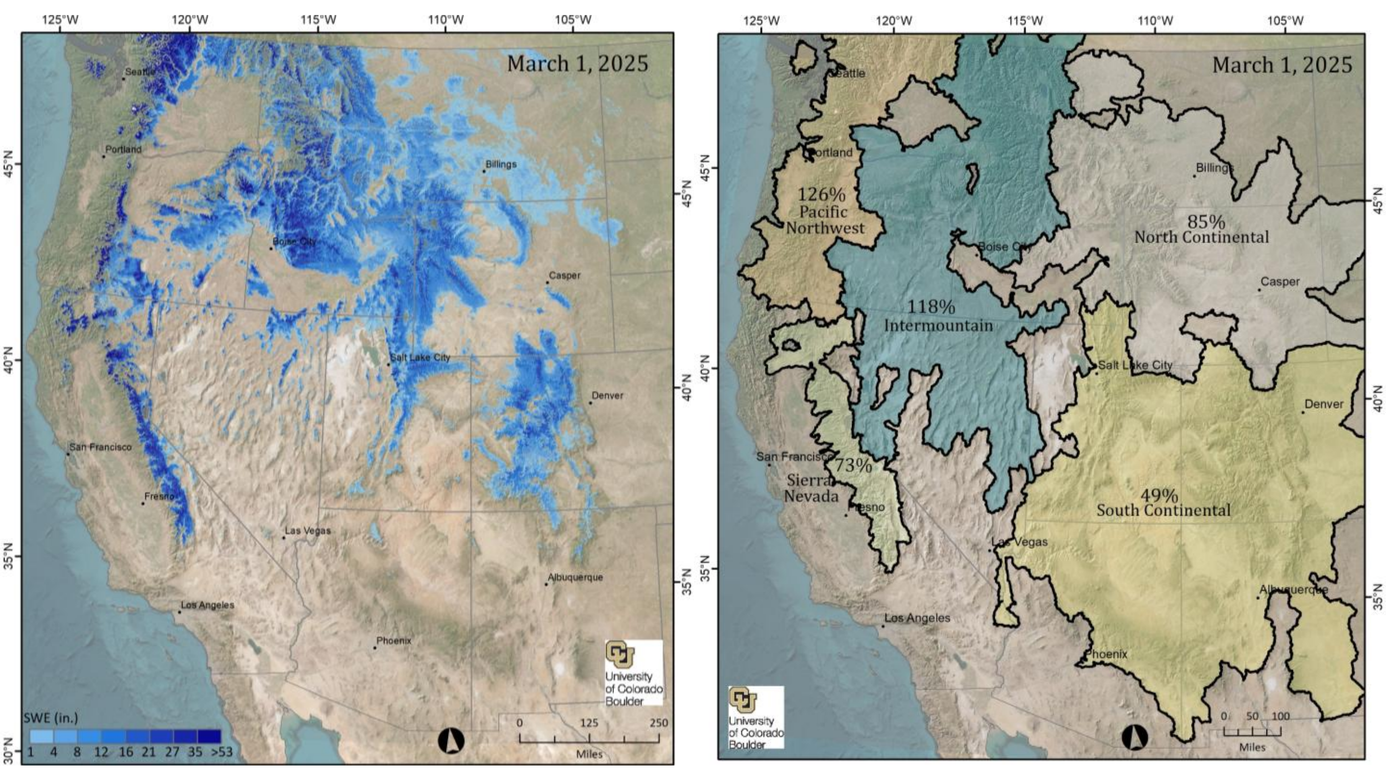

Figure 1. Estimated SWE and % of Average SWE across the Western U.S. SWE amounts across the entire Western region of the United States (left) and percent of long-term average (2001-2021) by five regions (right). Region boundaries are delineated based on Snowpack regimes of the Western United States (Trujillo and Molotch, 2014) and the Commission for Environmental Cooperation (CEC) Ecological Regions of North America, Level III [Commission for Environmental Cooperation, 2009, available at http://www.cec.org/north-american-environmental-atlas/terrestrial-ecoregions-level-iii/].

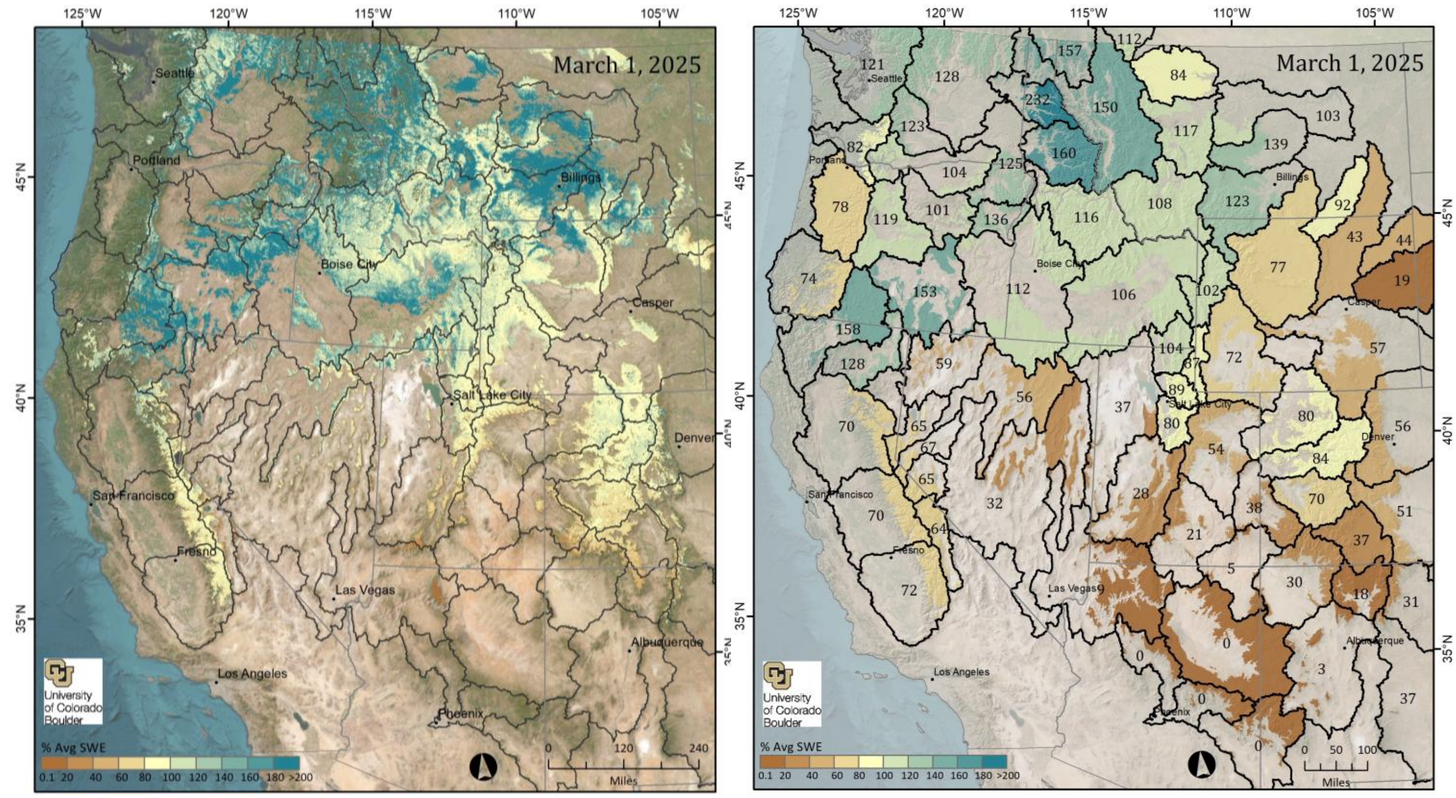

Figure 2. ***Estimated % of Average SWE across the Western U.S.*** Percent of long-term average (2001-2021) from the spatial SWE calculated for each pixel (left) and by HUC-6 basin (right); integer within each watershed represents the percent of average SWE for the report date. Shaded areas (right) correspond to the elevation bands used in the tables below.

For detailed maps and tabular summaries of SWE and snowpack water storage volumes for specific regions and watersheds, click on the links below:

Pacific Northwest
North Continental
South Continental
Intermountain
Sierra Nevada
Elevation Banded SWE Tables

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 meters for the Western region of the United States 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 2012.

The spatial SWE data fusion (SWE-fusion) analysis method for the Western U.S. uses the following data as inputs:

- In-situ SWE from all operational NRCS and CDEC snow pillow sites, and the CoCoRaHS network when appropriate
- Fractional snow-covered area (fSCA) data from recent cloud-free satellite images
- Physiographic information (elevation, latitude, upwind mountain barriers, slope, etc.)
- Historical daily SWE patterns (1985-2021) retrospectively generated using historical fSCA 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 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-fusion product.

Data availability for reporting

Snow pillows located throughout the Western U.S. region are input as the dependent variable in the SWE-fusion system. 799 Natural Resources Conservation Service (NRCS) Snow Telemetry (SNOTEL) sites and 131 California Department of Water Resources (CA-DWR) California Data Exchange Center (CDEC) are potentially available for each model run. In addition, the Community Collaborative Rain, Hail and Snow (CoCoRaHS, https://www.cocorahs.org/) network provides over 500 snow measurements across the modeling domain.

Maps and Tables by Region

Maps and tables for each of the five western regions (Figure 1b) are shown below. Note that the basin-wide averages may reflect variable conditions across the elevation bands; see banded-elevation tables (linked below). Basin-wide percent of average is calculated across all model pixels inside a given basin and base elevation. Basin base elevations vary anywhere between 2,000’ to 7,000’. Base elevations are dependent on long-term snow coverage. For example, a base elevation in the north could be lower as compared to a base elevation in the south.

Pacific Northwest

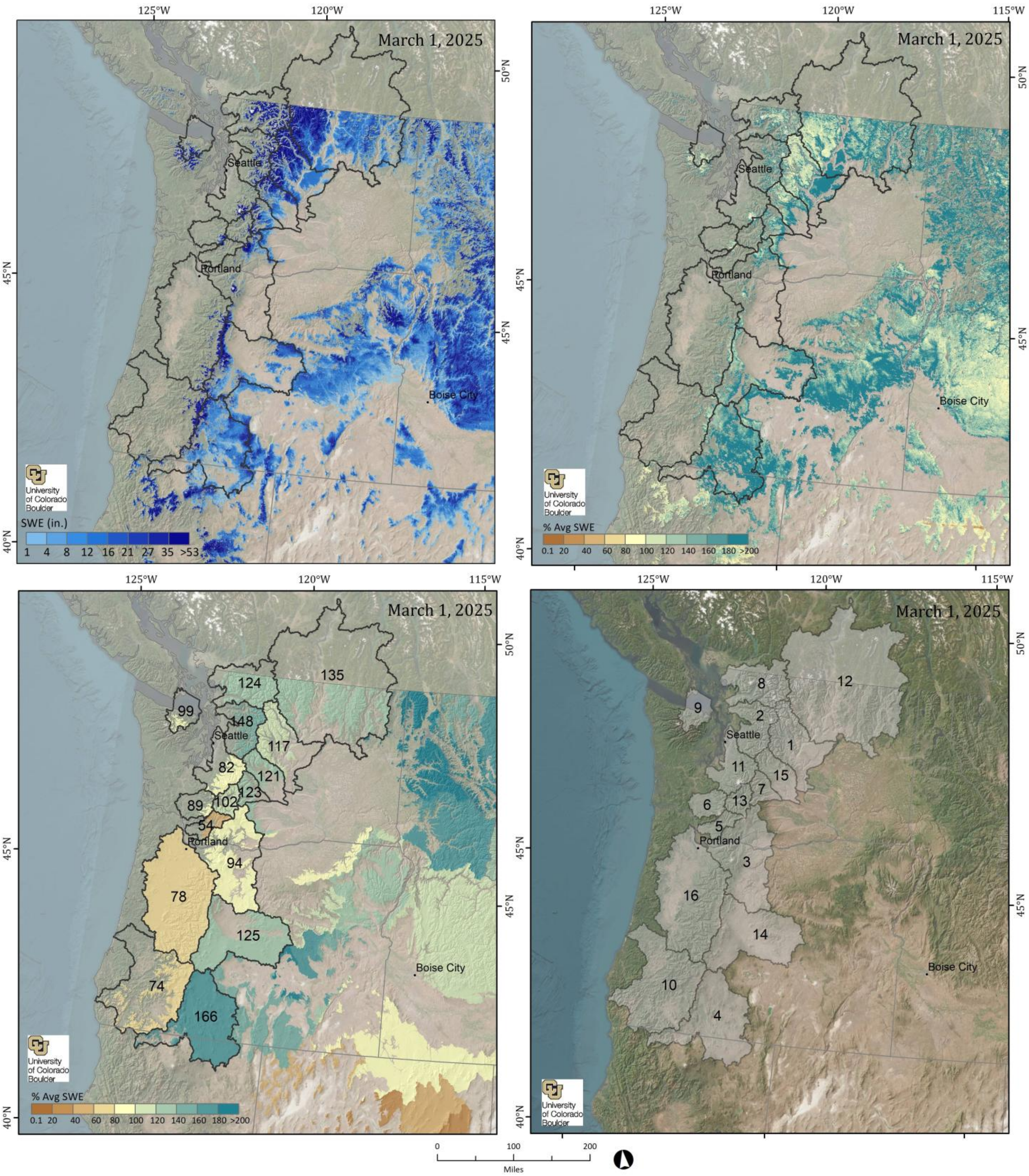

Figure 3. Estimated SWE and % of Average SWE across the Pacific Northwest Region. *SWE amounts (upper left), percent of long-term average (2001-2021) SWE calculated for each pixel (upper right), basin-wide percent of long-term average (lower left)* shaded areas correspond to the elevation bands used in the banded-elevation tables*, and basin identification numbers that correspond to Table 1 below (lower right). The North Puget Sound and Upper Columbia basin portions that are inside Canada do not contain SWE-fusion model data due to lack of data availability needed to run the model in Canada.*

Table 1. SWE by watershed. Shown are percent of average SWE to date for the current date (2001-21 as derived from the regression model), mean SWE for the current report, current percent of snow-covered area, current 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), first of the month snow surveys, and current snow pillow sensors (the number of stations are in parentheses), for those areas collected, summarized for each basin. ***SWE tables by banded elevation are available below.***

Pacific Northwest SWE Report for 3/1/2025

	% of Average		SWE (in)					Pillows		Surveys
Basin	2/16	3/1	2/16	3/1	SCA	Vol. (AF)	Area (mi. sq)	2/16	3/1	3/1
1. Central Columbia	121	117	17.6	20.4	79.7	2,326,385	2,134	15.8 (7)	18.9 (7)	NA
2. Central Puget Sound	181	148	12.2	11.6	41.4	767,105	1,239	24.0 (5)	28.3 (5)	19.9 (1)
3. Hood-Sandy-Lower Deschutes	121	94	3.0	2.5	12.4	681,737	5,079	17.2 (11)	19.1 (11)	7.9 (2)
4. Klamath	119	166	5.5	8.1	61.4	3,127,954	7,197	19.6 (16)	19.3 (15)	23.4 (5)
5. Lewis	73	54	2.6	2.2	8.4	68,294	581	25.9 (7)	29.0 (7)	NA
6. Lower Cowlitz	104	89	7.9	7.5	34.0	74,516	185	17.6 (2)	18.8 (2)	NA
7. Naches	151	123	11.6	11.0	52.8	358,523	610	28.4 (4)	34.3 (4)	NA
8. North Puget Sound	139	124	10.3	10.7	38.0	1,324,486	2,312	24.0 (8)	28.9 (9)	6.8 (6)
9. Olympic	114	99	17.5	17.7	58.1	224,884	238	19.4 (3)	24.1 (3)	11.6 (3)
10. Rogue-Umpqua	84	74	3.3	3.3	12.0	600,233	3,371	12.8 (6)	12.5 (6)	10.1 (13)
11. South Puget Sound	99	82	4.3	4.1	14.7	248,031	1,148	15.5 (14)	17.9 (14)	5.5 (4)
12. Upper Columbia	133	135	13.1	14.8	78.0	4,345,316	5,502	11.8 (7)	13.9 (7)	9.9 (19)
13. Upper Cowlitz	138	102	7.3	6.0	20.1	228,144	713	26.0 (3)	30.2 (3)	NA
14. Upper Deschutes-Crooked	150	125	7.9	6.5	39.0	1,932,177	5,607	22.3 (7)	24.4 (7)	17.0 (7)
15. Upper Yakima	134	121	12.6	13.5	66.2	745,656	1,033	16.8 (3)	20.0 (3)	NA
16. Willamette	94	78	1.2	1.1	4.0	668,992	11,360	11.1 (18)	11.3 (18)	NA

*Basin boundaries were derived from a combination of NRCS basins and HUC8 boundaries.

North Continental

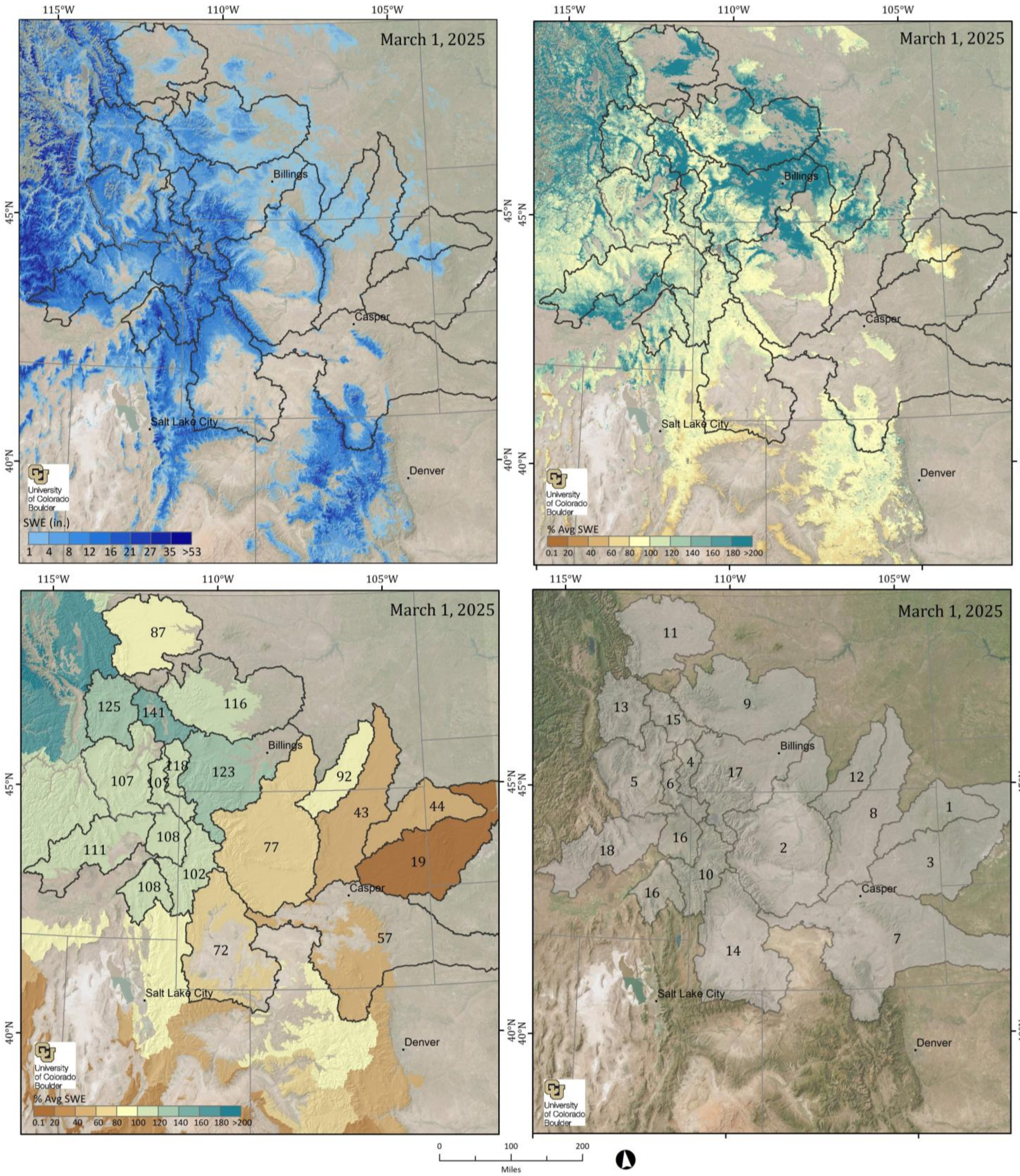

Figure 4. Estimated SWE and % of Average SWE across the North Continental Region. *SWE amounts (upper left), percent of long-term average (2001-2021) SWE calculated for each pixel (upper right), basin-wide percent of long-term average (lower left)* shaded areas correspond to the elevation bands used in the banded-elevation tables*, and basin identification numbers that correspond to Table 2 below (lower right).*

Table 2. SWE by watershed. Shown are percent of average SWE to date for the current date (2001-21 as derived from the regression model), mean SWE for the current report, current percent of snow-covered area, current 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), first of the month snow surveys, and current snow pillow sensors (the number of stations are in parentheses), for those areas collected, summarized for each basin. *SWE tables by banded elevation are available below.*

North Continental SWE Report for 3/1/2025

	% of Average		SWE (in)					Pillows		Surveys
Basin	2/16	3/1	2/16	3/1	SCA	Vol. (AF)	Area (mi. sq)	2/16	3/1	3/1
1. Belle Fourche	108	44	2.3	0.7	15.7	259,110	7,203	4.4 (1)	4.7 (1)	4.8 (4)
2. Bighorn	114	77	4.7	2.8	32.0	3,445,365	22,741	8.4 (21)	9.2 (21)	7.1 (11)
3. Cheyenne	129	19	1.7	0.2	3.9	145,862	15,348	4.4 (2)	4.7 (2)	2.7 (3)
4. Gallatin	106	118	7.1	8.1	80.2	795,418	1,846	14.6 (4)	16.6 (4)	12.4 (4)
5. Jefferson	107	107	7.7	7.2	64.5	3,387,135	8,788	8.7 (14)	10.3 (14)	9.8 (13)
6. Madison Headwaters in WY	112	107	7.9	7.4	65.6	1,000,311	2,521	12.3 (7)	14.0 (7)	7.9 (5)
7. North Platte	98	57	7.5	4.0	36.7	2,216,663	10,282	13.0 (22)	15.0 (22)	13.4 (13)
8. Powder	123	43	3.0	0.6	10.2	424,221	13,384	4.6 (5)	4.9 (5)	3.1 (2)
9. Smith-Judith-Musselshell	125	116	6.3	4.4	53.2	1,948,662	8,336	11.2 (9)	12.3 (9)	10.3 (6)
10. Snake	97	102	10.0	11.6	89.2	3,482,570	5,625	15.7 (11)	18.2 (11)	12.9 (11)
11. Sun-Teton-Marias	172	87	6.8	1.9	18.4	1,062,685	10,460	5.5 (5)	6.7 (5)	6.6 (4)
12. Tongue	119	92	4.0	1.6	29.9	460,915	5,400	6.3 (6)	6.8 (6)	8.4 (3)
13. Upper Clark Fork	112	125	6.7	7.8	72.7	2,485,038	5,983	8.3 (12)	9.9 (12)	7.0 (18)
14. Upper Green	94	72	7.7	6.0	55.6	3,076,771	9,542	10.7 (21)	11.9 (22)	13.7 (2)
15. Upper Missouri	127	141	6.3	5.9	68.2	928,795	2,950	5.7 (2)	6.5 (2)	5.8 (3)
16. Upper Snake Basins	104	108	7.8	8.8	78.2	3,237,058	6,872	15.2 (11)	17.8 (11)	16.4 (19)
17. Upper Yellowstone	120	123	7.1	6.8	67.0	4,014,566	11,070	11.1 (20)	12.7 (20)	7.8 (8)
18. Wood and Lost Basins	112	111	9.1	9.4	84.0	3,723,023	7,421	10.9 (16)	11.9 (16)	6.5 (13)

*Basin boundaries were derived from a combination of NRCS basins and HUC8 boundaries.

South Continental

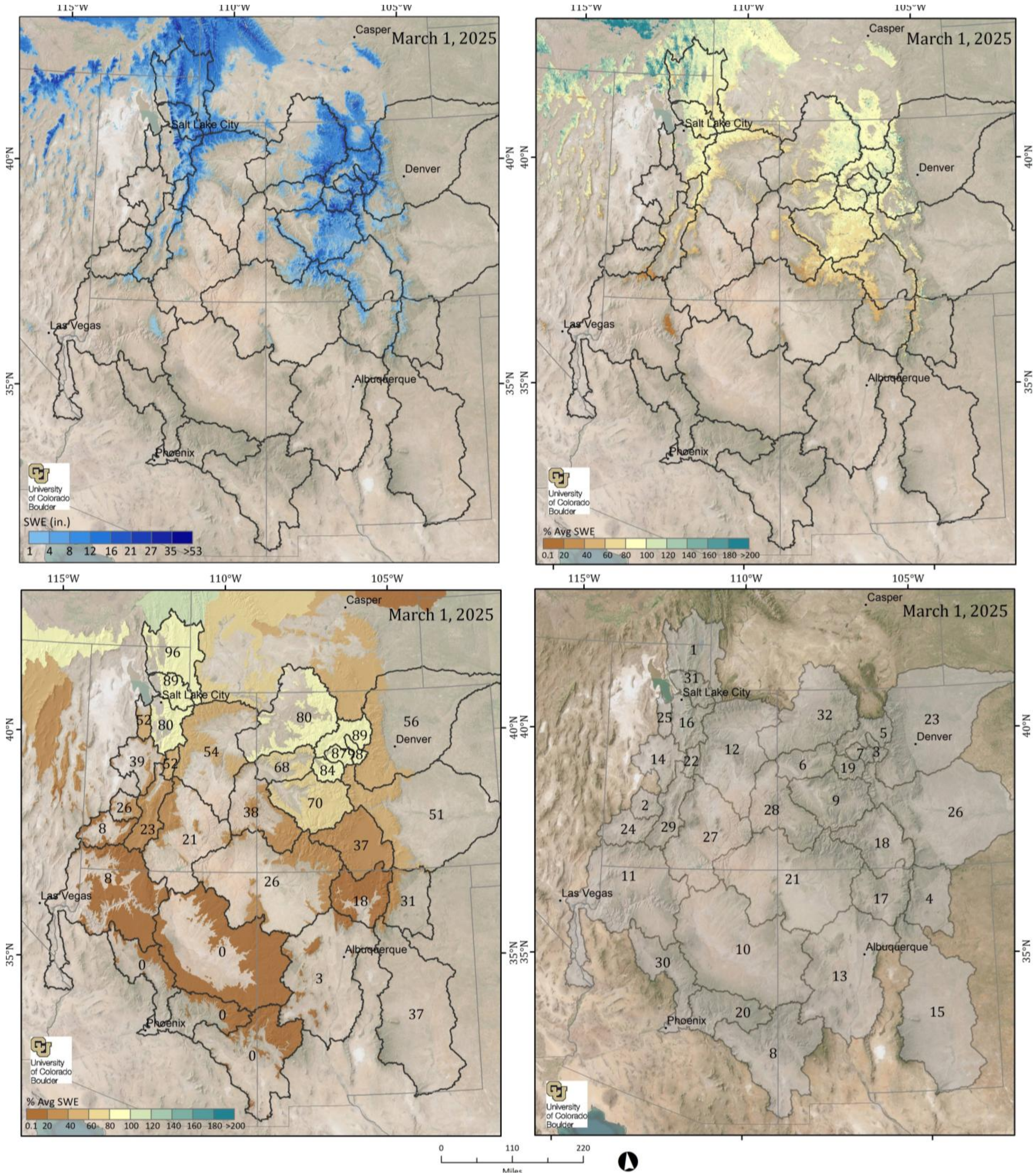

Figure 5. Estimated SWE and % of Average SWE across the South Continental Region. SWE amounts (upper left), percent of long-term average (2001-2021) SWE calculated for each pixel (upper right), basin-wide percent of long-term average (lower left) shaded areas correspond to the elevation bands used in the banded-elevation tables, and basin identification numbers that correspond to Table 3 below (lower right).

Table 3. SWE by watershed. Shown are percent of average SWE to date for the current date (2001-21 as derived from the regression model), mean SWE for the current report, current percent of snow-covered area, current 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), first of the month snow surveys, and current snow pillow sensors (the number of stations are in parentheses), for those areas collected, summarized for each basin. *SWE tables by banded elevation are available below.*

South Continental SWE Report for 3/1/2025

	% of Average		SWE (in)					Pillows		Surveys
Basin	2/16	3/1	2/16	3/1	SCA	Vol. (AF)	Area (mi. sq)	2/16	3/1	3/1
1. Bear	96	96	7.8	8.8	79.9	2,894,251	6,182	12.6 (18)	14.8 (18)	13.1 (10)
2. Beaver	52	26	1.5	0.7	9.7	32,651	836	7.8 (2)	8.1 (2)	NA
3. Blue	103	98	9.4	10.2	78.9	364,068	669	12.3 (5)	14.2 (5)	8.3 (2)
4. Canadian	55	31	1.7	0.6	12.2	40,619	1,265	4.2 (2)	4.3 (2)	0.5 (2)
5. Colorado Headwaters	95	89	8.2	8.7	75.4	1,338,475	2,873	11.0 (13)	13.0 (13)	11.8 (14)
6. Colorado Headwaters-Plateau	75	68	6.2	5.4	50.4	518,005	1,801	9.4 (1)	9.9 (1)	10.6 (1)
7. Eagle	97	87	8.6	8.3	65.1	406,439	921	10.7 (3)	11.9 (3)	13.4 (2)
8. Gila	2	0	0.0	0.0	0.0	25	4,924	0.2 (5)	0.1 (6)	2.7 (4)
9. Gunnison	77	70	6.5	6.2	64.9	2,115,701	6,434	9.5 (11)	10.1 (11)	9.3 (6)
10. Little Colorado	1	0	0.0	0.0	0.1	1,518	16,380	2.9 (5)	2.1 (5)	0.8 (12)
11. Lower Colorado Mainstream	4	8	0.0	0.1	2.9	28,632	10,695	3.4 (5)	2.9 (5)	1.2 (3)
12. Lower Green	71	54	5.8	4.6	44.6	1,393,597	5,648	7.1 (23)	7.7 (24)	13.6 (1)
13. Lower Rio Grande	11	3	0.2	0.1	1.1	5,251	1,795	1.7 (6)	1.4 (6)	0.0 (1)
14. Lower Sevier	71	39	3.5	1.4	16.2	67,090	897	6.6 (4)	7.6 (4)	NA
15. Pecos	56	37	2.4	1.2	19.1	20,675	331	3.0 (2)	1.3 (2)	NA
16. Provo-Utah Lake-Jordan	85	80	6.4	5.8	52.9	835,965	2,681	14.5 (17)	16.2 (17)	13.7 (9)
17. Rio Chama-Upper Rio Grande	21	18	0.9	0.6	10.7	172,144	5,207	3.6 (13)	3.4 (13)	2.6 (4)
18. Rio Grande Headwaters	50	37	2.6	1.8	23.6	728,888	7,594	6.2 (14)	6.4 (14)	4.7 (6)
19. Roaring Fork	93	84	9.8	9.2	70.7	663,798	1,359	11.1 (7)	12.1 (7)	10.6 (1)
20. Salt	0	0	0.0	0.0	0.2	368	2,362	0.8 (6)	0.3 (7)	NA
21. San Juan	28	26	1.5	1.4	17.2	472,504	6,406	7.8 (15)	7.7 (15)	1.0 (6)
22. San Pitch	57	52	3.6	3.1	28.2	141,898	858	9.5 (6)	10.0 (6)	11.2 (2)
23. South Platte	92	56	4.8	2.7	26.1	800,793	5,620	9.4 (21)	10.8 (21)	6.9 (29)
24. Southwestern Utah	14	8	0.3	0.1	3.0	11,084	1,440	2.9 (4)	3.0 (3)	2.6 (1)
25. Toole Valley-Vernon Creek	80	52	2.6	1.2	12.0	60,136	906	9.2 (4)	10.3 (4)	NA
26. Upper Arkansas	85	51	3.2	1.9	20.3	604,574	5,877	6.1 (7)	6.2 (7)	7.5 (5)
27. Upper Colorado-Dirty Devil	33	21	1.7	1.0	13.0	133,982	2,598	3.6 (7)	3.7 (7)	10.3 (2)
28. Upper Colorado-Dolores	46	38	2.9	2.4	33.6	442,383	3,434	8.4 (8)	8.8 (8)	5.2 (3)
29. Upper Sevier	36	23	1.8	1.1	16.7	220,498	3,759	4.9 (16)	5.0 (16)	3.4 (2)
30. Verde	0	0	0.0	0.0	0.0	104	1,817	1.2 (7)	0.2 (7)	0.0 (3)
31. Weber-Ogden	92	89	8.2	8.1	72.8	881,879	2,041	13.6 (17)	14.8 (16)	NA
32. White-Yampa	91	80	8.0	7.4	62.2	2,347,787	5,948	13.8 (15)	15.8 (15)	13.9 (4)

*Basin boundaries were derived from a combination of NRCS basins and HUC8 boundaries.

Intermountain

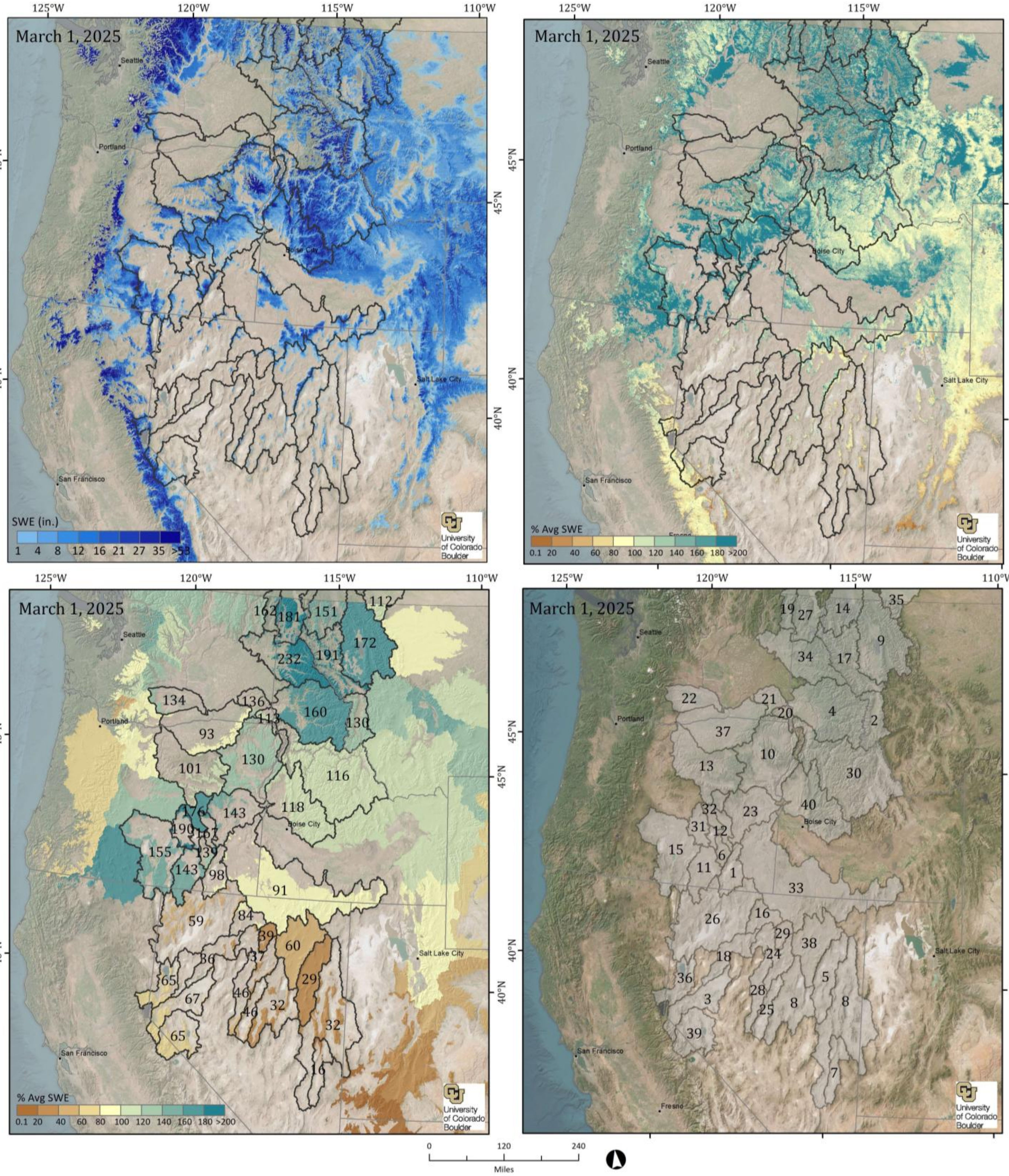

Figure 6. Estimated SWE and % of Average SWE across the Intermountain Region. SWE amounts (upper left), percent of long-term average (2001-2021) SWE calculated for each pixel (upper right), basin-wide percent of long-term average (lower left) shaded areas correspond to the elevation bands used in the banded-elevation tables, and basin identification numbers that correspond to Table 4 below (lower right).

Table 4. SWE by watershed. Shown are percent of average SWE to date for the current date (2001-21 as derived from the regression model), mean SWE for the current report, current percent of snow-covered area, current 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), first of the month snow surveys, and current snow pillow sensors (the number of stations are in parentheses), for those areas collected, summarized for each basin. <u>*SWE tables by banded elevation are available below.*</u>

Intermountain SWE Report for 3/1/2025

	% of Average		SWE (in)					Pillows		Surveys
Basin	2/16	3/1	2/16	3/1	SCA	Vol. (AF)	Area (mi. sq)	2/16	3/1	3/1
1. Alvord Lake	127	98	8.9	6.8	47.6	117,371	324	NA	NA	11.2 (4)
2. Bitterroot	113	130	7.9	10.2	69.1	1,062,153	1,952	15.4 (4)	18.2 (4)	5.4 (1)
3. Carson	83	67	4.4	3.7	23.0	279,029	1,405	14.9 (7)	14.4 (7)	3.8 (1)
4. Clearwater Basin	145	160	6.5	8.1	49.6	3,234,427	7,488	20.8 (11)	25.2 (11)	8.7 (2)
5. Clover Valley and Franklin	90	29	2.7	0.7	9.2	160,459	4,051	11.8 (2)	14.7 (2)	22.3 (1)
6. Donner und Blitzen	134	139	14.1	16.3	95.8	193,036	222	29.2 (2)	33.7 (2)	NA
7. Dry Lake Valley	19	16	0.8	0.4	6.6	5,733	289	NA	NA	NA
8. Eastern Nevada	67	32	2.8	1.0	12.4	240,836	4,372	4.6 (8)	4.9 (8)	2.7 (8)
9. Flathead	124	172	5.1	7.7	55.9	3,092,558	7,521	14.9 (13)	18.4 (12)	10.7 (18)
10. Grande Ronde-Burnt-Powder_Imnaha	124	130	10.0	10.3	66.7	2,917,093	5,311	15.7 (10)	17.8 (11)	17.6 (12)
11. Guano	141	143	3.9	2.4	23.3	258,337	2,039	0.7 (1)	0.0 (1)	8.7 (2)
12. Harney-Malheur Lakes	138	167	7.1	8.7	76.0	128,233	276	NA	NA	7.8 (2)
13. John Day	103	101	7.9	7.7	50.6	618,863	1,502	17.3 (2)	19.5 (2)	NA
14. Kootenai	137	151	5.9	7.4	44.7	662,214	1,673	14.6 (5)	16.9 (5)	15.8 (2)
15. Lake County-Goose Lake	135	155	6.8	7.9	55.8	1,511,466	3,600	21.1 (2)	22.5 (2)	17.1 (10)
16. Little Humboldt	120	84	7.4	4.6	35.2	103,421	419	9.9 (3)	14.7 (3)	NA
17. Lower Clark Fork	185	191	9.4	11.2	64.8	875,559	1,465	24.9 (4)	30.4 (4)	20.3 (5)
18. Lower Humboldt	60	36	2.5	1.1	9.5	16,091	274	6.1 (1)	7.9 (1)	NA
19. Lower Pend Oreille	161	162	12.7	13.1	60.1	90,058	129	17.7 (1)	20.9 (1)	NA
20. Lower Snake-Asotin	111	113	4.3	3.7	28.5	64,087	328	5.6 (2)	6.2 (2)	NA

*Basin boundaries were derived from a combination of NRCS basins and HUC8 boundaries.

Intemountain SWE Report for 3/1/2025

	% of Average		SWE (in)					Pillows		Surveys
Basin	2/16	3/1	2/16	3/1	SCA	Vol. (AF)	Area (mi. sq)	2/16	3/1	3/1
21. Lower Snake-Tucannon	149	136	11.0	10.0	71.7	58,026	109	NA	NA	NA
22. Lower Yakima	181	134	10.6	7.5	50.9	196,387	489	17.5 (2)	19.5 (2)	NA
23. Malheur	139	143	10.2	11.4	84.6	604,395	992	14.6 (3)	16.0 (3)	5.6 (2)
24. Middle Humboldt	95	37	3.9	0.9	8.3	32,027	633	NA	NA	13.7 (1)
25. Northern Big Smoky Valley	86	46	4.4	1.6	15.4	49,810	570	NA	NA	NA
26. Northern Great Basin	98	59	4.9	2.2	17.4	264,247	2,227	6.5 (2)	6.9 (2)	4.2 (2)
27. Panhandle Basins	171	181	7.6	8.5	48.9	747,329	1,643	21.0 (3)	25.0 (3)	17.6 (1)
28. Reese	94	46	5.4	1.7	14.0	43,598	491	9.4 (2)	10.7 (2)	NA
29. Rock	65	39	2.6	1.0	8.8	42,627	835	12.1 (1)	14.4 (1)	2.4 (1)
30. Salmon Basin	110	116	10.1	11.8	78.3	7,485,814	11,933	15.8 (11)	18.0 (11)	8.8 (6)
31. Silver	159	190	7.8	8.7	70.1	200,462	431	NA	NA	NA
32. Silvies	159	176	9.3	10.2	86.3	714,668	1,316	13.5 (2)	14.5 (2)	NA
33. Southern Snake Basins	101	91	4.6	3.6	29.5	2,404,209	12,501	9.3 (13)	11.9 (13)	7.0 (18)
34. Spokane	209	232	6.6	6.9	43.9	1,160,925	3,146	13.9 (8)	16.5 (8)	10.9 (9)
35. St. Mary	106	112	8.0	8.8	67.7	302,822	648	6.4 (1)	7.5 (1)	NA
36. Truckee	77	65	4.9	4.6	28.5	344,794	1,420	17.3 (8)	17.5 (9)	NA
37. Umatilla-Walla Walla-Willow	107	93	3.8	3.0	20.1	233,130	1,434	15.1 (7)	17.7 (7)	NA
38. Upper Humboldt	88	60	4.1	2.2	21.2	598,803	5,033	11.1 (8)	12.9 (8)	9.2 (12)
39. Walker	89	65	4.2	3.2	34.0	330,072	1,939	15.7 (7)	15.7 (7)	NA
40. West Central Basins	113	118	12.8	14.3	85.9	4,275,762	5,617	21.7 (14)	24.8 (14)	17.9 (12)

*Basin boundaries were derived from a combination of NRCS basins and HUC8 boundaries.

Sierra Nevada

There is a separate SWE report that has a stronger focus on the Sierra Nevada available **here**. The separate report uses additional vetting measures and bias-corrects with Airborne Snow Observatory data. Below is a sample of the maps provided in that report.

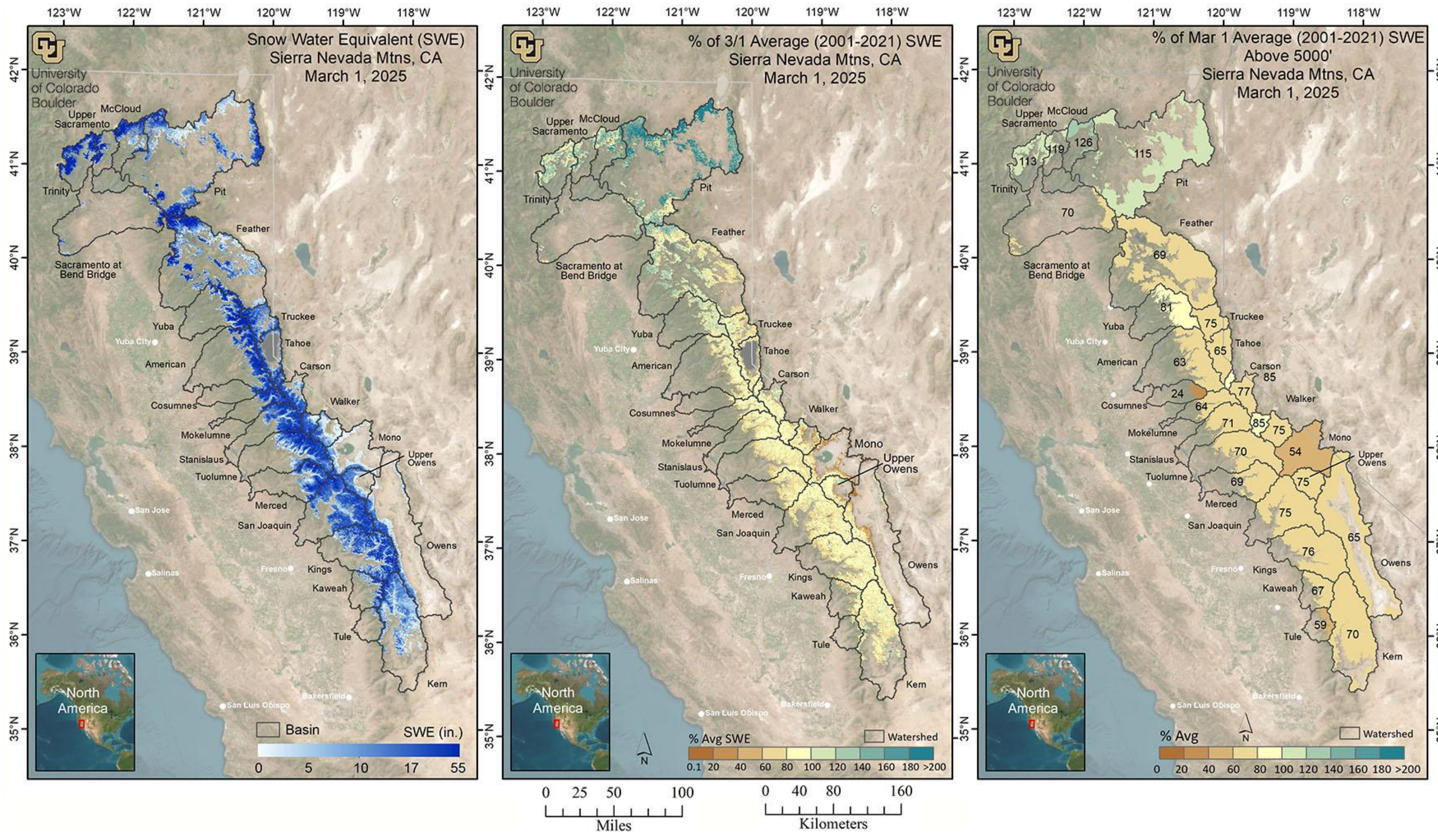

Figure 7. Estimated SWE and % of Average SWE across the Sierra Nevada. SWE amounts (left), and percent of average (2001-2021) SWE for the Sierra Nevada, calculated for each pixel (middle) and basin-wide (right). Basin-wide percent of average is calculated across all model pixels >5000' elevation.

Table 5. SWE by watershed. Shown are percent of average SWE to date for the current date (2001-21 as derived from the regression model), mean SWE for the current report, current percent of snow-covered area, current 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), first of the month snow surveys, and current snow pillow sensors (the number of stations are in parentheses), for those areas collected, summarized for each basin.

Sierra Nevada SWE Report for 3/1/2025

	% of Average		SWE (in)					Pillows		Surveys	
	2/16	3/1	2/16	3/1	SCA	Vol. (AF)‡	Area (mi. sq)	2/16	3/1	3/1	SNODAS*
Trinity	127	113	22.6	23.1	86.7	395,802	321.4	28.7 (4)	27.8 (4)	30.0 (1)	32.7
Upper Sacramento	136	119	22.5	22.5	80.6	138,233	115.2	33.7 (1)	32.3 (1)	37.5 (2)	28.3
McCloud	138	126	20.1	20.3	83.8	178,665	164.9	28.5 (1)	28.0 (1)	27.5 (2)	32.4
Pit	99	115	6.8	7.3	41.0	801,109	2063.1	21.3 (7)	22.0 (7)	16.0 (1)	6.6
Sacramento at Bend Bridge	60	70	7.5	8.8	35.9	111,864	239.6	NA	NA	NA	10.8
Feather§	77	69	9.2	9.0	48.8	999,786	2085.6	23.7 (6)	23.9 (6)	20.4 (21)	11.2
Yuba§	88	81	14.3	12.8	62.5	352,353	516.1	38.0 (5)	37.7 (5)	27.7 (12)	21.9
American	69	63	11.4	11.3	56.4	475,326	791.9	17.9 (10)	16.2 (11)	17.0 (18)	13.6
Cosumnes	25	24	2.9	2.9	17.3	14,212	91.9	NA	NA	NA	3.5
Mokelumne	71	64	11.7	11.6	56.7	193,954	314.1	20.2 (3)	22.0 (3)	19.4 (11)	13.9
Stanislaus	75	71	12.4	12.5	66.2	370,905	557.1	23.5 (5)	23.8 (5)	18.3 (12)	12.8
Tuolumne§	76	70	12.8	11.2	66.7	541,145	909.4	20.3 (7)	20.4 (7)	18.5 (17)	14.4
Merced§	79	69	12.3	11.0	65.1	315,163	538.8	22.0 (2)	22.7 (2)	17.4 (6)	13.7
San Joaquin	81	75	13.0	12.7	71.6	817,358	1207.1	11.9 (7)	12.5 (7)	18.1 (17)	11.9
Kings§	80	76	12.7	12.8	70.1	821,589	1207.0	14.4 (7)	13.6 (5)	16.9 (22)	12.0
Kaweah§	62	67	7.5	7.2	47.0	119,807	314.1	13.7 (2)	25.5 (1)	13.4 (4)	8.4
Tule	35	59	2.1	3.5	24.1	25,686	137.6	NA	5.2 (1)	3.8 (2)	1.4
Kern§	66	70	7.6	5.1	46.5	459,092	1682.1	11.7 (6)	9.0 (3)	14.3 (12)	4.1
Truckee	83	75	13.1	12.4	73.4	271,723	411.7	17.9 (6)	18.5 (6)	32.0 (1)	15.0
Tahoe	72	65	11.5	10.9	63.4	177,022	305.4	18.4 (7)	17.0 (7)	19.7 (6)	12.2
W Carson	95	85	16.2	16.0	86.3	54,779	64.3	18.3 (3)	17.9 (3)	24.0 (1)	15.6
E Carson	91	77	11.5	9.8	59.2	186,065	354.3	12.3 (4)	11.9 (4)	NA	8.8
W Walker	101	85	15.0	14.1	88.6	134,740	179.6	18.2 (4)	18.2 (4)	17.0 (1)	16.4
E Walker	99	75	7.3	5.8	66.0	108,592	350.7	12.6 (1)	12.6 (1)	NA	6.5
Mono	82	54	3.7	2.5	37.8	134,505	1003.4	NA	NA	20.0 (4)	2.2
Upper Owens	89	75	8.0	6.8	67.0	134,692	373.8	27.3 (1)	27.3 (1)	22.6 (3)	4.8
Owens	86	65	3.8	2.9	29.5	270,513	1772.1	11.9 (5)	12.8 (5)	11.9 (9)	2.2

§ Data in all ASO-collected basins have been bias-corrected using ASO data and therefore the SWE changes might not represent snowmelt/accumulation but rather an update to the SWE estimates based on airborne data.

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

‡ For volume totals above Shasta Lake add Upper Sac, McCloud and Pit volumes. For volume totals above Bend Bridge add Upper Sac, McCloud, Pit and Sac at Bend Bridge volumes.

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

Elevation Banded SWE Tables:

Due to the length of the banded elevation tables (tables 6-10), that data is being hosted on our GitHub repository. Direct links to all of the tables are below. Access to the GitHub repository for the tables in both HTML and CSV formats is **here**.

- Pacific Northwest
- North Continental
- South Continental
- Intermountain, part 1
- Intermountain, part 2
- Sierra Nevada

The value of spatially explicit estimates of SWE

Snowmelt makes up the large majority (~60-85%) of the annual streamflow in the Western U.S. The spatial distribution of 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 and California DWR CDEC snow pillow sites spread across the Western U.S., providing a critical first-order snapshot of conditions, and the basis for runoff forecasts from the CA DWR, NRCS and NOAA. However, conditions at snow pillow 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 pillow sites. The spatial SWE-fusion creates a detailed picture of the spatial pattern of SWE using snow pillows, satellite, and other data, extending beyond the snow pillow sites to unmonitored areas.

Interpreting the spatial SWE estimates in the context of snow pillow sites

The spatial SWE-fusion product estimates SWE for every pixel where the fractional snow-covered area (fSCA) satellite product identifies snow-cover. Comparatively, snow pillow samples on average 8-20 points per basin within a narrower elevation range. Thus, the basin-wide percent of long-term average from the spatial SWE-fusion estimates is not directly comparable with the snow pillow basin-wide percent of average. A better comparison might be made with the % average in the elevation bands (elevation-banded tables 6-10) that contain snow pillow sites.

Location of Reports, Excel Format Tables, and JPG Maps

https://github.com/CU-Mountain-Hydrology/WestWide

Methods

The spatial SWE-fusion estimation method is described in Yang, et. al. (2022) and Schneider and Molotch (2016). The method uses a General Linear Model in which the dependent variable is derived from the operationally measured in situ SWE from all online NRCS SNOTEL and CDEC snow pillow sites in the domain and when applicable the CoCoRaHS SWE values. The snow pillow SWE observations are scaled by the satellite-based fractional snow-covered area (fSCA) across the 500-meter pixel containing that snow pillow site before being used in the linear regression model. The fSCA is a near-real-time cloud-free daily satellite image from the Snow Today fSCA image (Rittger, et. al. 2019, https://nsidc.org/snow-today) which uses the SPIReS algorithm (Bair, et al. 2021).

The following independent variables (predictors) enter 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 snow pillow-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 snow pillow data are randomly removed and the model prediction is compared to the measured value at the removed snow pillow stations. This is repeated 30 times to obtain an average R-squared value, which denotes how closely the model fits the snow pillow data. During development of this regression method, the model was also validated against independent historical SWE data from Airborne Snow Observatory lidar data and from snow surveys at 10 locations in Colorado.

List of All Known Data Issues/Caveats

- GLACIER & NON-SEASONAL SNOW – SWE values on non-seasonal snow and glaciers need to be excluded before data analysis.
- 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 SNOW SENSOR 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.
- EARLY SEASON FSCA ERRORS – The gap-filled fSCA requires some cloud-free images to determine fSCA amounts. Early in the season and if it has been particularly cloudy the algorithm hasn't had time to calculate fSCA amounts in some areas, typically in the Pacific Northwest and northern areas of the domain.

References and Additional Sources

Bair, E.H., T. Stillinger and J. Dozier (2021). Snow Property Inversion From Remote Sensing (SPIReS): A Generalized Multispectral Unmixing Approach With Examples From MODIS and Landsat 8 OLI. IEEE Transactions on Geoscience and Remote Sensing, 59(9): 7270-7284. DOI: 10.1109/TGRS.2020.3040328.

Commission for Environmental Cooperation (2009). Ecological regions of North America, Level 3, scale 1:4,000,000, Commission for Environmental Cooperation, Montreal, Quebec, Canada.

Hall, D. K. and G. A. Riggs (2021). MODIS/Terra Snow Cover Daily L3 Global 500m SIN Grid, Version 61. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. doi: https://doi.org/10.5067/MODIS/MOD10A1.061. Date Accessed May 10, 2022.

Fang, Y., Liu, Y. & Margulis, S.A. A western United States snow reanalysis dataset over the Landsat era from water years 1985 to 2021 (2022). Sci Data 9, 677. https://doi.org/10.1038/s41597-022-01768-7.

Molotch, N.P. (2009). Reconstructing snow water equivalent in the Rio Grande headwaters using remotely sensed snow cover data and a spatially distributed snowmelt model. *Hydrological Processes*, Vol. 23, doi: 10.1002/hyp.7206, 2009.

Molotch, N.P., and S.A. Margulis (2008). Estimating the distribution of snow water equivalent using remotely sensed snow cover data and a spatially distributed snowmelt model: a multi-resolution, multi-sensor comparison. *Advances in Water Resources*, 31, 2008.

Molotch, N.P., and R.C. Bales (2006). Comparison of ground-based and airborne snow-surface albedo parameterizations in an alpine watershed: impact on snowpack mass balance. *Water Resources Research*, VOL. 42, doi:10.1029/2005WR004522.

Molotch, N.P., and R.C. Bales (2005). Scaling snow observations from the point to the grid-element: implications for observation network design. *Water Resources Research*, VOL. 41, doi: 10.1029/2005WR004229.

Molotch, N.P., T.H. Painter, R.C. Bales, and J. Dozier (2004). Incorporating remotely sensed snow albedo into a spatially distributed snowmelt model. *Geophysical Research Letters*, VOL. 31, doi:10.1029/2003GL019063, 2004.

Rittger, K., M. S. Raleigh, J. Dozier, A. F. Hill, J. A. Lutz, and T. H. Painter (2019). Canopy Adjustment and Improved Cloud Detection for Remotely Sensed Snow Cover Mapping. Water Resources Research 24 August 2019. doi:10.1029/2019WR024914.

Schneider D. and N.P. Molotch (2016). Real-time estimation of snow water equivalent in the Upper Colorado River Basin using MODIS-based SWE reconstructions and SNOTEL data. *Water Resources Research*, 52(10): 7892-7910. DOI: 10.1002/2016WR019067.

Trujillo, E., and N. P. Molotch (2014). Snowpack regimes of the Western United States, Water Resour. Res., 50, 5611–5623, doi:10.1002/ 2013WR014753.

Yang, K., K. N. Musselman, K. Rittger, S. A. Margulis, T. H. Painter and N. P. Molotch (2022). Combining ground-based and remotely sensed snow data in a linear regression model for real-time estimation of snow water equivalent. *Advances in Water Resources,* 160, 2022, 104075. DOI: 10.1016/j.advwatres.2021.104075.