Real-time mapping of SWE in the Sierra Nevada using satellite, airborne, and ground-based data: lessons learned from 2019 and plans for 2020

Noah Molotch

Center for Water, Earth Science, and Technology

Geography / INSTAAR, University of Colorado

Jet Propulsion Laboratory, California Institute of Technology

CCSS

11/07/2019

L. Lestak, K. Musselman, K. Rittger, N. Bair, J. Dozier

K. Yang, T. Painter & ASO team

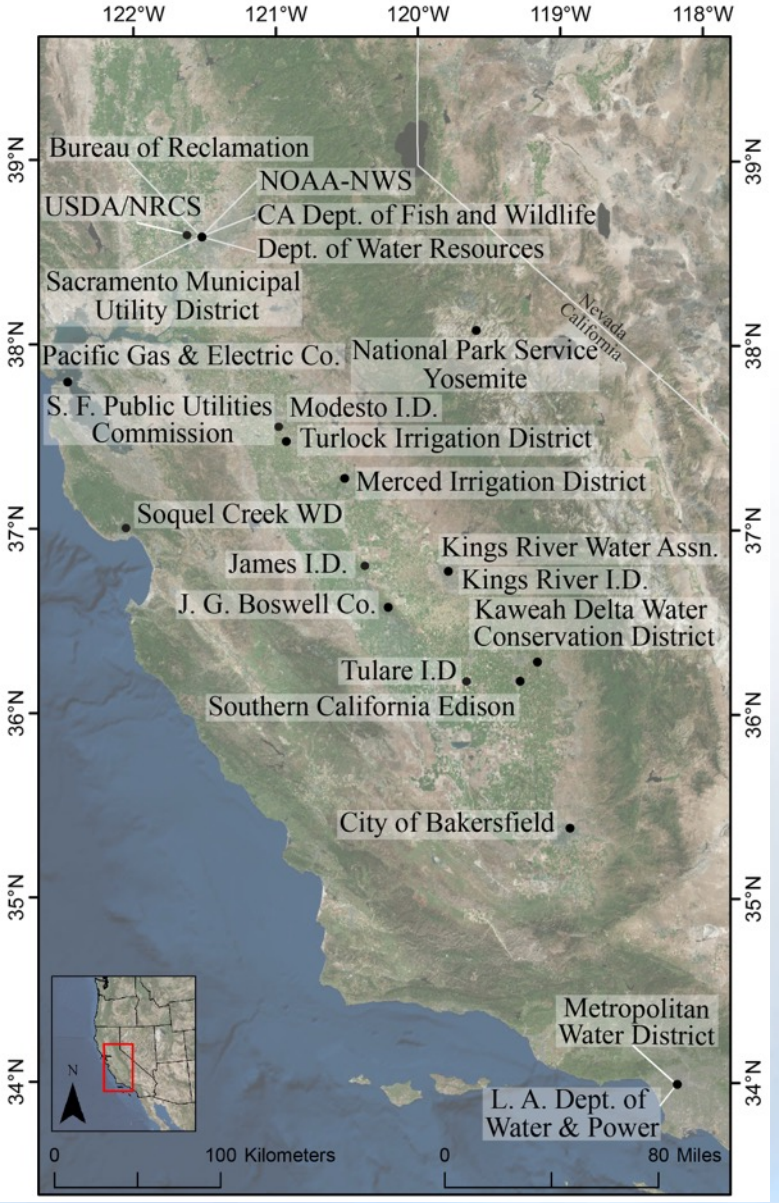
CWEST University of Colorado Boulder INSTAAR JPL

Integrated Real-Time SWE Mapping

Current partners and user community

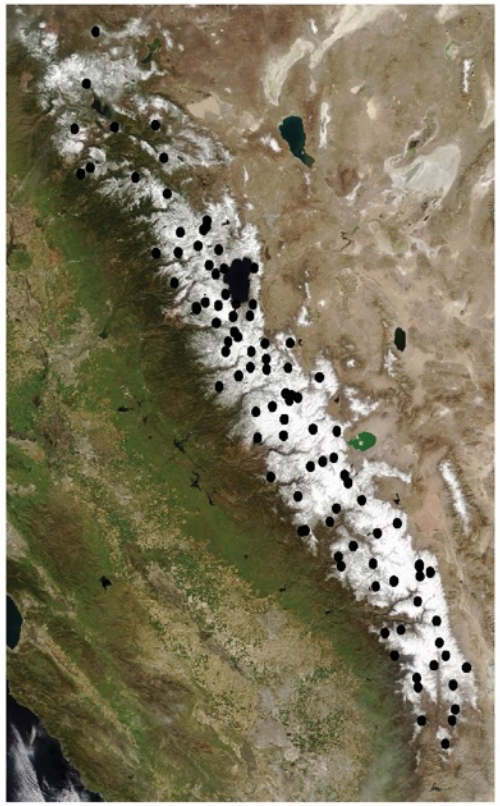
- Partner: California Dept of Water Resources
- Center for Water, Earth Science & Technology
- JPL
- Federal, state and local entities.
- UCSB

University of Colorado Boulder

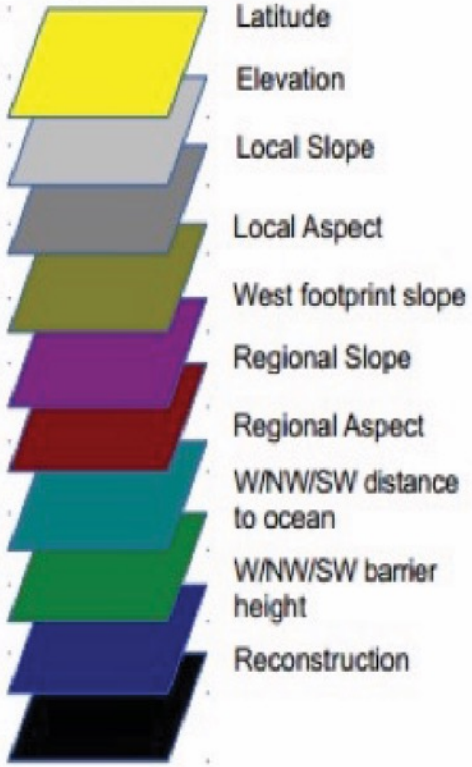


Linear Regression Model (LRM) SWE

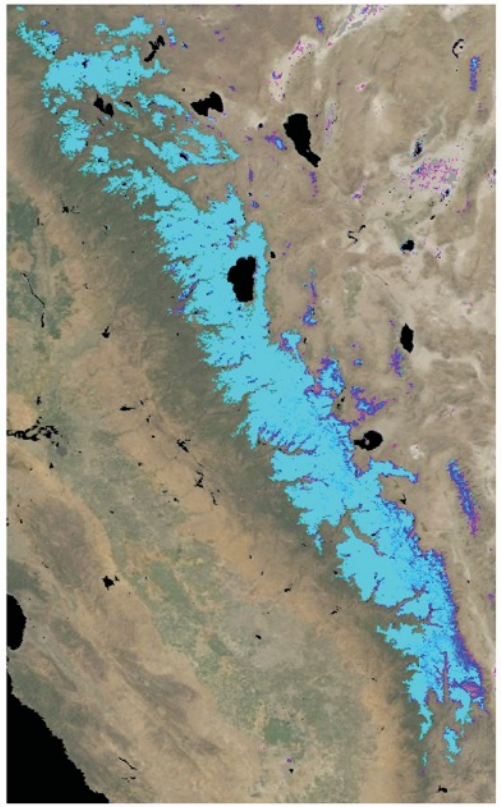
Snow Pillows



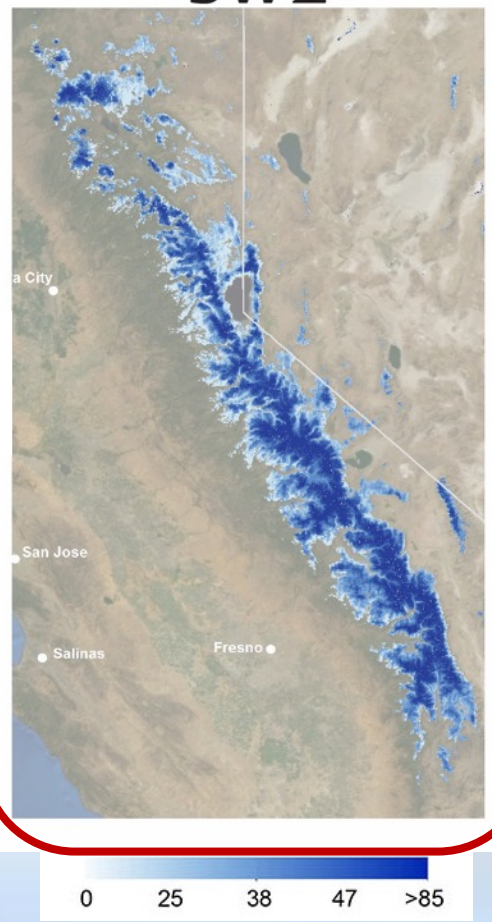
Independent Variables



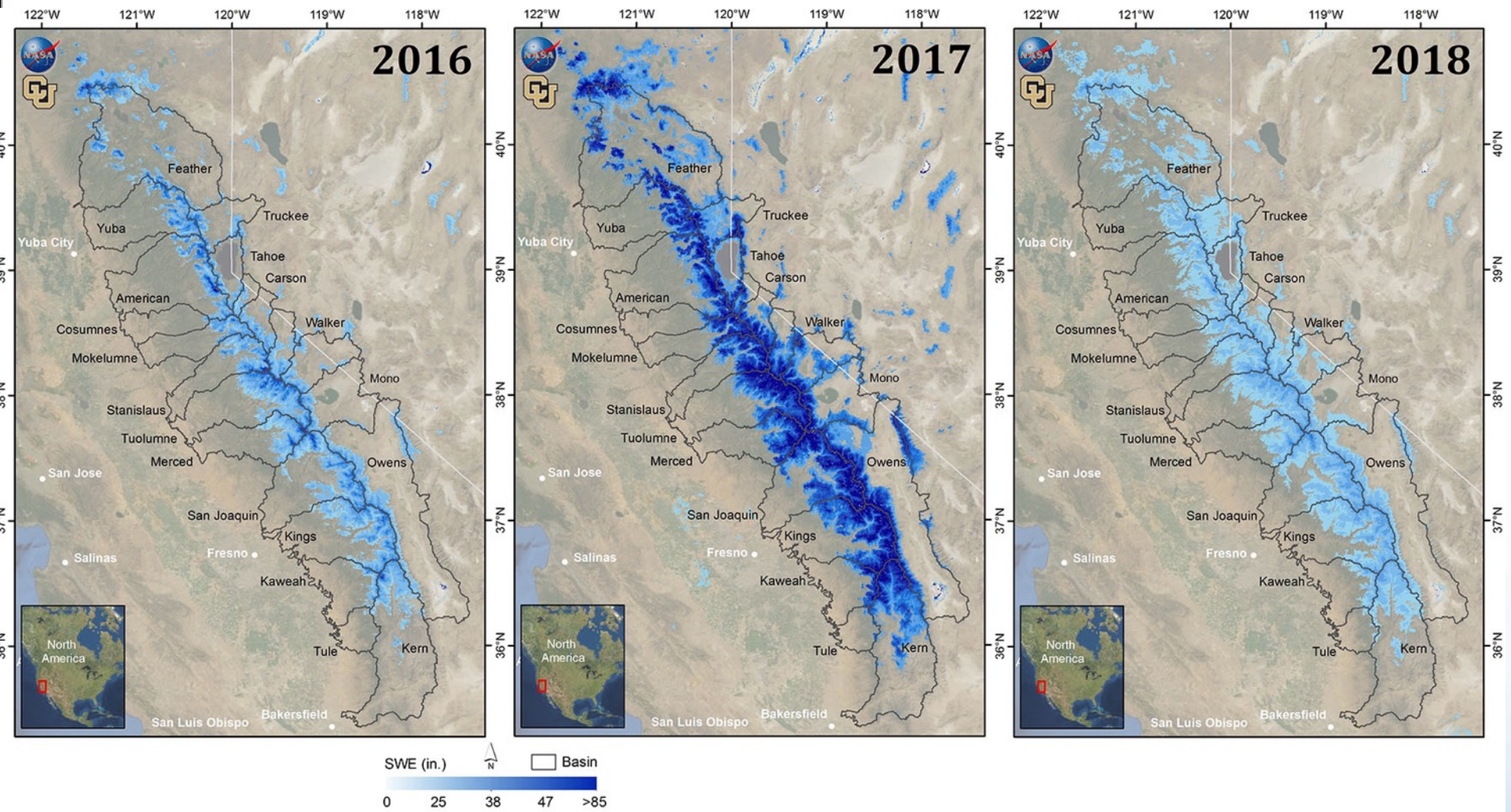
MODSCAG Snow-covered Area

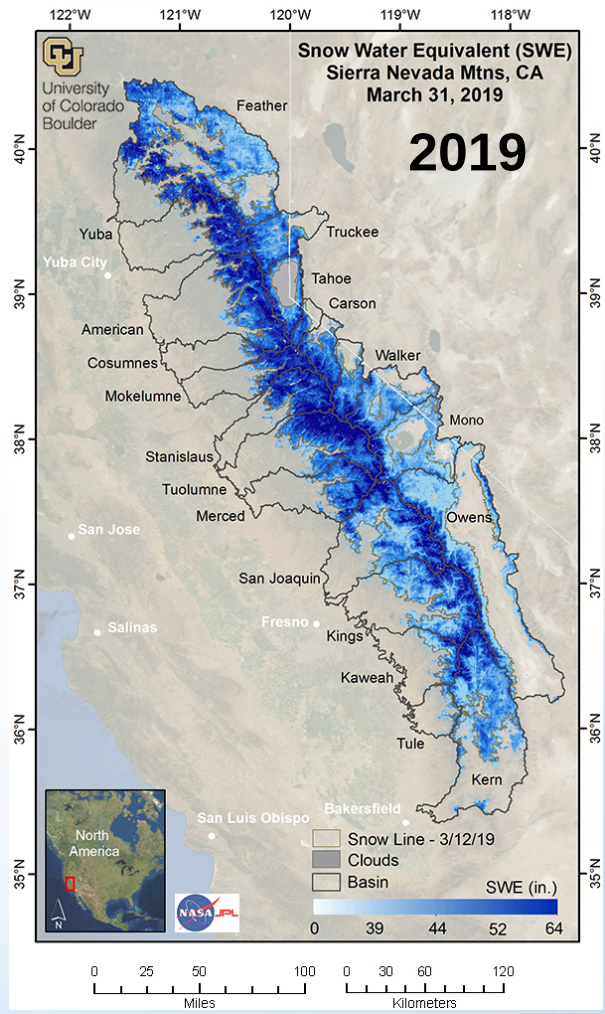


Regression SWE

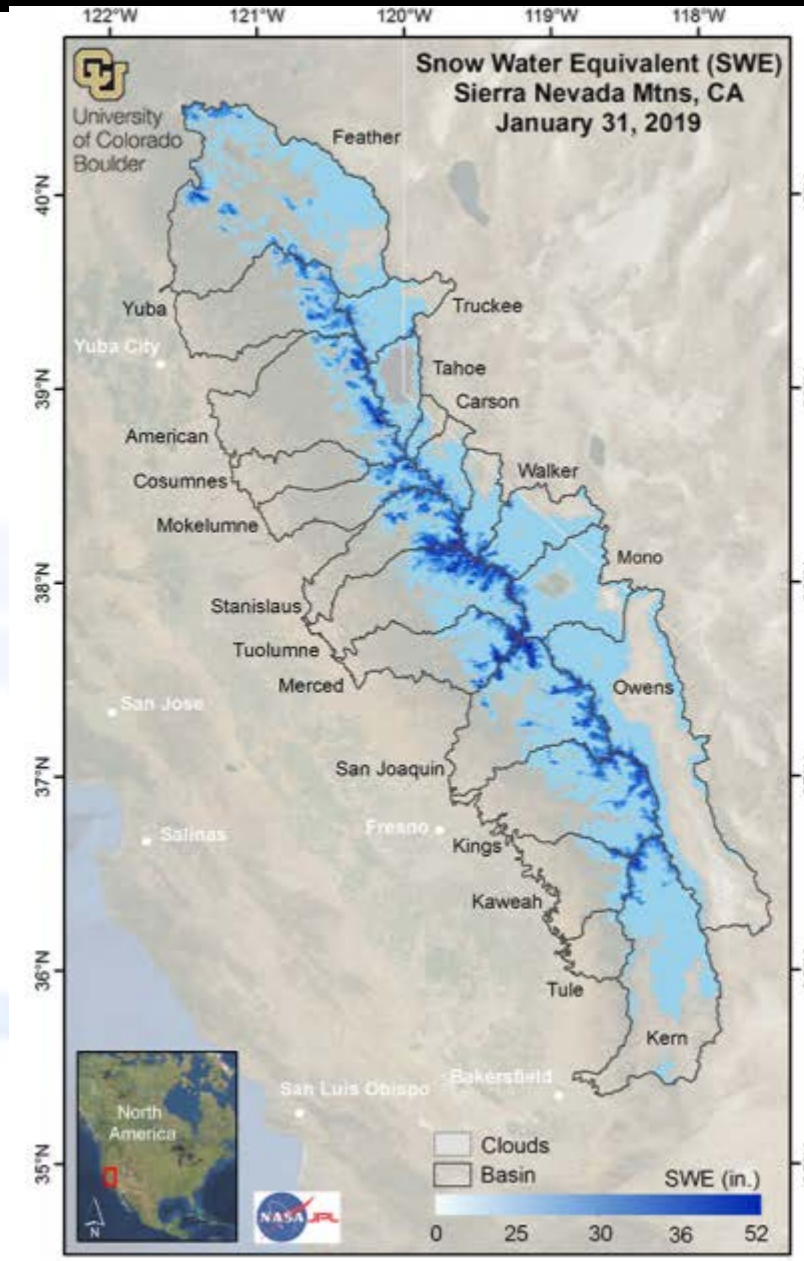


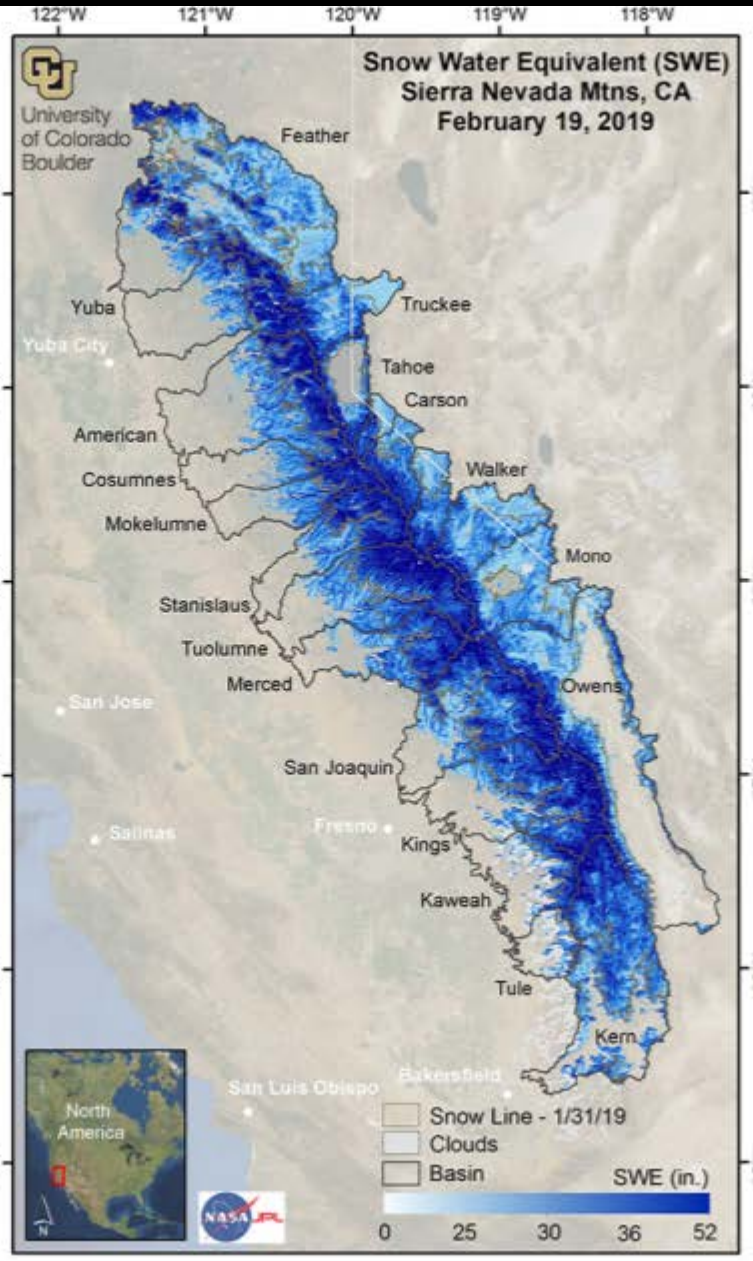
Recent inter-annual variability of April 1st SWE

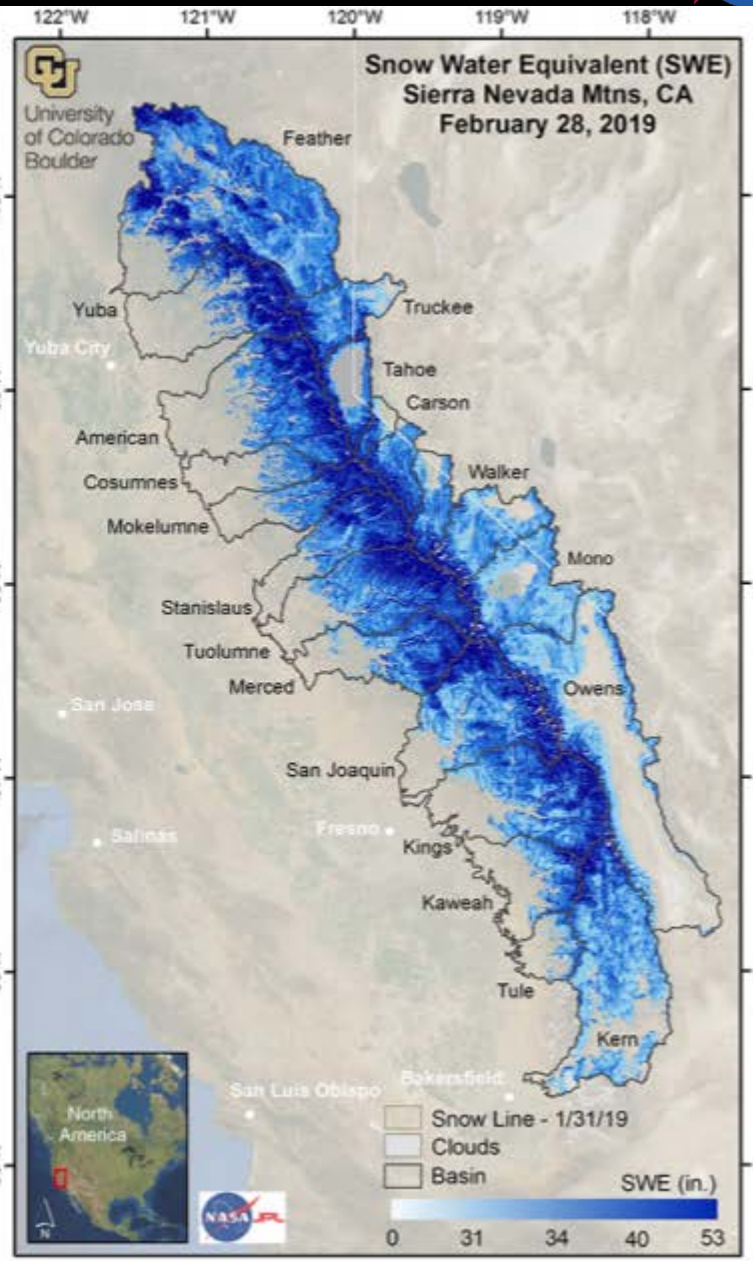




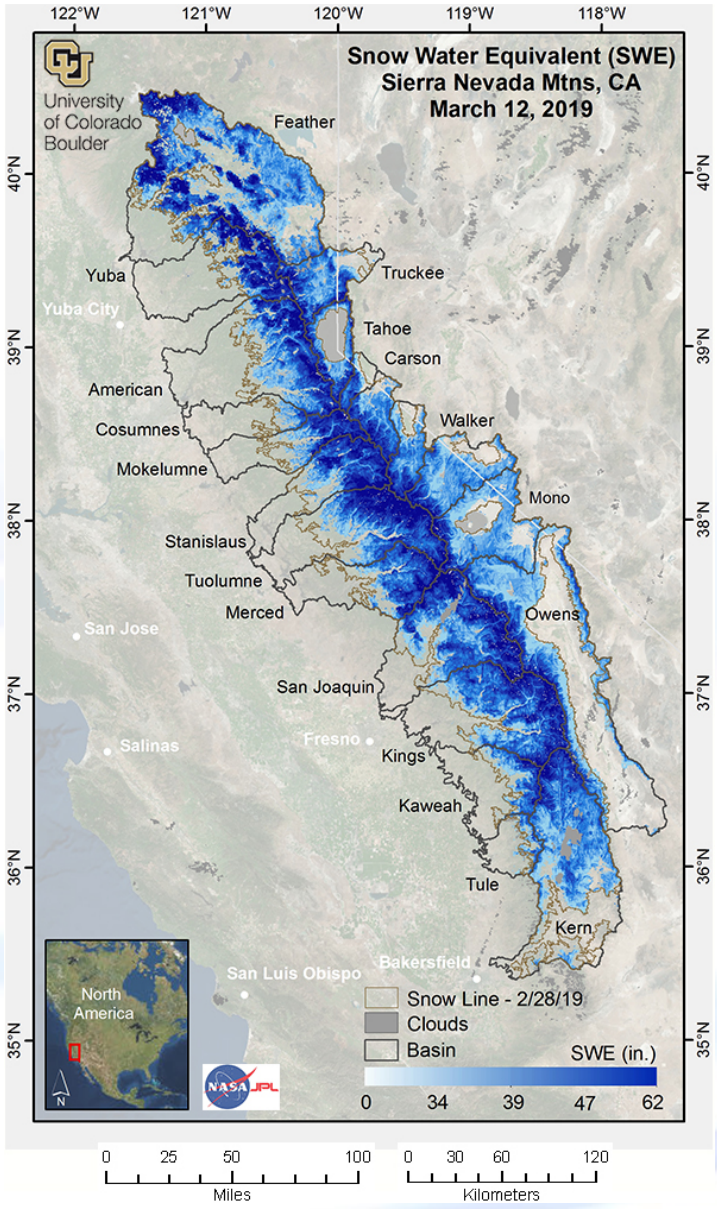
2019 Snow Year in Review

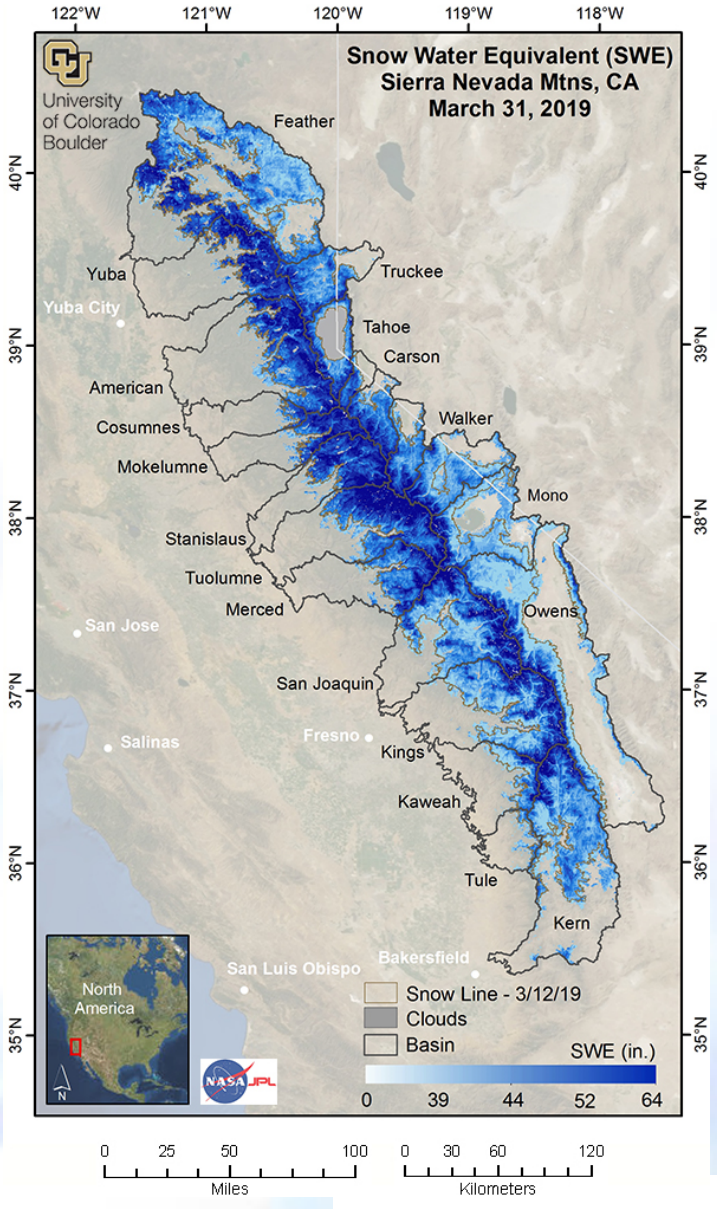


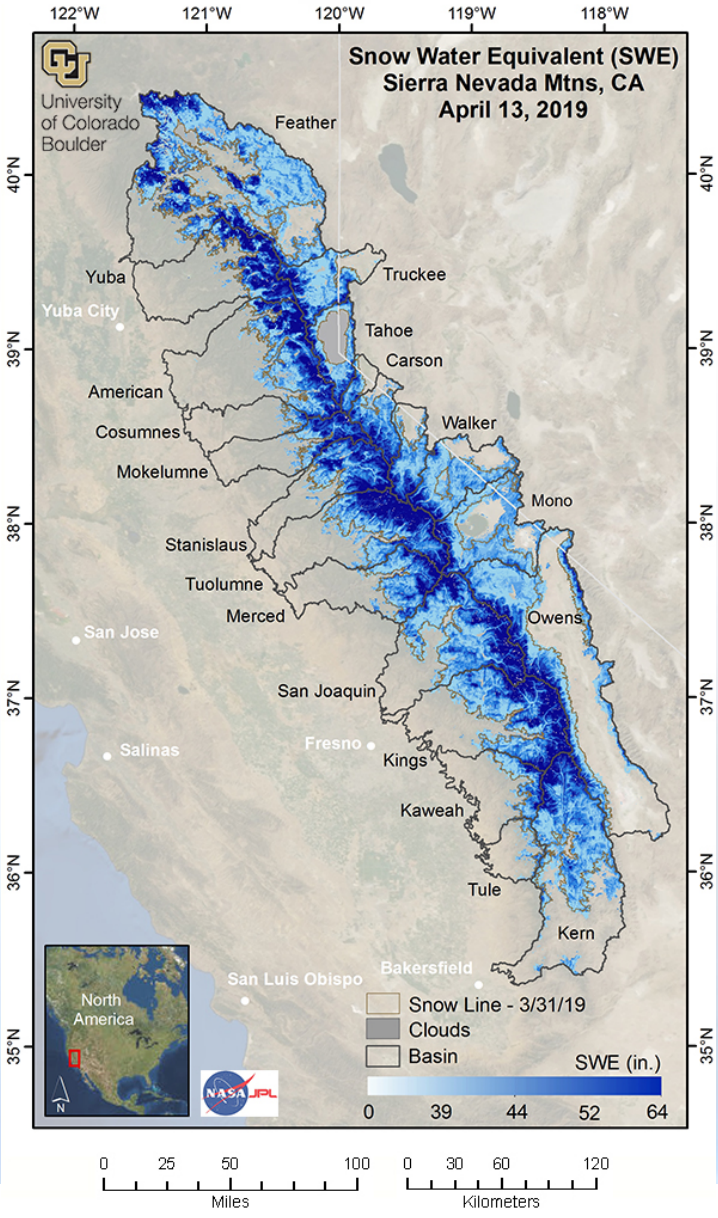




2019 Snow Year in Review

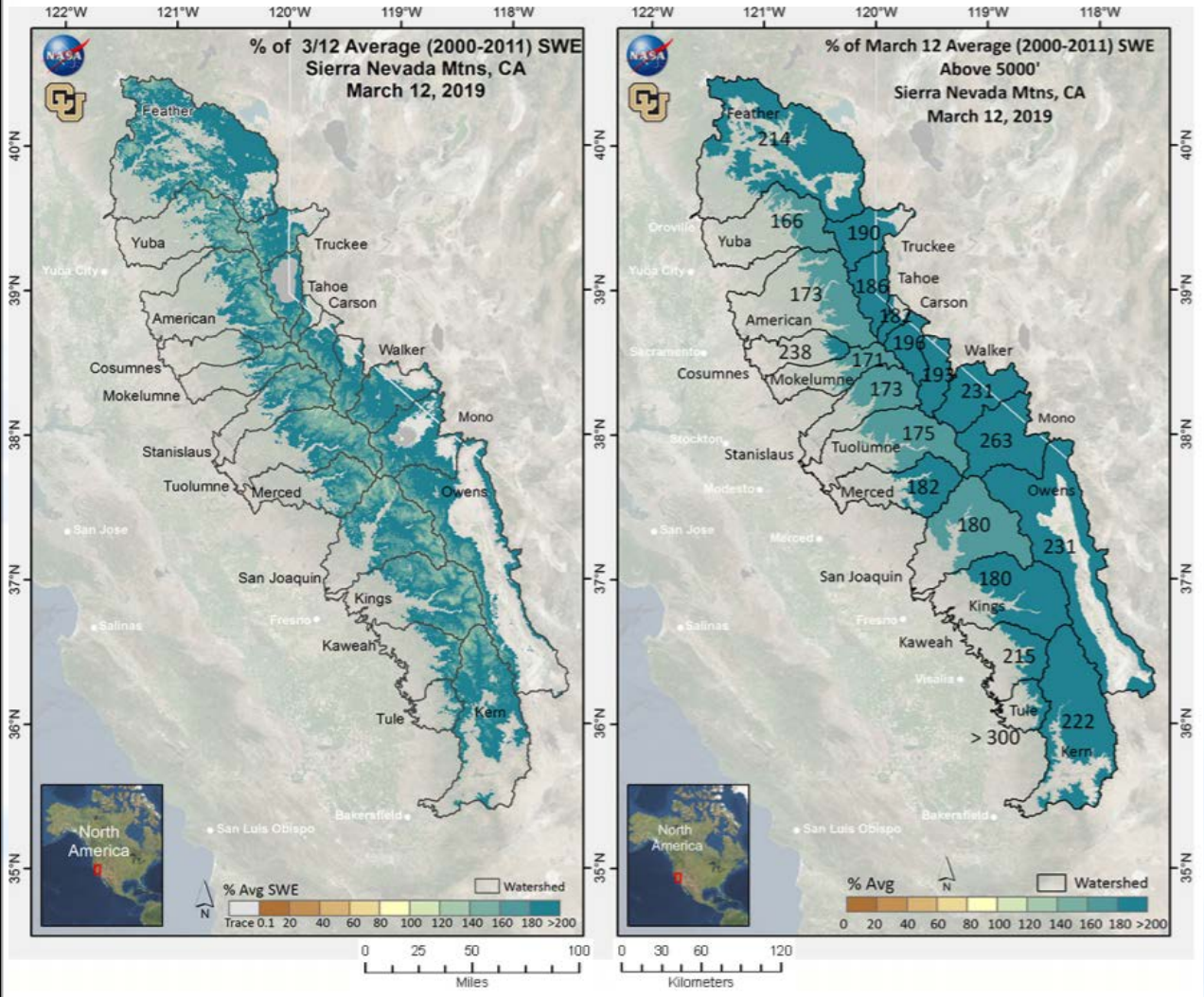




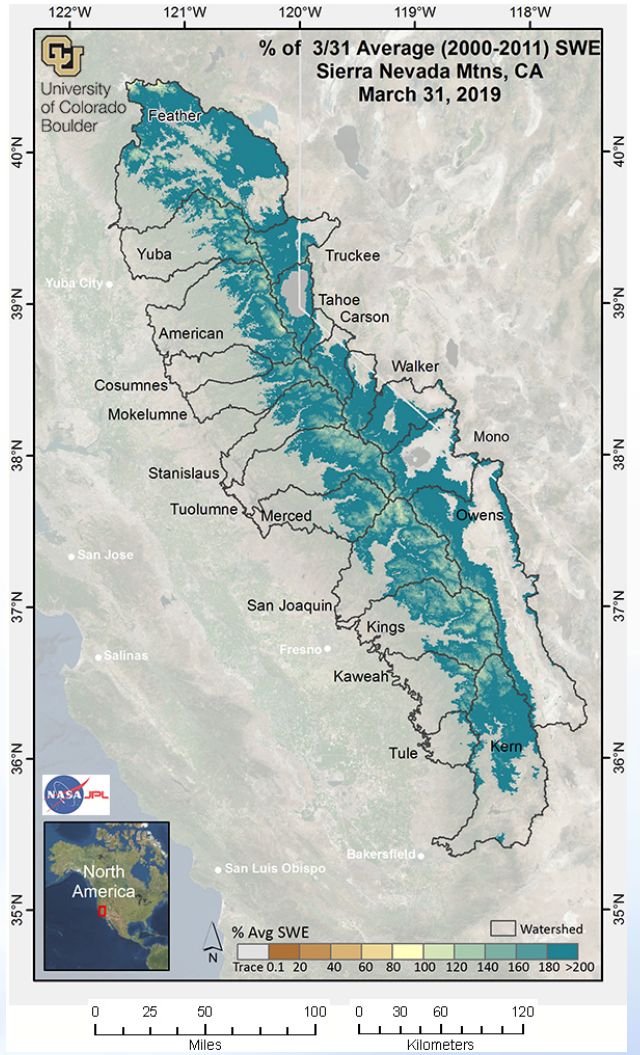


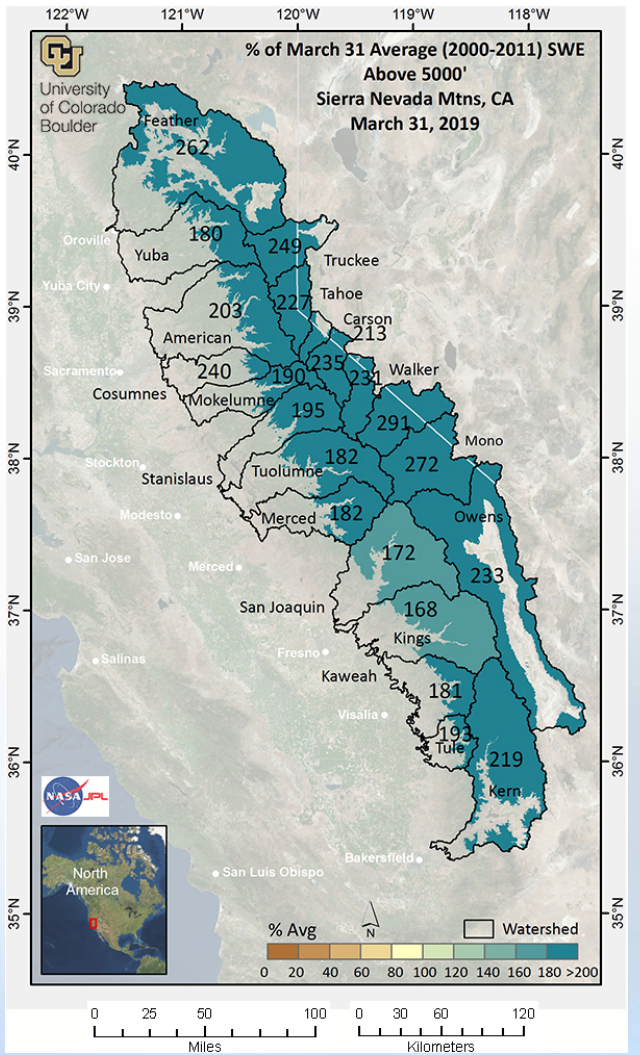
Real-time SWE Report : March 31, 2019

March 12, 2019



March 31, 2019



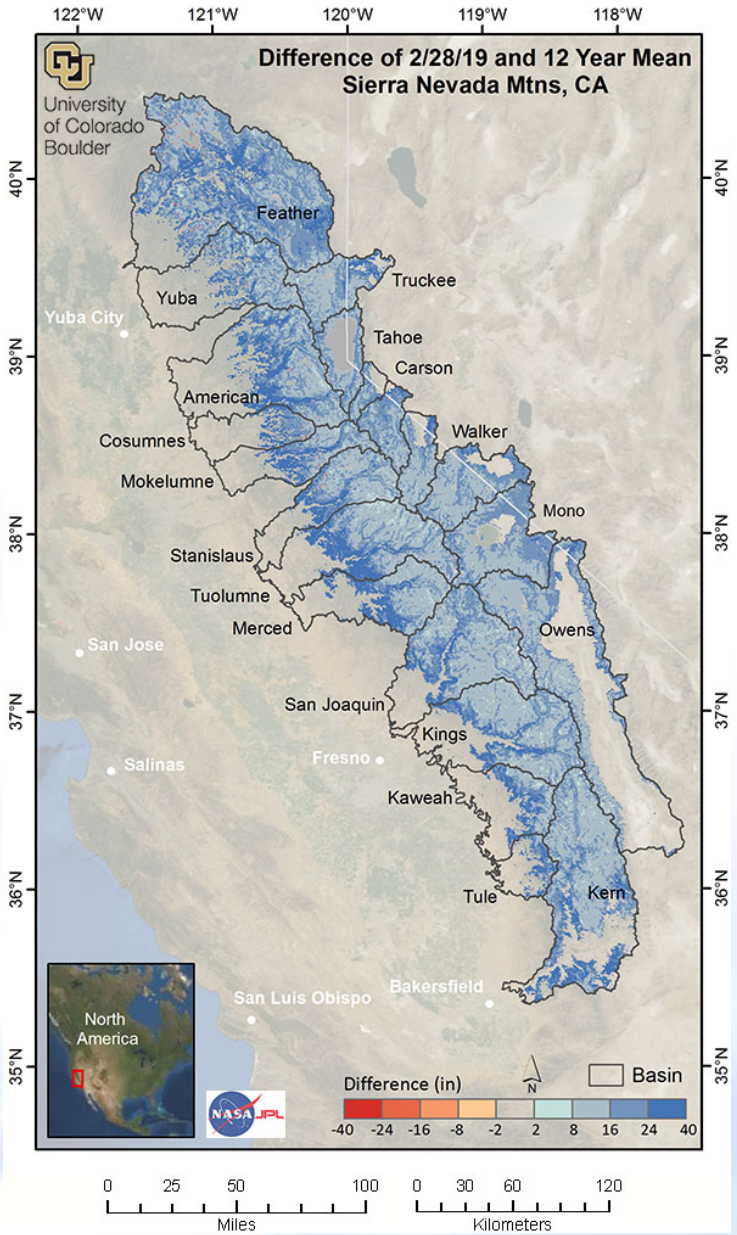


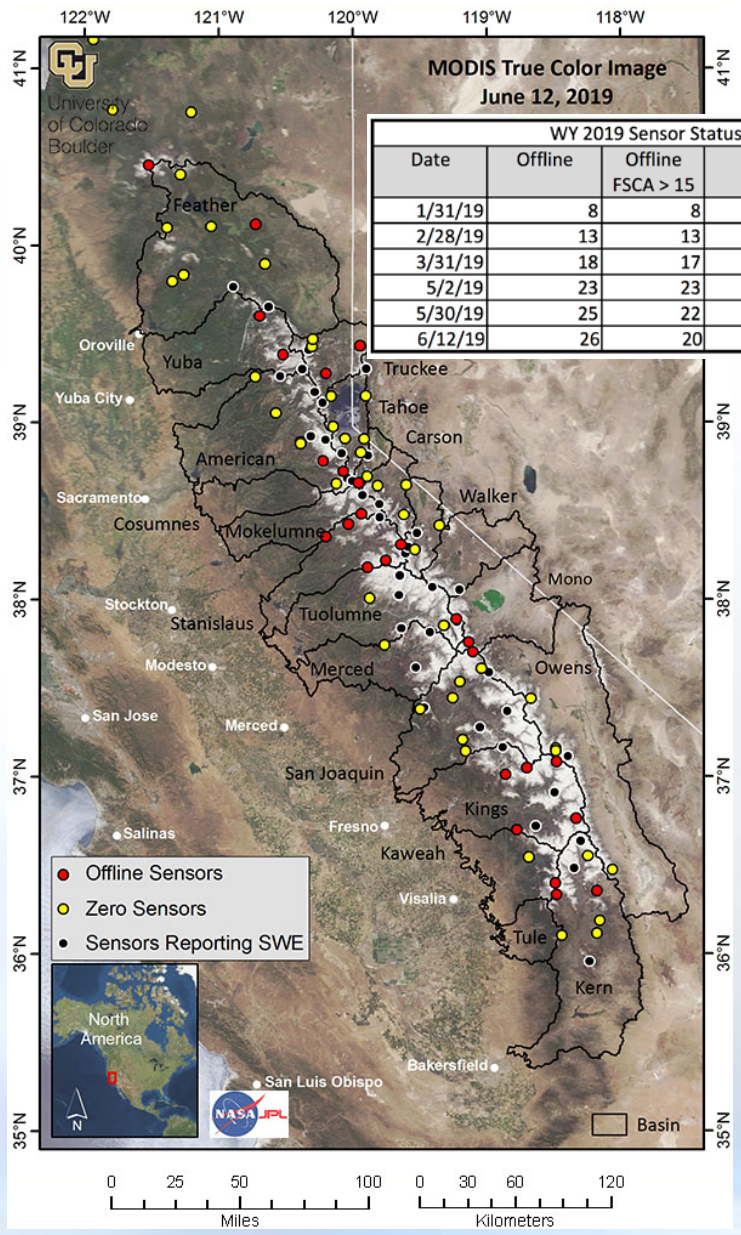
Real-time SWE Report Example: Mar. 31, 2019

Basin	Elevation Band	3/12/19 % 3/12 Avg.	3/31/19 % 3/31 Avg.	3/12/19 SWE (in)	3/31/19 SWE (in)	3/31/19 % SCA	3/31/19 Vol (af)	3/12 thru 3/31/19 Chg. in SWE (in)	3/31/19 Area (mi2)	4/1/19 Courses	3/31/19 Pillows	3/31/19 SNODAS* (in)
Feather	5000-6000'	241	> 300†	32.4	34.1	81.8	2,452,638	1.7	1,349.5	30.3	50.0	20.2
	6000-7000'	196	228	42.9	42.3	98.2	1,752,238	-0.6	776.0	52.4	51.1	32.3
	7000-8000'	167	165	48.7	46.0	99.8	308,535	-2.8	125.9	47.0	49.9	45.4
	8000-9000'	148	141	51.2	50.4	100.0	12,735	-0.9	4.7	N/A	N/A	42.2
Yuba	5000-6000'	198	246	36.1	40.7	82.4	442,105	4.6	203.7	45.8	N/A	28.5
	6000-7000'	160	171	50.3	52.6	97.9	641,075	2.3	228.5	70.3	68.2	51.3
	7000-8000'	150	146	52.5	53.1	99.5	334,837	0.6	118.2	76.7	N/A	64.8
	8000-9000'	146	139	56.0	56.5	100.0	13,666	0.5	4.5	N/A	N/A	68.3
American	5000-6000'	234	> 300†	32.1	38.7	84.1	647,914	6.7	313.6	29.5	28.7	22.2
	6000-7000'	164	202	42.7	49.2	96.8	737,250	6.5	281.2	52.7	53.0	43.2
	7000-8000'	151	161	49.0	53.5	98.6	502,426	4.6	176.0	46.6	63.0	62.4
	8000-9000'	146	149	53.2	58.0	98.3	218,250	4.8	70.6	59.5	61.2	65.9
	9000-10,000'	139	140	58.0	63.8	100.0	31,539	5.7	9.3	N/A	N/A	65.6
Cosumnes	5000-6000'	> 300†	254	23.4	22.7	51.4	75,991	-0.7	62.8	N/A	N/A	17.0
	6000-7000'	183	250	37.3	47.0	96.6	62,008	9.6	24.8	N/A	N/A	37.9
	7000-8000'	153	177	46.3	52.7	100.0	19,610	6.5	7.0	N/A	N/A	57.0
Mokelumne	5000-6000'	270	278	27.4	27.8	60.4	130,647	0.4	88.2	N/A	N/A	9.3
	6000-7000'	179	245	39.2	46.8	96.4	170,932	7.6	68.5	35.0	N/A	33.7
	7000-8000'	158	174	48.2	53.2	99.5	257,596	5.0	90.9	59.2	N/A	54.5
	8000-9000'	150	157	50.9	55.7	98.8	237,879	4.8	80.1	66.8	53.0	60.9
	9000-10,000'	147	152	54.6	60.4	100.0	28,287	5.8	8.8	N/A	N/A	59.8
Stanislaus	5000-6000'	> 300†	> 300†	27.6	28.7	64.8	172,121	1.1	112.5	N/A	N/A	9.7
	6000-7000'	187	249	40.4	46.9	93.8	352,594	6.5	141.0	43.3	N/A	35.0
	7000-8000'	163	187	46.8	51.3	99.4	416,882	4.5	152.5	49.9	N/A	48.9
	8000-9000'	157	166	50.5	54.7	99.9	345,151	4.2	118.3	73.0	81.7	56.7
	9000-10,000'	149	156	54.3	59.7	99.6	172,322	5.4	54.1	57.0	N/A	59.5
	10,000-11,000'	140	145	60.3	67.0	100.0	47,347	6.7	13.3	N/A	N/A	52.9

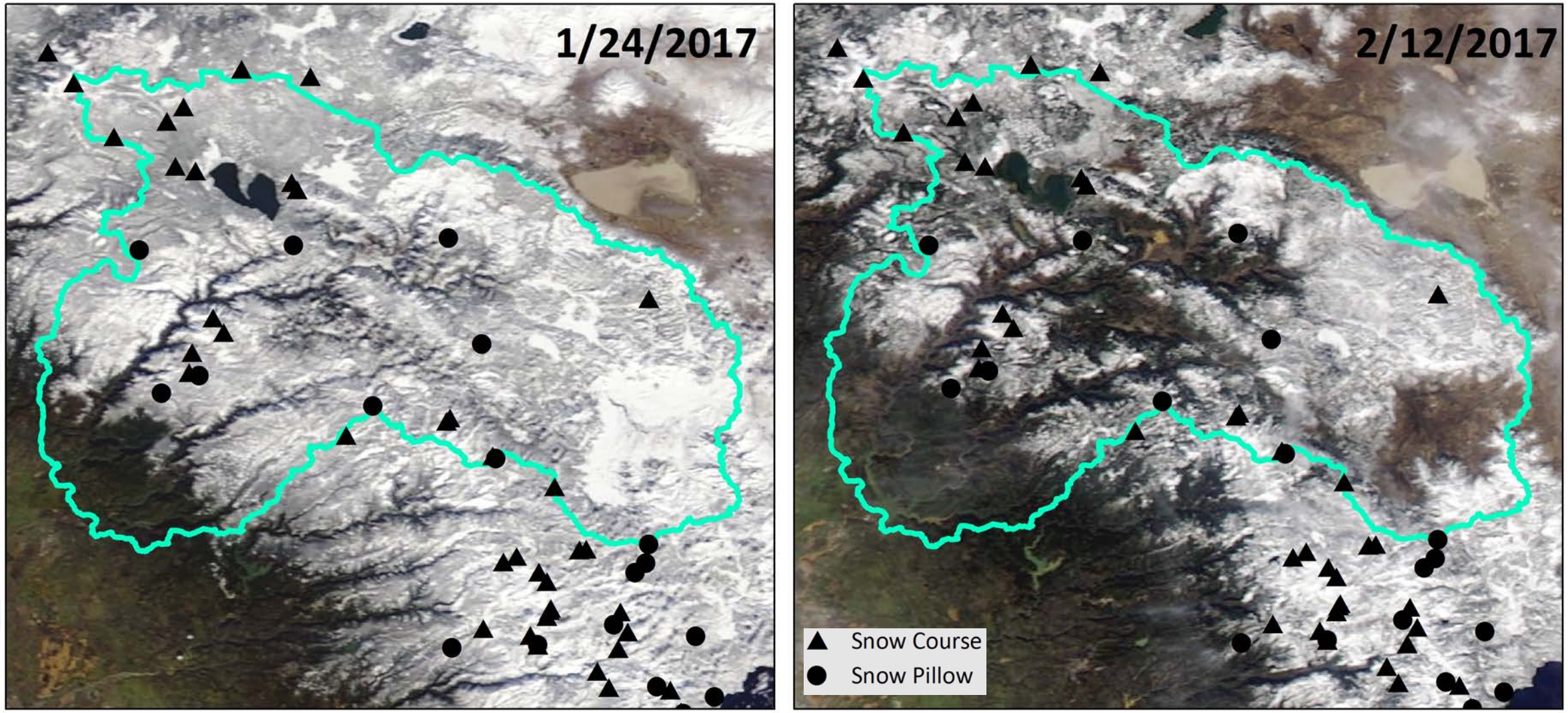
Water Year 2019 Near Real Time SWE Reporting Challenges

- Mid-season extremely deep snow, esp. in low elevations
- In June significant snow storage above sensors recording 0 values
- >20 sensors went offline by start of melt season



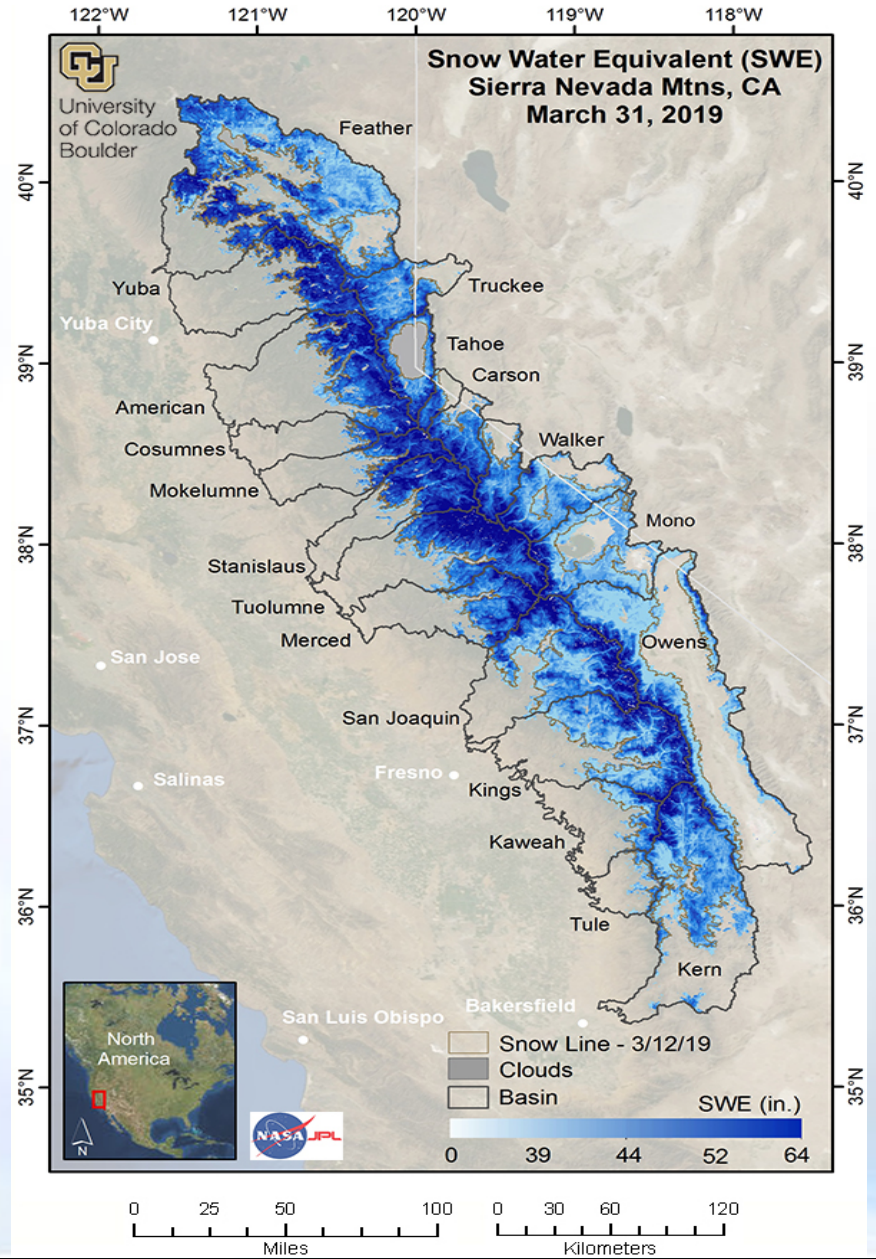


Oroville 2017



2019 New Additions to SWE Reports

- Report releases timed with B120 and snow course dates whenever possible.
- Percent of snow-covered area included in Tables.
- Volume calculations (Acre/Feet) included in Tables.
- The tables have been sorted in geographic order not in alphabetic order.
- Tables calculated using the new CNRFC basin boundaries and elevation bands.
- Validation with snow courses and with CoCoRaHS



Tim Bardsley's Cabin

Monday, February 25, 2019 at 12:34 PM

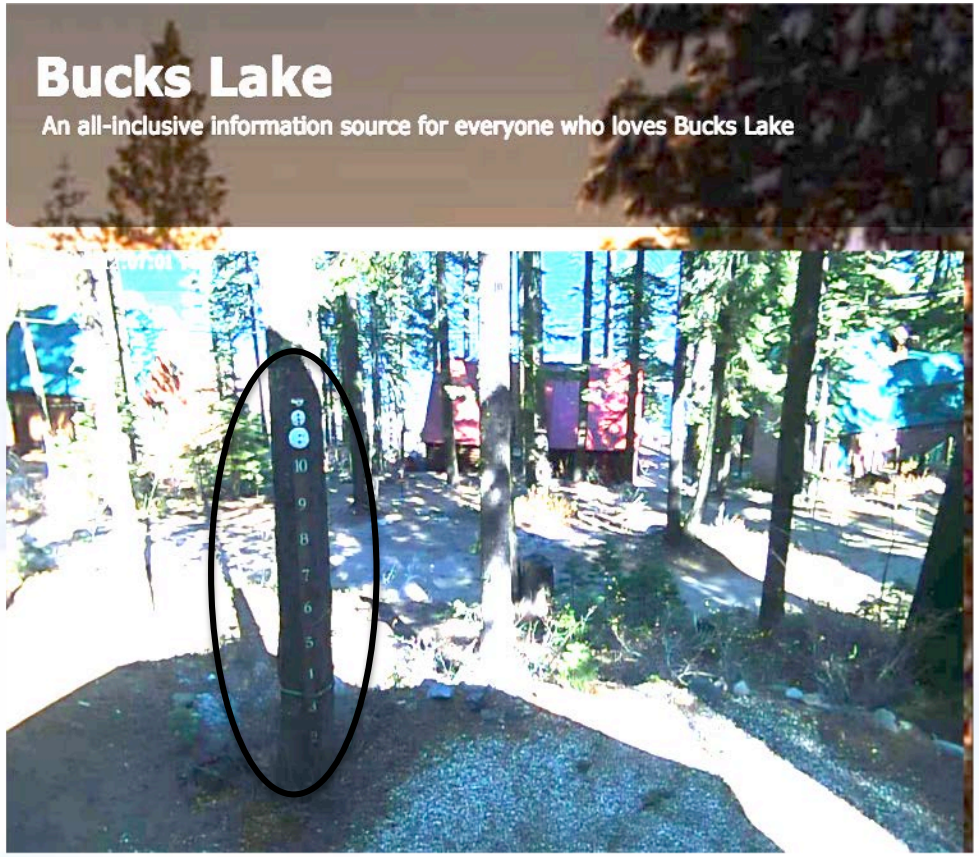
Tim Bardsley –

I have a little cabin at about 5850' in the MF of the Feather drainage.

Next time I'm up, I'll bring a probe.

The number you had for an average of that zone did not strike me as being out in the night though. Just guessing, I'd say the SWE near my cabin is probably about 15"

2019 SWE Reporting Challenges: low elevation SWE



May 27 2019

NEW POST

Well, that beats the tree well reference. So winter…..

Roads are plowed, there is a little mud, lake is high. Might just be getting toward serious summer. PG&E says there is still 25″ of water equivalent to melt. And that with the lake spilling for the last 6 weeks.The only other thing that would make things more ideal right now would be social tranquility. Hopefully, we are getting there, and Bucks will be a fun place once again…..

Written by Mike in: **Uncategorized** |

Mar 05 2019

THAT'S A TREE WELL

Remember, when you look at the snow gauge, it is on a tree, in a tree well. Add about two feet to what you see. For reference, all the STOP signs are buried, and they are 8 feet tall.

Written by Mike in: **Uncategorized** |

Feb 27 2019

THE NUTSO CONTINUES

As close as I can estimate, we got 67″ of snow fall during the last 24 hours. That is just more than enough. Mother Nature, can you hear me? Please…..

Written by Mike in: **Uncategorized** |

Feb 26 2019

RIDICULOUS

Yup. A ridiculous amount of snow over night. As close as I can tell, there is about 53″ of new snow over night.

I continue to be impressed with the Ranger. It made it up Mile High to the Dam Road just now. I had to back up and run at it several times, as the "sierra cement" just piles up in front and does not go anywhere. This much snow has to be just about the limit of what the Ranger will handle.

Written by Mike in: **Uncategorized** |

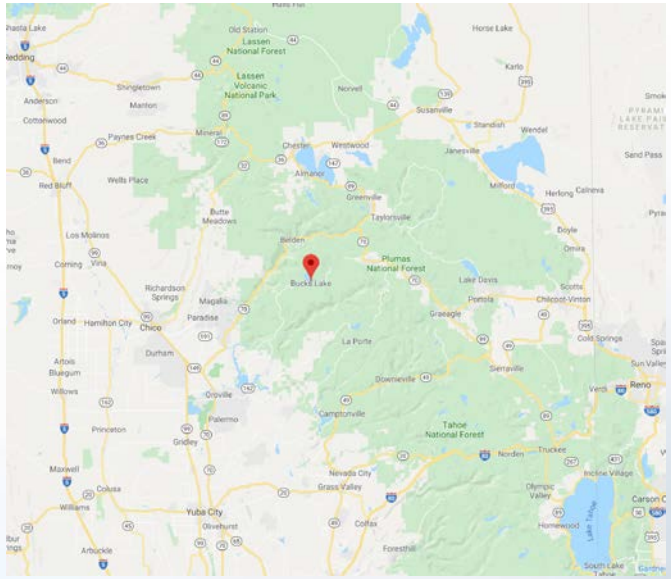
Feb 22 2019

AND STILL MORE WINTER

This is going down as a February to remember. (Or forget….) Since February 1, I have recorded 162″ of snow fall. I could be a little off, but so what. What I do know is that my shoulders and back feel like we have had all the winter we need. Now, if only Mom Nature would get that message…..

Written by Mike in: **Uncategorized** |

Bucks Lake is in the Feather basin, Plumas, county.
http://www.buckslake.net/home/
Elevation 5160'



2019 SWE Reporting Challenges: low elevation SWE

Low Elevation Webcams

Feather River & Northernmost Sierra Nevada WebCams

Amar Andalkar's Ski Mountaineering and Climbing Site

Burnt Rock Ranch, just SW of Paradise on SR 191, distant view of Sutter Buttes volcano in the Central Valley from 36 miles NNE

Elevation: 1200 ft

Bille Park in Paradise on SR 191, looking east

Elevation: 1750 ft

Magalia Weather, NE of Paradise on SR 191

Elevation: 2400 ft

Butte County Public Works Snow Cam, at Firestation 33 in Magalia, NE of Paradise on SR 191

Elevation: 2470 ft

Oroville Skyline Cam, on Oroville-Quincy Hwy (SR 162), 4 miles east of Oroville, 2 miles south of Oroville Dam

Elevation: 800 ft

Image modification time: Fri Nov 01, 2019 13:50:15 *(timestamp is incorrect)*

Bucks Lake, on Oroville-Quincy Hwy (FR 119), 13 miles WSW of Quincy

Elevation: 5160 ft

SR 70 / SR 89 Cam, at Greenville Wye, 10 miles north of Quincy

Elevation: 2856 ft

Spring Garden Cam, north side of SR 70 about 0.5 mile west of Spring Garden Overhead

Elevation: 3813 ft

Graeagle Weather Cam, in Graeagle near junction of SR 89 & SR 70

Elevation: 4400 ft

Whitehawk Ranch in Clio on SR 89

Elevation: 4520 ft

Image modification time: Fri Nov 01, 2019 13:54:23

Gold Mountain, just south of SR 70, west of Portola

Elevation: 5000 ft

Western Pacific Railroad Museum, in Portola on SR 70, alternates between east and west views

Elevation: 4850 ft

Portola on SR 70

Elevation: 4920 ft

Doyle Cam, on the west side of US 395 two miles south of Doyle

Elevation: 4283 ft

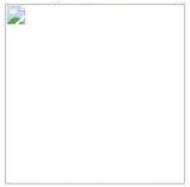
Alta Sierra Estates, south of Grass Valley on SR 49, looking east

Elevation: 2100 ft

Nevada County Weather Cam, SW of Nevada City, 1 mile NW of SR 49 @ MP 183, looking NE

Elevation: 2810 ft

Nevada City Webcam, on SR 49 @ MP 186, looking north



Elevation: 2600 ft

Alleghany Weather Cam, 6 miles south of SR 49, 17 miles NE of Nevada City

Elevation: 4400 ft

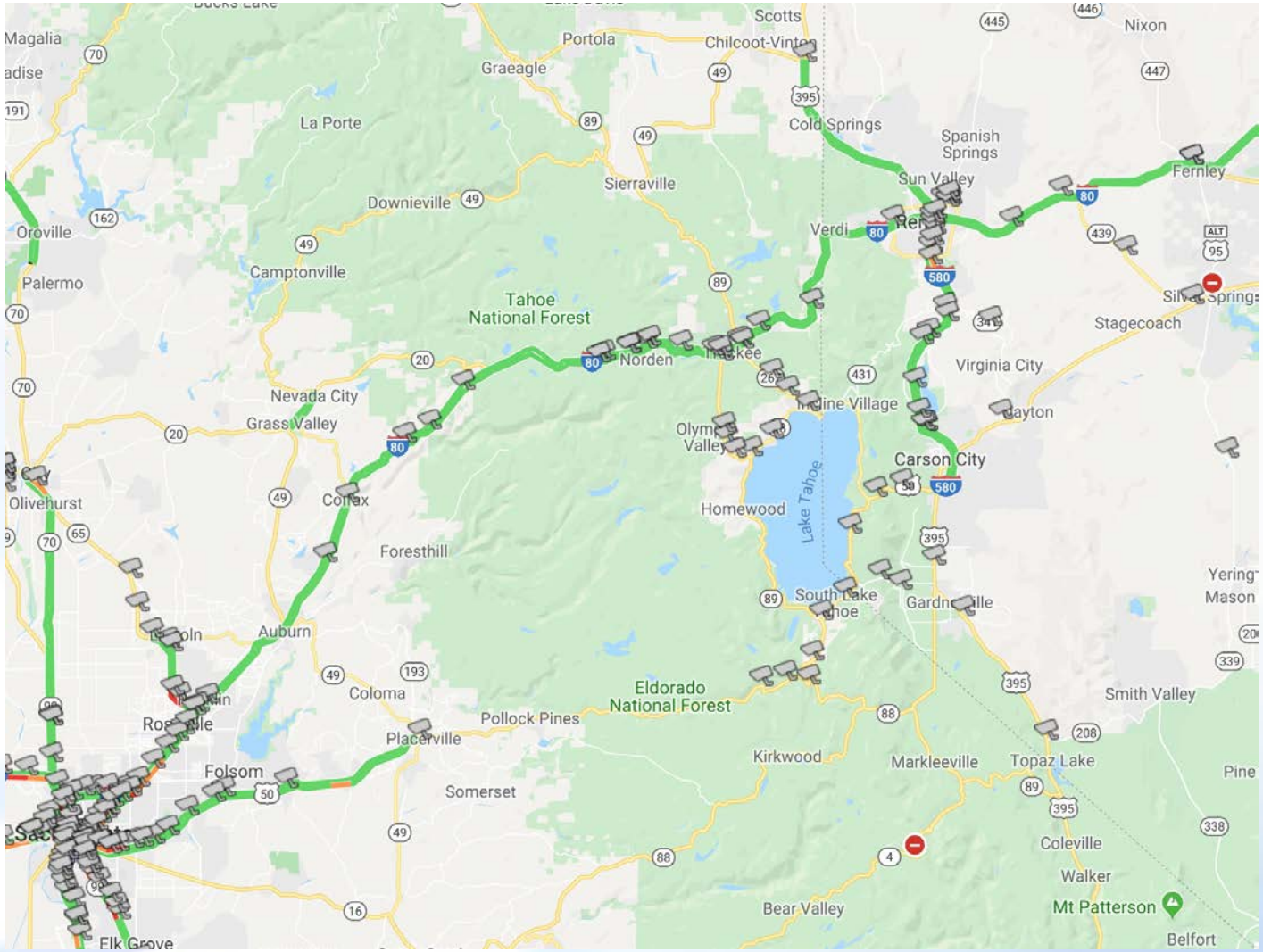
Sierra City Webcam, on SR 49, looking east

Elevation: 4200 ft

Bassett's Station Webcam, on SR 49, 5 miles east of Sierra City, looking SW

Elevation: 5400 ft

OSS (One Stop Shop) Webcams

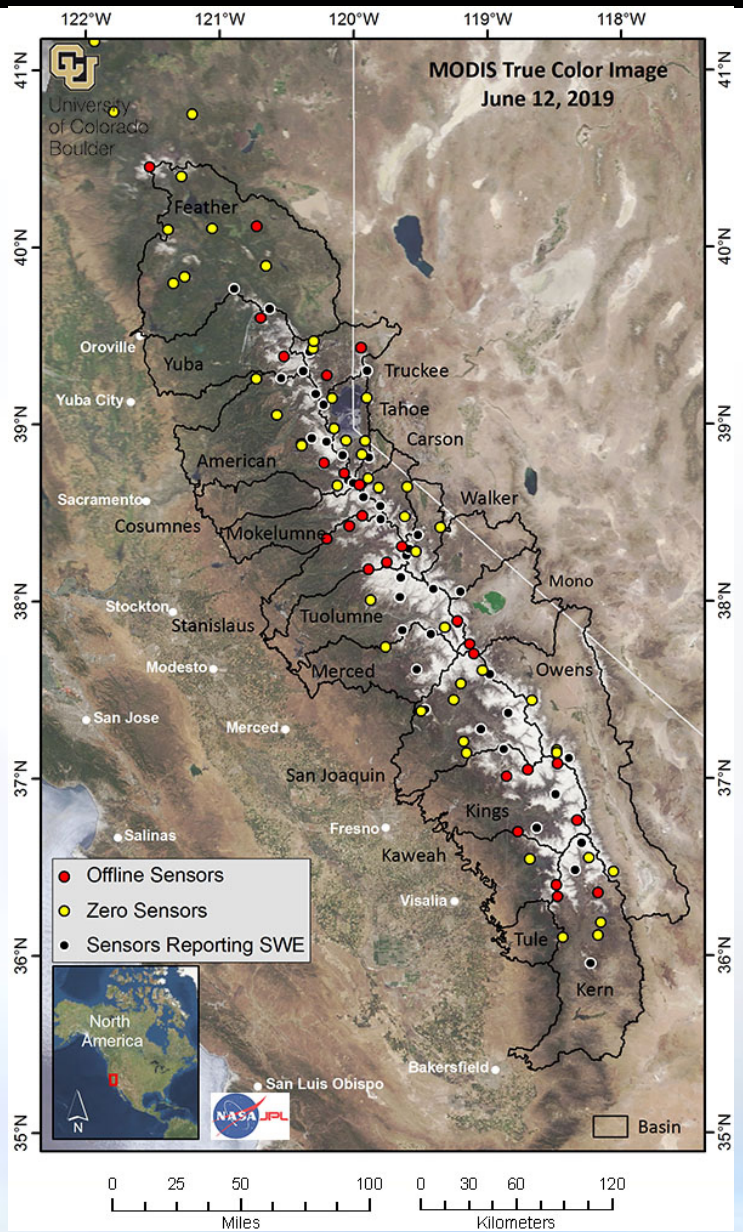


2020 SWE Reporting Improvements

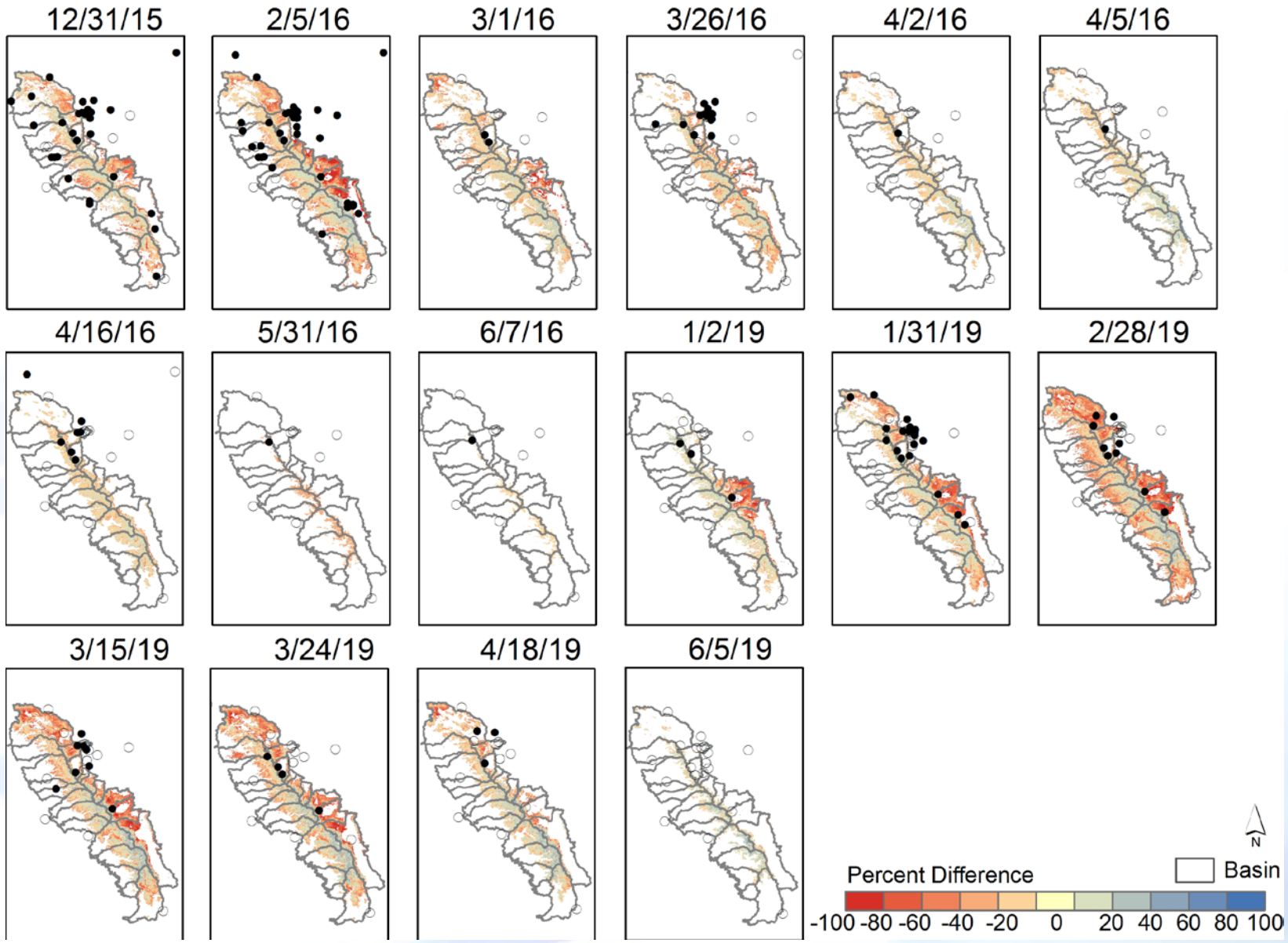
Two primary improvements have been made to the SWE estimation procedure:

1) We now include CoCoRaHS data in the regression model.

2) We are now using an improved SWE reconstruction data set based on validation with ASO data.



2020 SWE Reporting Improvements: Inclusion of CoCoRaHS



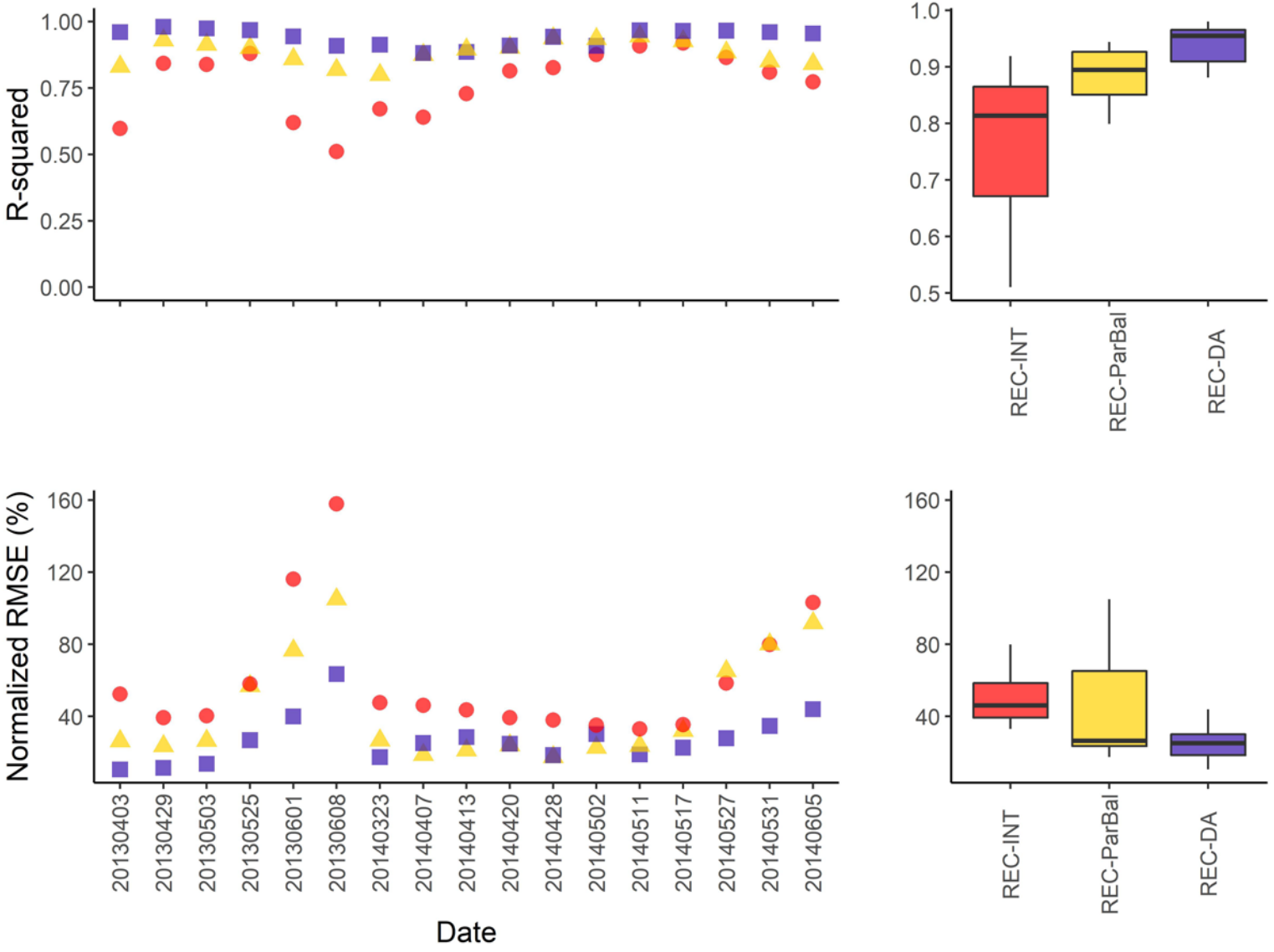
- SWE Differerences for sample dates 2015 – 2019.
- Red (blue) areas have less (more) SWE when CoCoRaHS are included.
- Lower elevation SWE decreases substantially

2020 SWE Reporting Improvements: Inclusion of CoCoRaHS

Basin	Elevation Band	Barrier Margulis Rittger fSCA reg 3/24/19 SWE (in)	Barrier Margulis Rittger fSCA coco 3/24/19 SWE (in)	Diff coco-reg	Barrier Margulis Rittger fSCA reg 3/24/19 Vol (af)	Barrier Margulis Rittger fSCA coco 3/24/19 Vol (af)	coco-reg Vol (af)	3/12/19 Area (mi2)	3/24/19 SNODAS* (in)
Feather	5000-6000'	33.7	22.8	-10.9	2,418,707	1,635,005	-783,702	1,331.2	19.7
	6000-7000'	41.9	34.3	-7.6	1,728,735	1,415,267	-313,468	745.2	30.8
	7000-8000'	47.6	44.1	-3.6	319,594	295,668	-23,926	120.0	42.5
	8000-9000'	52.5	51.4	-1.1	13,286	13,007	-279	4.7	39.4
Yuba	5000-6000'	40.0	31.6	-8.4	434,527	343,457	-91,070	199.8	27.2
	6000-7000'	49.4	43.1	-6.3	602,358	525,116	-77,242	221.2	48.1
	7000-8000'	53.9	50.3	-3.6	339,945	317,363	-22,583	112.1	60.6
	8000-9000'	58.6	60.1	1.5	14,176	14,536	360	4.4	64.7
American	5000-6000'	41.4	33.2	-8.2	692,677	555,189	-137,489	313.4	21.4
	6000-7000'	46.8	42.2	-4.5	701,140	633,195	-67,945	281.2	40.5
	7000-8000'	51.5	51.4	-0.1	483,198	482,672	-526	176.0	58.7
	8000-9000'	56.3	60.1	3.8	211,954	226,381	14,427	70.6	62.0
	9000-10,000'	61.2	68.6	7.4	30,279	33,919	3,640	9.3	62.3
Cosumnes	5000-6000'	37.2	32.1	-5.1	124,452	107,542	-16,910	62.8	16.5
	6000-7000'	48.5	45.6	-2.9	64,074	60,264	-3,810	24.8	35.7
	7000-8000'	53.9	53.7	-0.2	20,030	19,956	-74	7.0	54.5
Mokelumne	5000-6000'	38.4	32.8	-5.6	180,877	154,450	-26,427	88.2	9.6
	6000-7000'	45.9	43.1	-2.8	167,796	157,444	-10,352	68.5	31.8
	7000-8000'	51.6	51.8	0.3	249,892	251,277	1,385	90.9	51.2
	8000-9000'	55.1	58.2	3.1	235,259	248,359	13,100	80.1	57.2
	9000-10,000'	58.6	66.7	8.1	27,441	31,255	3,814	8.8	56.6
Stanislaus	5000-6000'	36.0	30.8	-5.3	216,276	184,613	-31,663	112.5	10.3
	6000-7000'	44.5	41.5	-3.1	334,979	311,833	-23,146	141.0	32.8
	7000-8000'	49.3	49.9	0.6	401,093	406,088	4,994	152.5	45.4
	8000-9000'	53.3	58.0	4.7	336,170	365,933	29,763	118.3	52.5
	9000-10,000'	56.0	63.7	7.6	161,669	183,747	22,079	54.1	55.7
	10,000-11,000'	57.7	67.4	9.6	40,803	47,606	6,804	13.3	49.8
	> 11,000'	56.1	64.3	8.2	835	957	122	0.3	32.8
Tuolumne	5000-6000'	32.7	28.1	-4.6	311,984	267,868	-44,116	179.1	7.8
	6000-7000'	42.4	40.1	-2.2	332,485	315,076	-17,409	147.2	29.2
	7000-8000'	47.7	48.4	0.8	400,113	406,599	6,485	157.4	46.4
	8000-9000'	50.1	52.7	2.6	462,745	486,899	24,154	173.1	54.1
	9000-10,000'	51.7	56.7	5.0	505,132	554,071	48,939	183.1	55.3
	10,000-11,000'	53.4	61.7	8.2	260,563	300,660	40,098	91.6	45.8
	11,000-12,000'	54.3	64.8	10.5	75,762	90,411	14,649	26.2	25.2
	> 12,000'	55.8	67.4	11.6	8,504	10,275	1,771	2.9	15.3
Merced	5000-6000'	18.5	16.6	-1.9	73,935	66,327	-7,608	74.8	6.1
	6000-7000'	39.5	37.2	-2.3	174,155	163,943	-10,212	82.6	24.3
	7000-8000'	45.1	44.5	-0.5	338,521	334,668	-3,852	141.9	41.0
	8000-9000'	49.1	51.2	2.1	325,409	339,339	13,931	124.4	49.1
	9000-10,000'	51.8	57.1	5.3	244,140	269,250	25,110	88.4	49.6
	10,000-11,000'	55.4	63.9	8.5	117,114	135,094	17,981	39.6	45.7
	11,000-12,000'	58.2	69.6	11.4	35,734	42,727	6,993	11.5	33.5
	> 12,000'	60.5	73.9	13.4	5,174	6,320	1,146	1.6	29.4

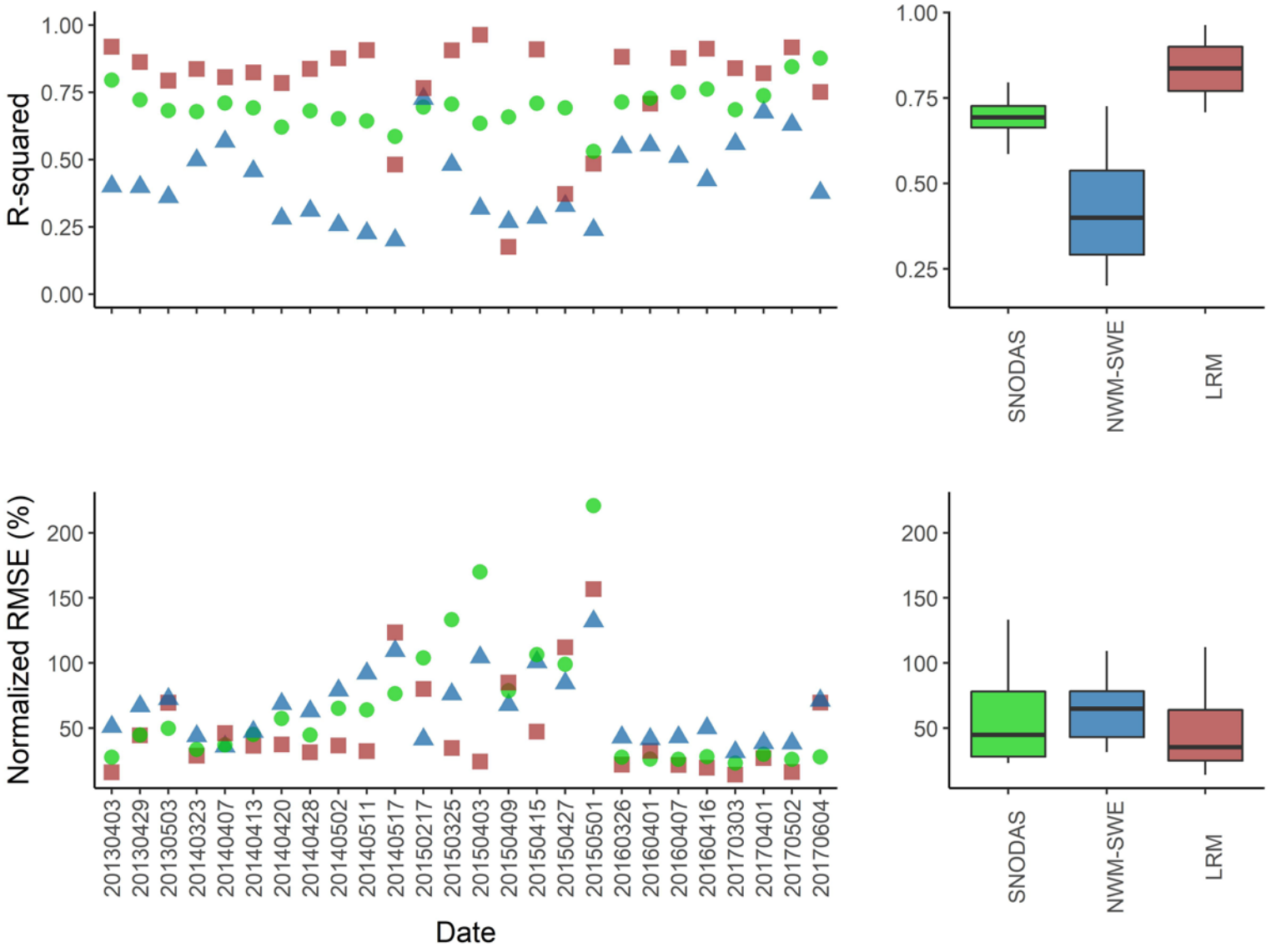
Basin	Elevation Band	Barrier Margulis Rittger fSCA reg 3/24/19 SWE (in)	Barrier Margulis Rittger fSCA coco 3/24/19 SWE (in)	Diff coco-reg	Barrier Margulis Rittger fSCA reg 3/24/19 Vol (af)	Barrier Margulis Rittger fSCA coco 3/24/19 Vol (af)	coco-reg Vol (af)	3/12/19 Area (mi2)	3/24/19 SNODAS* (in)
San Joaquin	5000-6000'	18.4	13.9	-4.5	136,716	103,402	-33,314	132.4	7.4
	6000-7000'	35.0	27.7	-7.3	341,074	270,247	-70,827	177.4	22.5
	7000-8000'	39.7	35.4	-4.3	465,033	414,442	-50,591	214.6	35.0
	8000-9000'	44.3	44.3	0.0	477,782	477,582	-200	197.2	42.6
	9000-10,000'	47.4	50.5	3.1	523,975	558,022	34,047	206.4	45.4
	10,000-11,000'	49.8	56.3	6.5	426,811	482,913	56,102	160.6	41.9
	11,000-12,000'	50.2	58.9	8.7	319,510	374,572	55,062	119.3	29.2
	> 12,000'	51.3	62.8	11.5	77,126	94,349	17,224	28.2	19.3
Kings	5000-6000'	12.7	10.1	-2.6	69,404	55,173	-14,230	103.9	5.9
	6000-7000'	30.8	26.5	-4.3	225,649	194,222	-31,427	137.2	16.0
	7000-8000'	37.6	35.2	-2.3	354,520	332,386	-22,133	177.0	32.3
	8000-9000'	41.8	42.4	0.7	492,036	499,707	7,671	220.9	44.2
	9000-10,000'	44.3	48.0	3.7	523,126	566,489	43,363	221.5	48.8
	10,000-11,000'	45.8	52.2	6.4	473,298	539,410	66,112	193.8	45.6
	11,000-12,000'	47.2	55.8	8.5	390,823	461,460	70,637	154.7	33.3
	> 12,000'	48.4	59.5	11.1	136,155	167,448	31,293	52.2	22.2
Kaweah	5000-6000'	4.3	3.8	-0.5	14,174	12,659	-1,515	62.6	7.1
	6000-7000'	27.9	26.5	-1.3	90,877	86,473	-4,403	60.7	21.0
	7000-8000'	38.5	39.9	1.4	128,505	133,317	4,812	62.4	37.3
	8000-9000'	44.1	48.3	4.1	136,163	148,960	12,796	57.9	49.0
	9000-10,000'	47.3	54.5	7.1	109,849	126,403	16,554	43.5	58.0
	10,000-11,000'	50.2	60.0	9.8	82,134	98,114	15,980	30.7	58.8
	11,000-12,000'	51.9	62.4	10.4	23,372	28,069	4,697	8.4	50.5
	> 12,000'	49.6	57.5	8.0	553	642	89	0.2	52.6
Tule	5000-6000'	5.1	4.8	-0.3	14,851	13,861	-990	42.7	4.3
	6000-7000'	25.5	24.9	-0.7	56,922	55,406	-1,516	33.6	15.1
	7000-8000'	38.6	40.6	2.0	55,655	58,522	2,867	25.6	30.9
	8000-9000'	44.6	49.7	5.2	34,827	38,853	4,026	14.6	43.1
	9000-10,000'	47.8	53.5	5.7	11,566	12,936	1,370	4.5	55.6
	10,000-11,000'	47.5	52.7	5.2	353	392	39	0.1	59.1
Kern	5000-6000'	2.2	1.3	-0.9	30,654	17,732	-12,922	281.7	0.5
	6000-7000'	12.4	9.1	-3.4	233,074	170,288	-62,785	359.2	3.8
	7000-8000'	29.1	24.2	-4.9	515,380	428,018	-87,362	335.0	14.3
	8000-9000'	37.4	33.9	-3.5	651,045	589,570	-61,475	308.8	28.3
	9000-10,000'	40.6	40.6	0.0	418,855	418,572	-282	185.4	34.2
	10,000-11,000'	43.2	46.9	3.7	307,071	333,192	26,121	129.4	33.4
	11,000-12,000'	45.9	53.1	7.3	232,152	269,000	36,848	93.9	30.7
	> 12,000'	48.5	60.1	11.7	118,292	146,753	28,462	45.1	22.0

2020 SWE Reporting Improvements: Improved SWE reconstruction



- SWE Reconstructions were compared with ASO data in the Tuolumne Basin.
- The following SWE reconstruction data sets were included:
  - REC-ParBal (*Bair et al.*, 2016)
  - REC-DA (Margulis et al., 2015)
  - REC-INT (*Guan et al.,* 2013)
- Data shown for 2013 and 2014.
- REC-DA (*Margulis et al.,* 2015)
- showed the highest accuracy.

2020 SWE Reporting Improvements: Improved SWE reconstruction

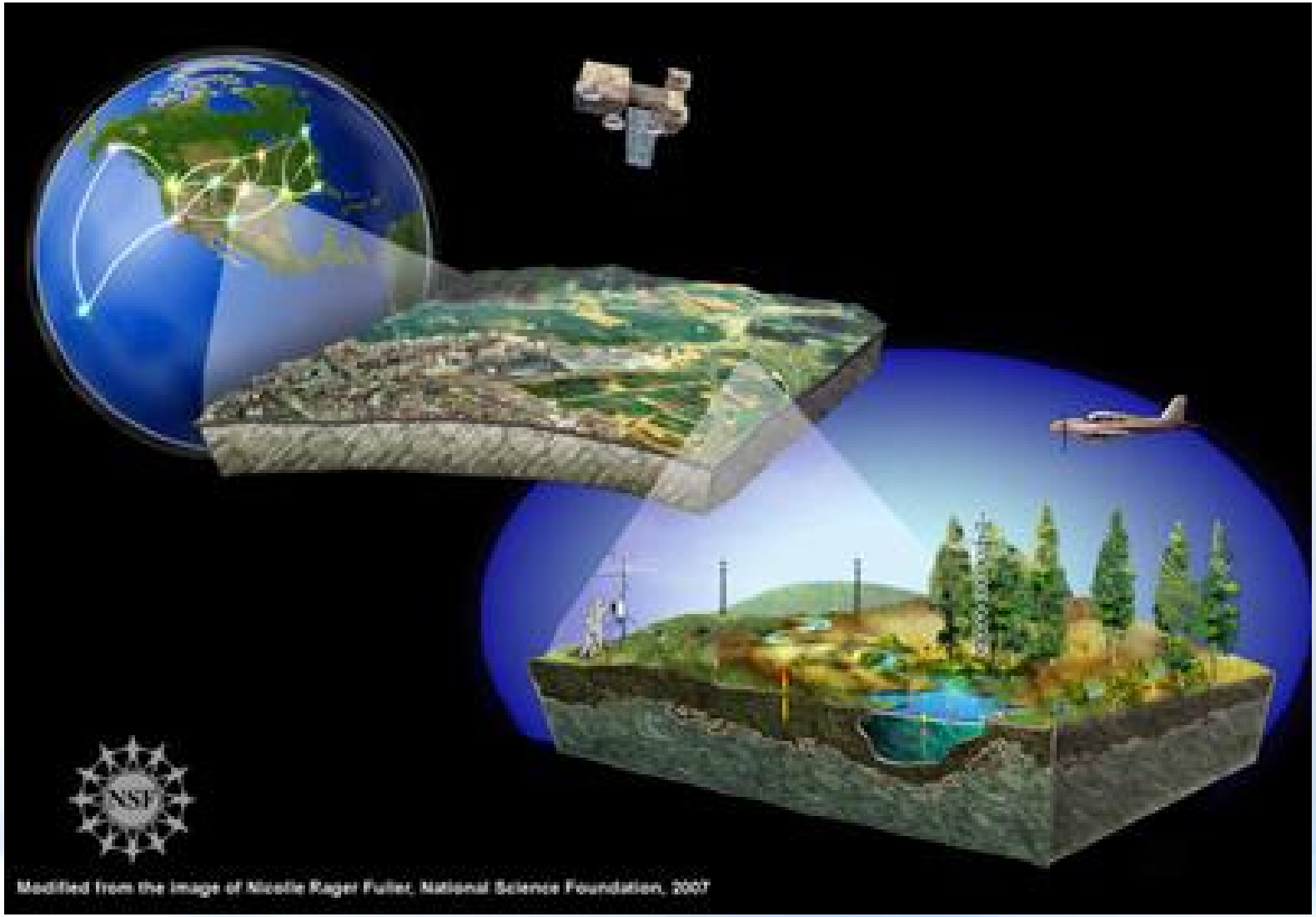


- Comparison of real time SWE from the Regression model, SNODAS, and National Water Model are shown.
- Validation against ASO in Tuolune.
- Data from 2013 to 2017 are shown.
- Regression model shows the best performance.

An integrated SWE observing system

Merging satellite data with airborne and ground data to estimate SWE

- Ground data:
  - Truth
  - Long record
  - Limited in space
- Airborne data:
  - Accurate
  - High resolution
  - Limited in extent and frequency ($$)
- Satellite data
  - Large extent
  - Frequent sampling
  - Limited in resolution and accuracy



2020 SWE Reporting Improvements: Inclusion of CoCoRaHS

Basin	Elevation Band	2/28/19 % 2/28 Avg.	3/12/19 % 3/12 Avg.	2/28/19 SWE (in)	3/12/19 SWE (in)	3/12/19 % SCA	3/12/19 Vol (af)	2/28 thru 3/12/19 Chg. in SWE (in)	3/12/19 Area (mi2)	3/12/19 SNODAS* (in)
Feather	5000-6000'	199	241	33.7	32.4	83.0	2,299,493	-1.3	1,331.2	22.6
	6000-7000'	174	196	37.8	42.9	94.1	1,705,331	5.1	745.2	32.7
	7000-8000'	155	167	41.0	48.7	95.2	311,600	7.7	120.0	42.5
	8000-9000'	134	148	43.1	51.2	100.0	12,955	8.2	4.7	39.3
Yuba	5000-6000'	182	198	36.9	36.1	82.8	384,649	-0.8	199.8	29.9
	6000-7000'	151	160	44.3	50.3	96.2	593,178	6.0	221.2	49.4
	7000-8000'	143	150	46.2	52.5	94.8	314,049	6.3	112.1	60.2
	8000-9000'	126	146	45.5	56.0	96.9	13,130	10.5	4.4	64.5
American	5000-6000'	202	234	35.2	32.1	88.4	535,882	-3.1	313.4	24.1
	6000-7000'	160	164	40.4	42.7	98.2	639,970	2.3	281.2	41.9
	7000-8000'	146	151	44.3	49.0	99.7	459,626	4.7	176.0	58.5
	8000-9000'	135	146	46.1	53.2	99.2	200,118	7.1	70.6	61.7
	9000-10,000'	125	139	47.8	58.0	100.0	28,708	10.3	9.3	62.0
Cosumnes	5000-6000'	216	> 300†	29.9	23.4	70.0	78,340	-6.5	62.8	18.4
	6000-7000'	164	183	35.3	37.3	94.6	49,317	2.0	24.8	36.5
	7000-8000'	147	153	41.8	46.3	100.0	17,205	4.5	7.0	54.9
Mokelumne	5000-6000'	208	270	32.2	27.4	79.9	128,889	-4.8	88.2	11.9
	6000-7000'	169	179	37.5	39.2	97.0	143,092	1.6	68.5	33.2
	7000-8000'	150	158	42.9	48.2	100.0	233,503	5.3	90.9	51.5
	8000-9000'	144	150	44.6	50.9	99.9	217,547	6.3	80.1	56.6
	9000-10,000'	138	147	46.3	54.6	100.0	25,582	8.3	8.8	56.0
Stanislaus	5000-6000'	221	> 300†	31.5	27.6	82.8	165,428	-3.9	112.5	12.5
	6000-7000'	166	187	36.7	40.4	97.9	304,047	3.7	141.0	34.2
	7000-8000'	151	163	40.9	46.8	99.9	380,418	5.9	152.5	46.1
	8000-9000'	142	157	43.1	50.5	100.0	318,524	7.4	118.3	51.9
	9000-10,000'	132	149	44.7	54.3	100.0	156,864	9.7	54.1	54.6
	10,000-11,000'	123	140	48.1	60.3	100.0	42,647	12.3	13.3	49.2
	> 11,000'	122	134	46.5	59.5	100.0	885	13.0	0.3	33.0
Tuolumne	5000-6000'	252	> 300†	32.0	27.8	85.1	265,831	-4.1	179.1	10.8
	6000-7000'	182	220	34.5	37.0	98.4	290,139	2.4	147.2	31.1
	7000-8000'	152	170	38.3	44.4	99.9	372,725	6.1	157.4	47.3
	8000-9000'	144	157	41.1	47.5	100.0	438,622	6.5	173.1	53.6
	9000-10,000'	139	152	43.5	51.2	100.0	500,271	7.7	183.1	54.5
	10,000-11,000'	137	149	45.3	54.7	99.9	267,345	9.4	91.6	45.5
	11,000-12,000'	141	147	47.4	57.0	100.0	79,522	9.6	26.2	26.0
	> 12,000'	135	143	47.3	59.0	100.0	8,990	11.7	2.9	16.7
Merced	5000-6000'	> 300†	> 300†	32.4	19.8	60.5	78,865	-12.6	74.8	9.5
	6000-7000'	205	273	33.2	32.7	91.3	143,934	-0.6	82.6	25.8
	7000-8000'	163	183	35.7	39.8	99.3	300,930	4.0	141.9	41.2
	8000-9000'	153	167	38.0	43.3	99.9	287,453	5.3	124.4	48.5
	9000-10,000'	142	156	40.8	47.6	100.0	224,574	6.8	88.4	48.7
	10,000-11,000'	130	146	45.5	55.7	100.0	117,737	10.2	39.6	45.0
	11,000-12,000'	131	141	49.9	61.2	100.0	37,540	11.3	11.5	34.0
	> 12,000'	126	138	51.9	66.5	100.0	5,689	14.6	1.6	30.3

Basin	Elevation Band	2/28/19 % 2/28 Avg.	3/12/19 % 3/12 Avg.	2/28/19 SWE (in)	3/12/19 SWE (in)	3/12/19 % SCA	3/12/19 Vol (af)	2/28 thru 3/12/19 Chg. in SWE (in)	3/12/19 Area (mi2)	3/12/19 SNODAS* (in)
San Joaquin	5000-6000'	> 300†	> 300†	29.7	22.1	67.2	156,165	-7.5	132.4	11.3
	6000-7000'	193	243	31.4	33.8	92.1	319,738	2.4	177.4	25.2
	7000-8000'	172	197	33.9	38.6	95.6	441,562	4.7	214.6	36.2
	8000-9000'	162	172	37.3	42.6	96.9	447,770	5.3	197.2	42.2
	9000-10,000'	154	162	39.7	45.6	99.5	501,819	5.9	206.4	44.8
	10,000-11,000'	144	154	43.1	51.2	99.8	438,533	8.1	160.6	41.4
	11,000-12,000'	139	148	45.1	53.9	100.0	342,723	8.8	119.3	29.3
	> 12,000'	147	149	45.4	54.3	100.0	81,651	9.0	28.2	19.8
Kings	5000-6000'	> 300†	> 300†	30.2	19.5	62.6	108,115	-10.7	103.9	10.1
	6000-7000'	232	> 300†	31.1	31.7	94.3	231,559	0.5	137.2	19.5
	7000-8000'	176	210	32.3	36.3	99.4	342,694	4.0	177.0	34.7
	8000-9000'	165	184	34.2	38.7	99.4	456,055	4.5	220.9	44.8
	9000-10,000'	156	171	36.0	41.2	100.0	487,183	5.3	221.5	48.3
	10,000-11,000'	147	156	40.3	47.0	100.0	485,418	6.7	193.8	44.8
	11,000-12,000'	146	148	43.4	51.1	99.7	421,248	7.7	154.7	33.0
	> 12,000'	148	146	44.1	52.9	98.4	147,445	8.9	52.2	22.3
Kaweah	5000-6000'	> 300†	> 300†	26.3	13.6	43.7	45,271	-12.8	62.6	10.5
	6000-7000'	> 300†	> 300†	30.3	29.0	86.8	93,983	-1.3	60.7	22.5
	7000-8000'	207	241	32.5	35.9	98.1	119,585	3.4	62.4	37.9
	8000-9000'	168	191	35.1	39.9	100.0	123,064	4.8	57.9	48.3
	9000-10,000'	154	173	37.5	43.4	100.0	100,813	5.9	43.5	56.9
	10,000-11,000'	138	152	43.1	50.1	100.0	82,040	7.1	30.7	57.7
	11,000-12,000'	136	144	45.1	51.9	100.0	23,370	6.8	8.4	49.9
	> 12,000'	130	132	40.8	47.9	100.0	534	7.0	0.2	51.6
Tule	5000-6000'	> 300†	> 300†	20.4	17.0	42.3	38,681	-3.4	42.7	7.6
	6000-7000'	> 300†	> 300†	28.4	28.7	68.2	51,511	0.3	33.6	17.3
	7000-8000'	227	266	33.2	37.3	92.5	50,850	4.1	25.6	31.7
	8000-9000'	179	204	34.3	39.3	99.5	30,514	4.9	14.6	43.1
	9000-10,000'	160	183	34.2	39.8	100.0	9,627	5.6	4.5	54.8
	10,000-11,000'	149	161	31.8	40.1	100.0	299	8.4	0.1	58.2
Kern	5000-6000'	> 300†	> 300†	18.1	6.3	19.4	94,094	-11.8	281.7	1.4
	6000-7000'	256	> 300†	24.2	17.6	52.6	337,553	-6.6	359.2	5.4
	7000-8000'	200	> 300†	28.9	32.2	92.1	574,776	3.3	335.0	16.9
	8000-9000'	173	200	30.9	36.1	94.5	595,059	5.2	308.8	29.3
	9000-10,000'	166	183	32.4	38.1	95.9	377,153	5.7	185.4	34.4
	10,000-11,000'	156	165	35.9	42.1	97.1	290,738	6.2	129.4	33.3
	11,000-12,000'	150	152	40.7	47.9	98.8	239,948	7.2	93.9	30.7
	> 12,000'	157	153	42.2	50.9	98.6	122,505	8.8	45.1	22.6

Basin	Elevation Band	2/28/19 % 2/28 Avg.	3/12/19 % 3/12 Avg.	2/28/19 SWE (in)	3/12/19 SWE (in)	3/12/19 % SCA	3/12/19 Vol (af)	2/28 thru 3/12/19 Chg. in SWE (in)	3/12/19 Area (mi2)	3/12/19 SNODAS* (in)
Truckee	5000-6000'	234	256	28.0	21.0	63.1	148,456	-7.0	132.7	6.6
	6000-7000'	182	204	33.4	36.8	92.8	487,592	3.4	248.3	25.2
	7000-8000'	158	168	38.8	45.1	96.1	321,792	6.3	133.7	42.2
	8000-9000'	144	156	39.8	47.6	98.2	108,139	7.8	42.6	47.3
	9000-10,000'	143	157	41.3	50.1	100.0	25,527	8.8	9.6	49.7
	10,000-11,000'	135	150	40.2	50.1	100.0	1,117	9.9	0.4	47.1
Tahoe	6000-7000'	202	237	32.4	33.3	41.2	236,032	0.9	132.9	20.4
	7000-8000'	176	179	38.7	41.5	98.3	252,901	2.9	114.2	41.3
	8000-9000'	153	159	41.7	47.6	99.6	184,739	5.9	72.7	48.2
	9000-10,000'	140	153	41.2	49.3	100.0	44,754	8.1	17.0	48.3
	10,000-11,000'	142	155	42.8	51.1	100.0	2,279	8.3	0.8	35.0
W. Carson	5000-6000'	> 300†	> 300†	19.0	3.5	13.0	4,911	-15.5	26.3	0.7
	6000-7000'	241	> 300†	29.9	29.3	94.1	21,761	-0.6	13.9	14.1
	7000-8000'	182	182	36.2	39.2	100.0	88,582	2.9	42.4	36.0
	8000-9000'	171	166	39.9	43.9	100.0	85,262	4.0	36.4	40.1
	9000-10,000'	156	158	40.0	46.3	100.0	29,433	6.3	11.9	41.2
	10,000-11,000'	142	147	38.4	46.0	100.0	2,911	7.6	1.2	33.5
E. Carson	5000-6000'	294	> 300†	24.8	9.0	28.6	33,046	-15.8	69.0	0.8
	6000-7000'	223	> 300†	32.5	31.2	91.2	160,796	-1.3	96.7	8.4
	7000-8000'	187	195	35.5	39.1	99.5	231,946	3.6	111.2	24.9
	8000-9000'	165	164	39.0	44.1	99.9	243,644	5.1	103.6	40.6
	9000-10,000'	150	159	40.7	47.5	100.0	92,142	6.8	36.4	46.2
	10,000-11,000'	141	156	40.3	49.2	100.0	28,543	8.9	10.9	40.5
	> 11,000'	131	145	40.8	52.0	100.0	774	11.3	0.3	28.4
W. Walker	5000-6000'	180	296	7	1	3	3,591	-5.8	80.9	0.0
	6000-7000'	252	> 300†	29.6	25.0	76.3	96,287	-4.6	72.3	2.3
	7000-8000'	194	225	31.8	34.4	99.5	190,005	2.6	103.6	12.6
	8000-9000'	171	178	33.9	38.2	100.0	180,877	4.3	88.8	29.1
	9000-10,000'	150	157	39.7	46.1	100.0	191,362	6.4	77.8	46.3
	10,000-11,000'	140	150	43.6	52.4	100.0	86,191	8.8	30.8	42.5
	> 11,000'	137	149	41.5	51.3	100.0	7,816	9.8	2.9	26.7
E. Walker	5000-6000'	81	0	0.9	0.0	0.0	0	-0.9	23.2	0.0
	6000-7000'	234	> 300†	18.8	13.9	44.3	163,611	-4.9	221.5	1.9
	7000-8000'	212	297	30.0	31.5	94.7	453,356	1.5	269.9	8.9
	8000-9000'	184	199	32.0	36.2	100.0	383,568	4.2	198.5	16.8
	9000-10,000'	168	171	36.6	41.9	100.0	182,470	5.3	81.6	28.1
	10,000-11,000'	154	158	42.0	49.2	99.8	111,517	7.2	42.5	27.4
	11,000-12,000'	149	154	41.7	50.5	100.0	30,608	8.8	11.4	16.7
	> 12,000'	148	154	42.8	51.9	100.0	772	9.1	0.3	14.3
Mono	6000-7000'	232	> 300†	22.7	12.8	33.7	220,092	-9.9	321.4	1.5
	7000-8000'	215	> 300†	29.7	32.7	98.4	728,419	3.0	418.2	5.9
	8000-9000'	188	205	31.0	35.1	99.5	348,289	4.1	186.1	11.8
	9000-10,000'	179	171	35.9	40.3	99.8	140,176	4.4	65.2	25.5
	10,000-11,000'	164	154	44.3	50.1	98.9	128,889	5.9	48.2	32.3
	11,000-12,000'	157	151	45.8	53.4	100.0	73,906	7.6	25.9	22.8
	> 12,000'	145	148	44.1	54.0	100.0	12,445	9.8	4.3	16.4
Owens	5000-6000'	70	> 300†	1	2	6	36,015	0.3	433.9	0.0
	6000-7000'	236	> 300†	15	14	48	311,079	-1.0	416.8	1.7
	7000-8000'	203	> 300†	23.5	27.9	88.0	716,135	4.5	480.6	7.4
	8000-9000'	199	242	28.0	32.8	96.3	466,680	4.7	267.0	14.9
	9000-10,000'	187	198	31.2	36.2	99.1	379,393	5.0	196.5	20.1
	10,000-11,000'	170	173	33.4	39.5	99.3	423,839	6.1	201.4	22.0
	11,000-12,000'	162	160	37.6	45.0	98.8	358,752	7.4	149.5	18.2
	> 12,000'	162	157	38.8	47.5	97.6	204,583	8.6	80.8	13.2