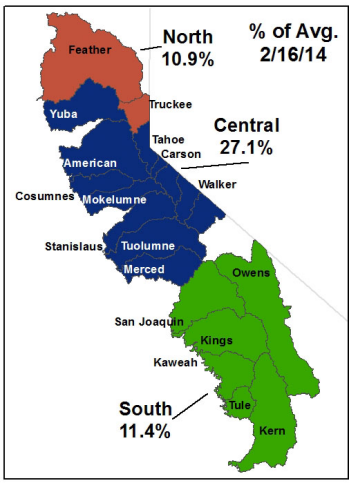
Real Time (RT) Snow Water Equivalent (SWE) Simulation
February 16, 2014
Sierra Nevada Mountains, California



Abstract

The most recent cloud-free MODIS/MODSCAG image available is for February 16, 2014. SWE depths have increased across the Sierra the last week. On February 16th, % of average values for this date are 10.9% for the Northern watersheds, 27.1% for the Central, and 11.4% for the Southern watersheds (see map at right). 84 snow sensors in the Sierra network were recording snow out of a total of 99 sensors. The locations of sensors that aren't recording snow (shown in yellow in Figure 3, left map) are lower elevation and a few that are offline in other strategic locations.

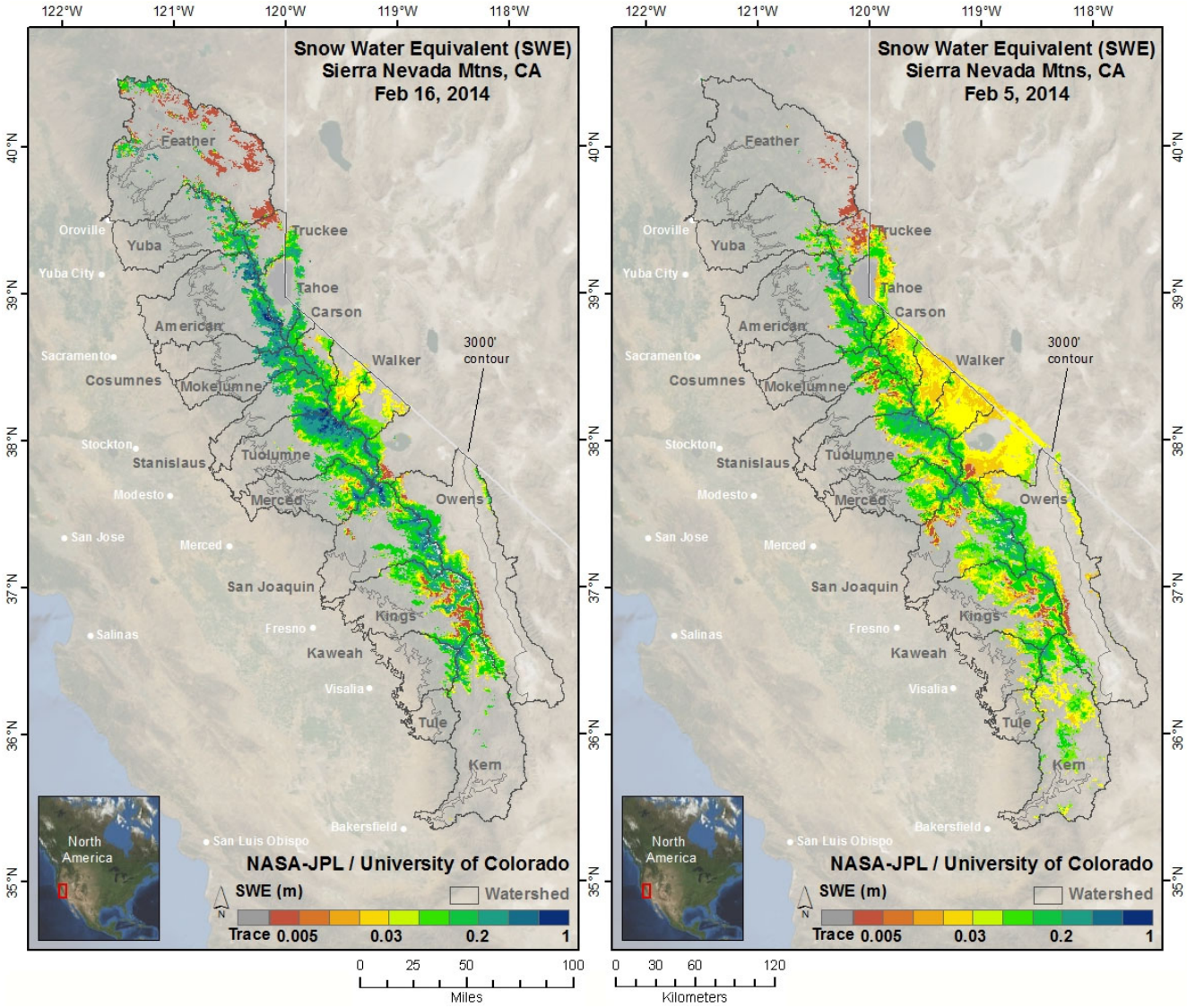


Figure 1. RT simulated SWE amounts for Feb 16, 2014 is shown on the left and for Feb 5, 2014 is shown on the right. SWE depths have increased across the Sierra in the last week.

Introduction

We have developed a real-time SWE estimation scheme based on historical SWE reconstructions between 2000-2012, a near real time MODIS/MODSCAG image, and daily in situ SWE measurements for the Sierra Nevada in California (Molotch, 2009; Molotch and Margulies, 2008; Molotch and Bales, 2006; Molotch and Bales, 2005, Molotch, et. al., 2004 and Guan). Real-time SWE will be released on a weekly basis during the maximum snow accumulation/ablation period.

Discussion

The most recent cloud-free MODIS/MODSCAG image available is for February 16, 2014. Figure 1 shows SWE amounts for February 16, 2014 and for February 5, 2014. On February 16, 2014, 84 snow sensors in the Sierra network were recording snow out of a total of 99 sensors. For comparison in 2012, a very dry year, 85 out of 99 recorded snow on February 16th, and in 2009, a normal year, 86 out of 99 sensors recorded snow on February 16th. Note the locations of sensors that aren't recording snow (shown in yellow in Figure 3, left map) are lower elevation sensors and a few that are offline in other strategic locations, so calculations from sensors alone do not accurately calculate SWE for each watershed. Figure 2 shows the percent of average SWE for February 16, 2014 for the snow-covered area on left and on the right is the mean percent of average for February 16, 2014 shown by watershed for all model pixels above 3000' (shown as gray elevation contour line on left map). Note that watershed averages are much lower than those calculated using snow sensors alone. Snow sensors produce a point value whereas the spatial SWE allows for areal calculations. Every square foot above 3000' in the watershed can be used to calculate the mean, therefore the mean value will be different than those calculated by snow sensor point data. Figure 3 shows the 13 year modeled average SWE for March 1st (reanalysis SWE modeling begins on March 1st each year) on the left with snow sensors shown in yellow that recorded no snow and in red for sensors that recorded snow on February 16, 2014; and a banded elevation map on the right. Table 1 shows mean SWE and mean % of Average SWE for February 16, 2014, summarized for each watershed above 3000'. Table 2 shows mean SWE by elevation band inside each watershed for February 16, 2014 and the mean percent of average by watershed for February 16, 2014.

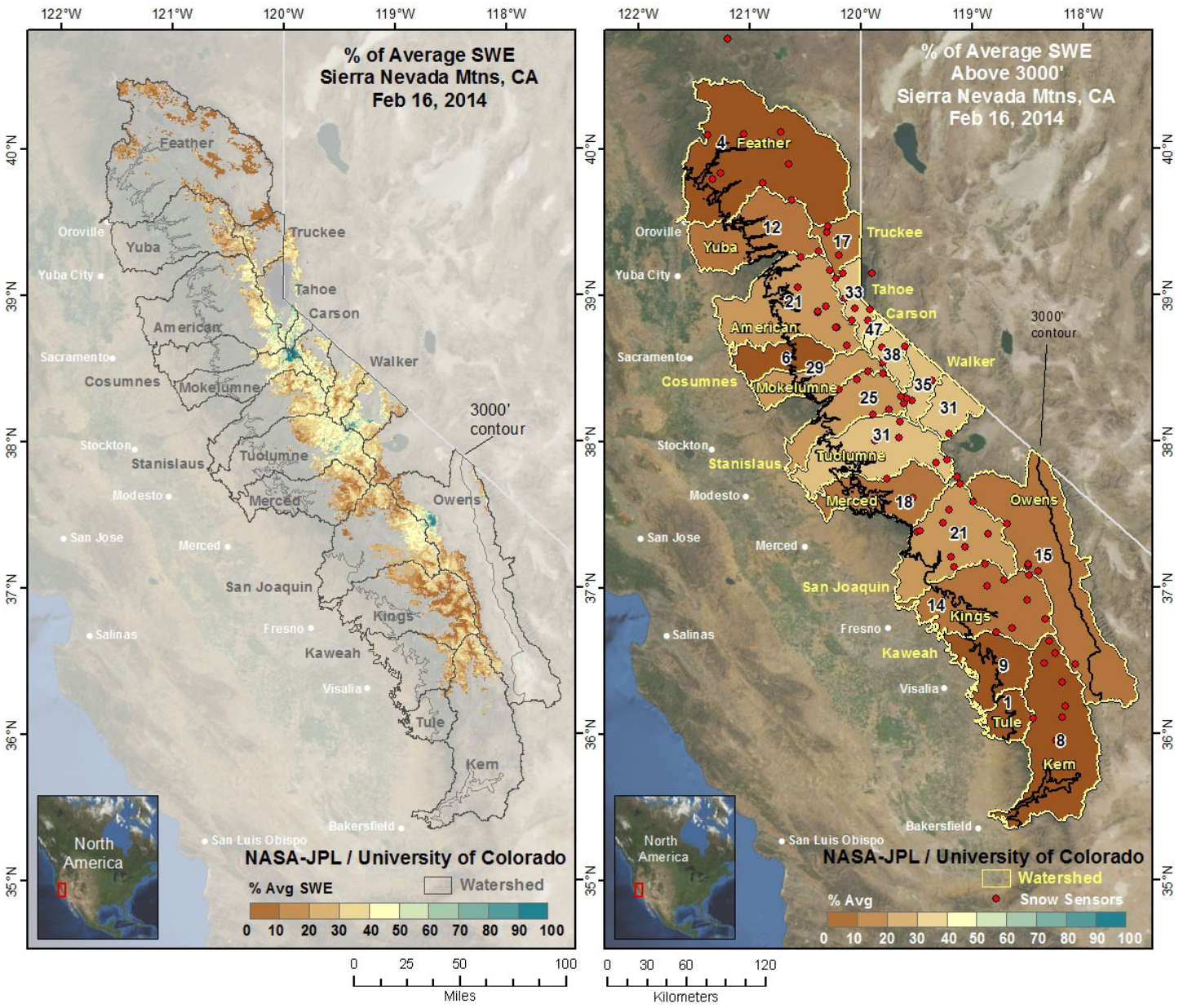


Figure 2. Percent of average RT simulated SWE for February 16, 2014 for the entire Sierra (on left) and by watershed (on right). Watershed percentages are calculated for all model pixels above 3000' (shown as gray line on left map). SWE snow sensors that had snow on February 16, 2014 have been added to the map on the right.

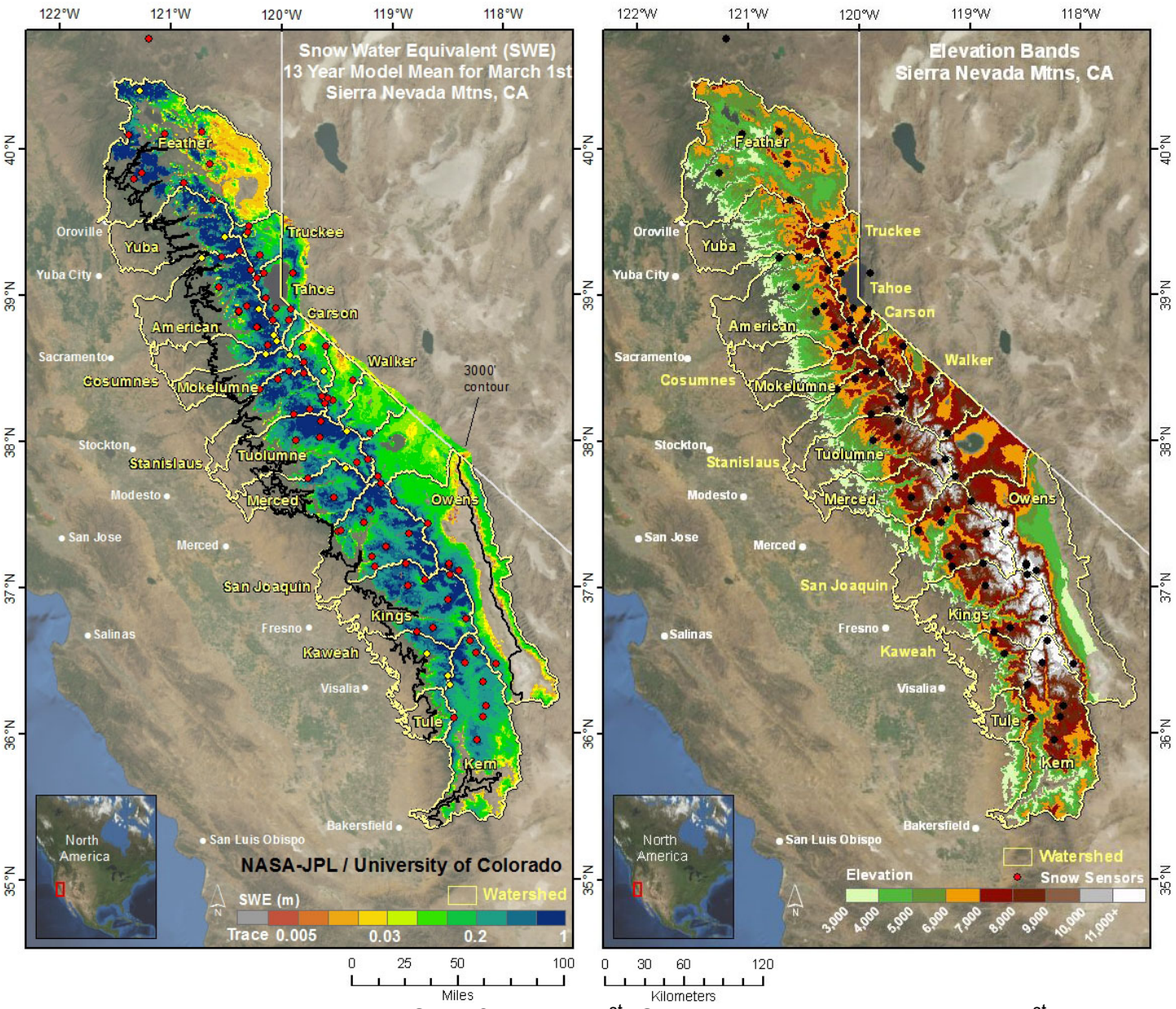


Figure 3. 13 year modeled average SWE for March 1st (SWE modeling begins on March 1st each year) on the left with snow sensors shown in yellow that recorded no snow (see discussion above for an explanation) and in red for sensors that recorded snow on February 16, 2014; and a banded elevation map on the right.

Methods

Results for the date of February 16, 2014 are based on February 16, 2014 real-time data from 84 in situ SWE measurements distributed across the Sierra Nevada, one Moderate Resolution Imaging Spectroradiometer (MODIS)/Terra Snow cover daily cloud-free image which has been processed using the MODSCAG fractional snow cover program (Painter, et. al. 2009), a normalized reconstructed spatial SWE image for March 1, 2009, and an anomaly map based on 13 years of modeled SWE (2000-2012). Relative to snow stations and the NWS SNODAS product, the spatial reconstructed SWE product correlates strongly with full natural flow, especially late in the snowmelt season (Guan, et. al. 2013).

Table 1. All calculations are for elevations above 3000'. Shown are mean SWE and mean % of Average SWE for 2/16/2014, mean SWE for 2/16/2014, change in SWE between 2/5/2014 and 2/16/2014 for each watershed.

Watershed	2/16/14 SWE (in)	2/16/14 % Avg to Date	2/5/14 SWE (in)	2/5 thru 2/16 Change in SWE (in)
AMERICAN	2.47	20.74	1.18	1.29
FEATHER	0.51	4.48	0.03	0.49
KAWEAH	0.74	8.57	0.64	0.10
KERN	0.79	7.93	1.01	-0.22
KINGS	2.23	14.00	1.75	0.48
TAHOE	7.46	32.59	4.39	3.07
MERCED	2.02	17.61	1.58	0.44
OWENS	0.96	15.48	0.85	0.11
SAN JOAQUIN	3.59	21.35	2.55	1.04
STANISLAUS	3.71	25.04	1.57	2.13
TRUCKEE	2.68	17.30	1.34	1.34
TUOLUMNE	4.61	30.85	2.46	2.15
YUBA	1.37	11.84	0.29	1.08
COSUMNES	0.19	5.78	0.09	0.10
MOKELUMNE	3.14	29.37	1.36	1.78
TULE	0.07	1.21	0.21	-0.14
WEST WALKER RIVER	3.36	34.76	2.43	0.93
EAST WALKER RIVER	2.48	31.43	2.06	0.42
WEST FORK CARSON RIVER	6.98	47.26	3.73	3.25
EAST FORK CARSON RIVER	4.21	38.17	2.89	1.32

Table 2. Mean SWE and mean % of Average SWE for 2/16/2014, mean SWE for 2/5/2014, change in SWE between 2/5/2014 and 2/16/2014, and area in square miles for each elevation band inside each watershed.

Watershed	Elevation	2/16/14 % Avg to Date	2/16/14 SWE (in)	2/5/14 SWE (in)	2/5 thru 2/16 Change SWE (in)	Area Sq Mi
AMERICAN	3000-4000'	0.47	0.00	0.00	0.00	191.9
	4000-5000'	0.02	0.00	0.00	0.00	249.3
	5000-6000'	0.46	0.07	0.06	0.01	294.8
	6000-7000'	12.96	3.84	1.81	2.02	296.4
	7000-8000'	36.98	13.72	6.59	7.14	175.7
	8000-9000'	44.69	17.94	8.38	9.56	74.2
	9000-10,000'	46.96	23.04	11.41	11.63	8.9
COSUMNES	3000-4000'	0.00	0.00	0.00	0.00	77.8
	4000-5000'	0.33	0.01	0.00	0.01	84.7
	5000-6000'	0.00	0.00	0.00	0.00	63.6
	6000-7000'	4.62	1.10	0.57	0.53	28.1
	7000-8000'	30.73	10.65	5.02	5.63	8.6
E CARSON	5000-6000'	0.11	0.00	1.32	-1.32	32.7
	6000-7000'	11.15	0.70	1.68	-0.98	77.7
	7000-8000'	34.38	3.59	2.61	0.99	102.6
	8000-9000'	46.69	7.33	4.01	3.31	96.5
	9000-10,000'	47.20	8.33	4.42	3.92	29.7
	10,000-11,000'	46.28	7.85	4.29	3.57	13.5
	> 11,000'	46.82	14.47	8.15	6.32	0.3
E WALKER	6000-7000'	2.13	0.08	1.66	-1.58	73.6
	7000-8000'	22.89	1.02	1.43	-0.41	157.4
	8000-9000'	27.31	1.74	1.39	0.35	154.9
	9000-10,000'	36.76	4.51	2.76	1.74	63.1
	10,000-11,000'	42.94	9.33	5.33	4.00	48.8
	> 11,000'	41.88	10.64	6.18	4.46	7.8
FEATHER	3000-4000'	0.48	0.02	0.00	0.02	286.2
	4000-5000'	0.45	0.03	0.00	0.03	735.8
	5000-6000'	1.65	0.22	0.00	0.22	1305.1
	6000-7000'	7.99	1.29	0.05	1.24	871.3
	7000-8000'	14.16	3.07	0.27	2.80	124.6
	8000-9000'	17.65	4.46	1.88	2.59	5.2
KAWEAH	3000-4000'	0.11	0.00	0.01	-0.01	74.4
	4000-5000'	0.01	0.00	0.02	-0.02	64.8
	5000-6000'	0.00	0.00	0.01	-0.01	60.9
	6000-7000'	0.12	0.02	0.19	-0.18	63.1
	7000-8000'	1.58	0.30	1.07	-0.78	63.5
	8000-9000'	9.06	1.96	2.16	-0.19	56.3
	9000-10,000'	15.02	3.53	2.59	0.95	38.8
	10,000-11,000'	21.94	8.33	5.78	2.55	36.6
	> 11,000'	25.35	10.92	8.03	2.89	8.9
KERN	3000-4000'	3.29	0.04	0.04	0.00	175.2
	4000-5000'	0.37	0.01	0.05	-0.04	221.9
	5000-6000'	0.06	0.00	0.07	-0.07	273.6
	6000-7000'	0.02	0.00	0.26	-0.26	391.9
	7000-8000'	0.14	0.02	1.15	-1.14	334.9
	8000-9000'	1.37	0.19	1.92	-1.73	308.7
	9000-10,000'	6.27	0.89	1.33	-0.44	166.3
	10,000-11,000'	20.76	4.05	1.95	2.10	149.7
	> 11,000'	25.86	7.00	5.07	1.94	142.5

KINGS	3000-4000'	0.00	0.00	0.01	-0.01	83.1
	4000-5000'	0.08	0.00	0.02	-0.02	92.8
	5000-6000'	0.08	0.01	0.04	-0.03	95.0
	6000-7000'	0.25	0.04	0.43	-0.39	136.0
	7000-8000'	1.85	0.39	1.48	-1.09	170.0
	8000-9000'	7.69	1.55	1.81	-0.26	209.9
	9000-10,000'	13.79	2.78	1.97	0.81	187.6
	10,000-11,000'	22.67	6.01	3.73	2.28	221.4
	> 11,000'	27.15	9.10	6.52	2.58	199.5
MERCED	3000-4000'	0.00	0.00	0.00	0.00	138.3
	4000-5000'	0.96	0.05	0.07	-0.02	88.7
	5000-6000'	0.40	0.04	0.03	0.00	72.9
	6000-7000'	1.55	0.28	1.28	-1.00	78.3
	7000-8000'	9.40	1.96	2.95	-0.99	132.8
	8000-9000'	20.01	3.94	2.99	0.95	124.1
	9000-10,000'	28.89	6.90	4.22	2.68	76.2
	10,000-11,000'	33.91	13.04	7.71	5.33	50.6
	> 11,000'	35.49	18.96	11.48	7.49	13.5
MOKELUMNE	3000-4000'	0.00	0.00	0.00	0.00	83.3
	4000-5000'	0.50	0.03	0.01	0.02	87.2
	5000-6000'	3.32	0.46	0.08	0.38	84.0
	6000-7000'	14.03	3.12	0.94	2.17	72.7
	7000-8000'	37.78	11.53	4.93	6.59	85.9
	8000-9000'	51.01	14.18	6.54	7.63	81.2
	9000-10,000'	45.89	15.11	7.76	7.34	7.8
	10,000-11,000'	45.45	20.10	9.85	10.25	0.1
OWENS	3000-4000'	0.00	0.00	0.00	0.00	184.1
	4000-5000'	0.00	0.00	0.00	0.00	428.5
	5000-6000'	0.00	0.00	0.00	0.00	254.6
	6000-7000'	0.03	0.00	0.12	-0.12	255.2
	7000-8000'	1.01	0.07	0.62	-0.55	302.6
	8000-9000'	8.44	0.87	1.64	-0.77	165.3
	9000-10,000'	15.83	2.01	2.15	-0.14	112.4
	10,000-11,000'	26.90	4.70	3.40	1.30	188.0
	> 11,000'	33.20	8.85	6.03	2.82	167.2
SAN JOAQUIN	3000-4000'	0.00	0.00	0.00	0.00	76.2
	4000-5000'	0.08	0.00	0.00	0.00	93.8
	5000-6000'	0.30	0.02	0.04	-0.02	130.9
	6000-7000'	1.11	0.15	0.35	-0.21	183.9
	7000-8000'	5.41	0.95	1.60	-0.65	214.5
	8000-9000'	15.25	3.30	2.98	0.33	194.1
	9000-10,000'	24.75	6.11	4.06	2.05	173.8
	10,000-11,000'	33.56	11.22	6.74	4.48	188.0
	> 11,000'	34.49	13.61	9.10	4.51	146.3
STANISLAUS	3000-4000'	0.00	0.00	0.00	0.00	61.6
	4000-5000'	0.11	0.00	0.00	0.00	100.0
	5000-6000'	0.60	0.08	0.02	0.06	105.7
	6000-7000'	12.15	2.80	0.77	2.03	142.3
	7000-8000'	27.88	7.27	2.83	4.43	145.4
	8000-9000'	37.50	10.25	4.40	5.85	121.9
	9000-10,000'	40.73	13.31	6.67	6.64	47.1
	10,000-11,000'	42.19	17.77	9.89	7.88	18.0
	> 11,000'	29.24	9.23	7.93	1.30	0.7

	> 11,000'	25.24	5.28	7.08	-1.80	8.7
TAHOE	6000-7000'	12.79	1.89	2.35	-0.46	103.2
	7000-8000'	34.77	9.62	5.01	4.61	74.7
	8000-9000'	44.17	13.35	6.76	6.59	51.3
	9000-10,000'	50.13	14.58	7.20	7.38	12.1
	10,000-11,000'	50.42	13.49	6.33	7.16	0.9
TRUCKEE	5000-6000'	0.00	0.00	0.36	-0.36	51.2
	6000-7000'	8.59	1.09	0.62	0.47	254.6
	7000-8000'	27.38	6.61	2.95	3.66	111.9
	8000-9000'	34.76	10.08	5.03	5.04	14.1
TULE	3000-4000'	0.06	0.00	0.04	-0.04	34.9
	4000-5000'	0.00	0.00	0.06	-0.06	48.0
	5000-6000'	0.00	0.00	0.07	-0.07	51.8
	6000-7000'	0.00	0.00	0.27	-0.27	45.2
	7000-8000'	0.24	0.04	1.21	-1.18	27.0
	8000-9000'	2.00	0.33	1.62	-1.29	15.7
	9000-10,000'	7.36	1.38	1.09	0.29	5.8
TUOLUMNE	3000-4000'	2.09	0.02	0.00	0.02	122.4
	4000-5000'	2.98	0.12	0.00	0.12	149.9
	5000-6000'	2.17	0.21	0.11	0.11	172.8
	6000-7000'	8.19	1.43	0.91	0.52	149.0
	7000-8000'	26.69	6.76	3.28	3.49	151.1
	8000-9000'	37.36	10.72	5.41	5.31	170.9
	9000-10,000'	42.45	13.93	7.45	6.48	152.7
	10,000-11,000'	42.97	15.23	8.59	6.63	116.7
	> 11,000'	37.46	13.85	8.63	5.22	28.8
W CARSON	4000-5000'	0.00	0.00	2.22	-2.22	1.6
	5000-6000'	1.54	0.05	1.92	-1.87	16.8
	6000-7000'	22.70	2.75	2.83	-0.08	8.3
	7000-8000'	48.84	7.45	3.46	3.99	35.6
	8000-9000'	52.96	9.60	4.49	5.11	32.7
	9000-10,000'	50.37	11.59	5.49	6.10	9.5
	10,000-11,000'	48.85	15.14	7.38	7.76	2.3
W WALKER	5000-6000'	0.00	0.00	1.57	-1.57	46.8
	6000-7000'	12.43	0.50	1.59	-1.09	60.0
	7000-8000'	26.12	1.31	1.23	0.08	91.4
	8000-9000'	32.40	2.44	1.59	0.85	93.8
	9000-10,000'	38.87	7.27	4.14	3.14	73.3
	10,000-11,000'	41.40	10.63	5.96	4.67	42.4
	> 11,000'	39.60	7.91	4.64	3.27	2.6
YUBA	3000-4000'	0.00	0.00	0.00	0.00	168.8
	4000-5000'	0.00	0.00	0.00	0.00	202.8
	5000-6000'	0.78	0.17	0.00	0.16	188.0
	6000-7000'	11.60	3.82	0.59	3.23	238.7
	7000-8000'	25.58	8.70	2.16	6.54	123.0
	8000-9000'	34.12	12.71	5.96	6.75	6.3

Location of Reports and Excel Format Tables
ftp://snowserver.colorado.edu/pub/fromLeanne/forCADWR/Near_Real_Time_Reports/

References
Guan, B., N. P. Molotch, D. E. Waliser, S. M. Jepsen, T. H. Painter, and J. Dozier. Snow water equivalent in the Sierra Nevada: Blending snow sensor observations with snowmelt model simulations. Submitted to *Water Resour. Res.*

Molotch, N.P., 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, 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, 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, 2006.

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

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

Painter, T.H., K. Rittger, C. McKenzie, P. Slaughter, R. E. Davis and J. Dozier, Retrieval of subpixel snow covered area, grain size, and albedo from MODIS. *Remote Sensing of the Environment*, 113: 868-879, 2009.