Real-time mapping of SWE based on satellite data, models, and SNOTEL

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Photo: Jim Steenburgh

Objective

- Develop more accurate spatial snow estimates using satellite data.

    - Reconstruct SWE distribution using MODIS snow cover data and an energy balance model.

    - Use multi-variate regression to interpolate SNOTEL & CoCoRaHS SWE based on topography & historical satellite data.

    - Reanalysis and real time daily SWE products at 500-m resolution from 2000 – present.
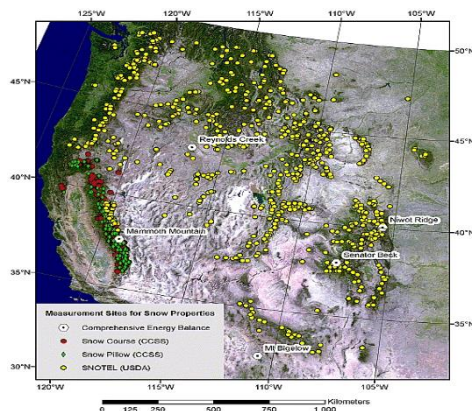
SNOTEL SWE Interpolation

Independent Variables
DEM: slope, aspect, elevation, NW barrier difference, distance to ocean, others.
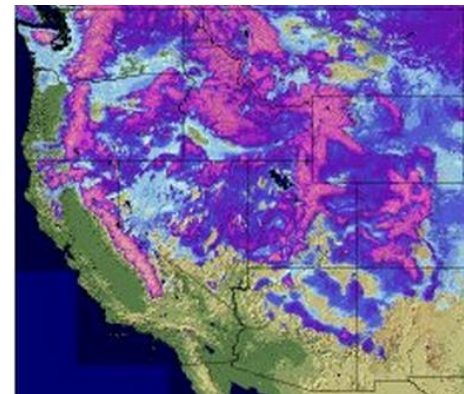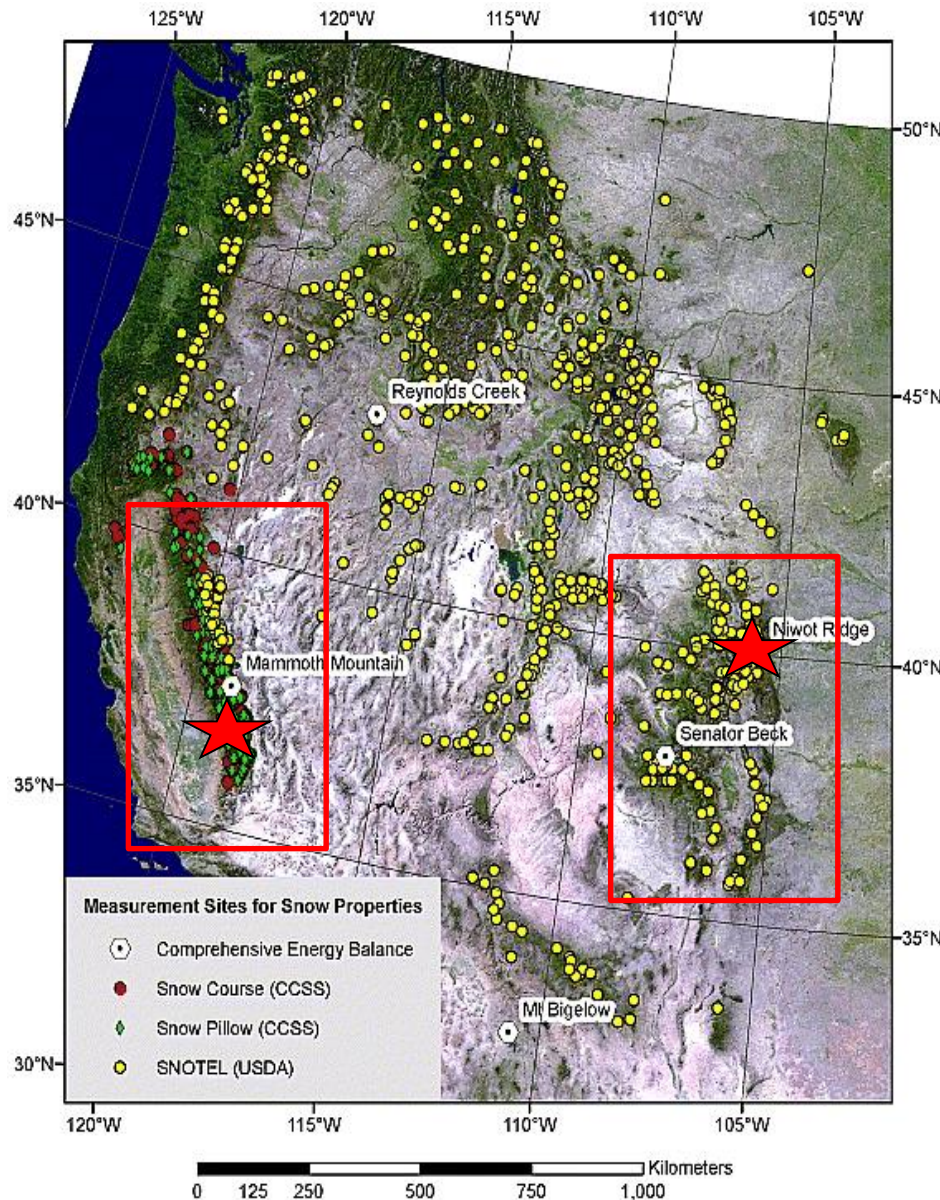Historical Satellite-model derived SWE.
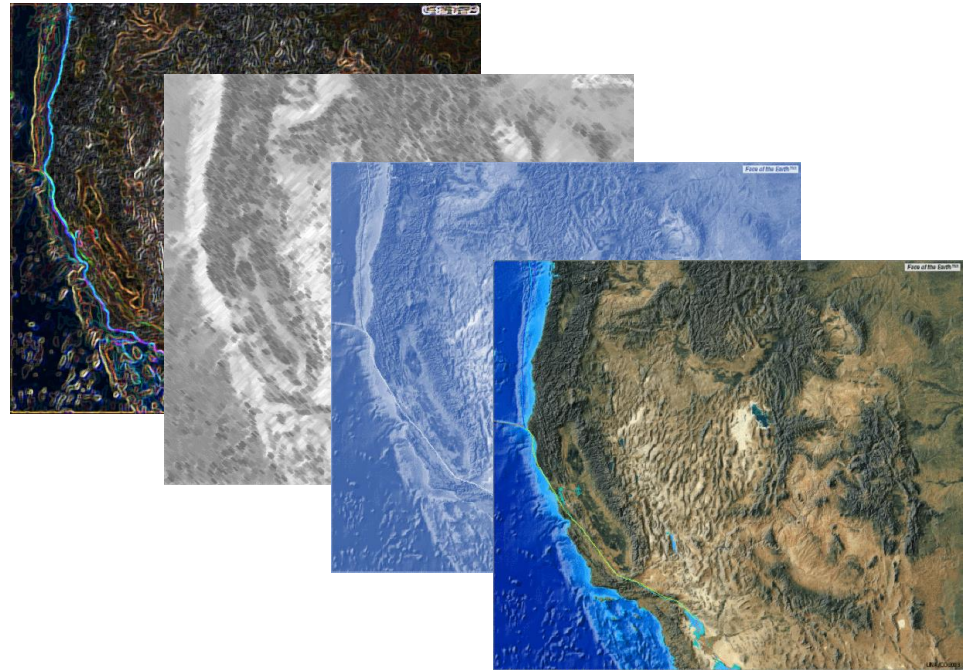
Dependent Variable
SNOTEL SWE
CoCoRaHS
Measurements

Gridded SWE Prediction

Study Areas & Data

Snowpack Metrics

- 350+ SNOTEL SWE sites

- 300+ CoCoRaHS sites

- MODIS-based SWE Reconstruction (*Guan et al., 2013; Molotch et al., 2009*)

Independent Variables

- Elevation, slope, aspect, distance to ocean, barrier height, others.
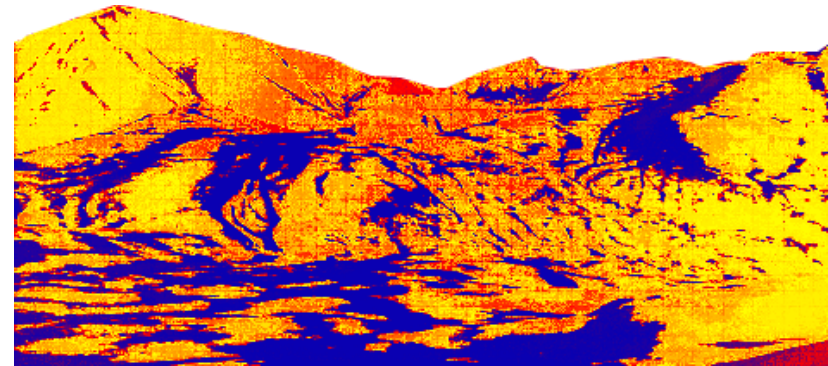
- MODIS-based SWE Reconstruction

SWE Reconstruction model

- Model uses energy balance to recover amount of snow prior to melt.

- Requires adequate estimate of snowpack energy balance and satellite observed snow covered area.
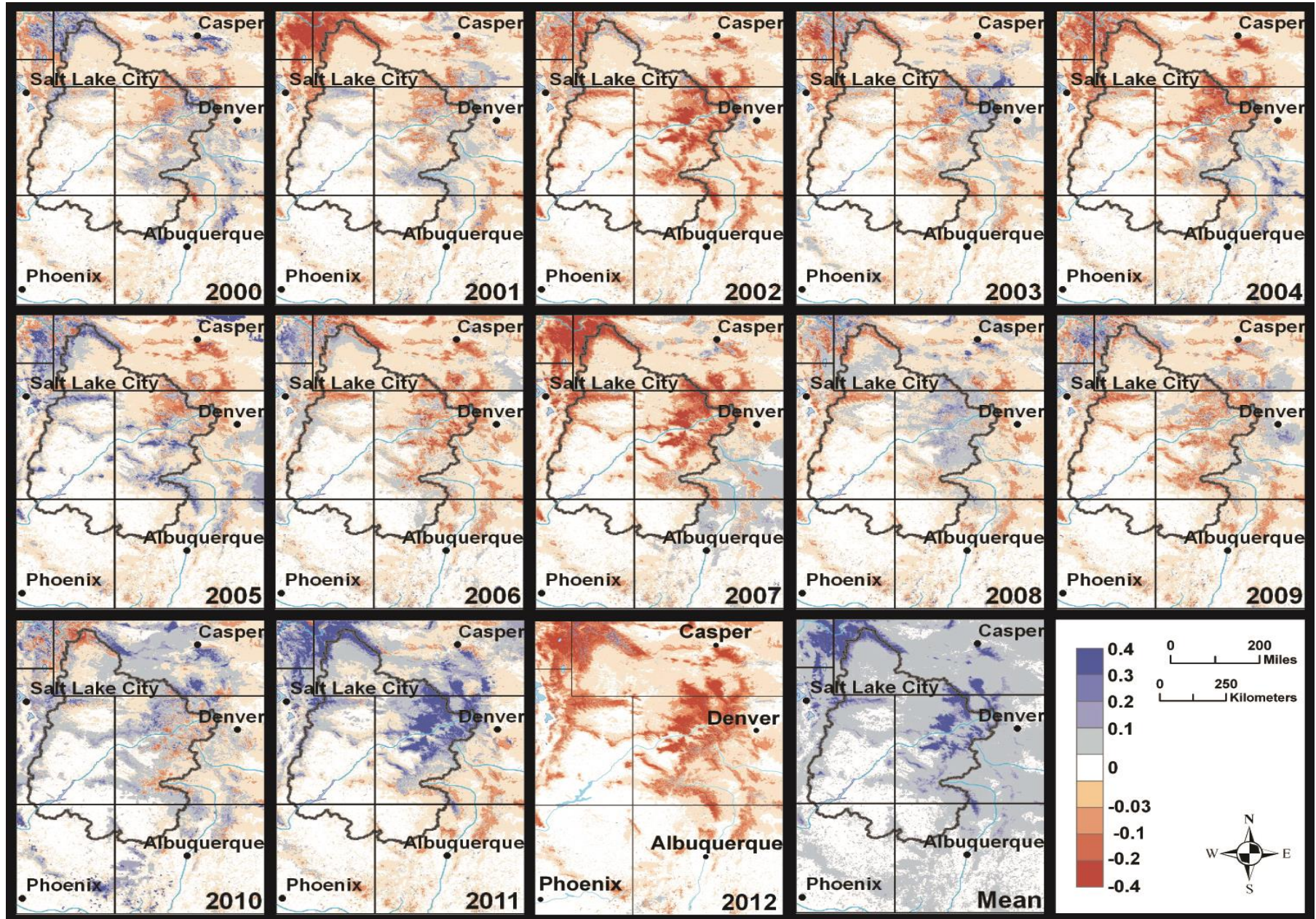
snow covered area
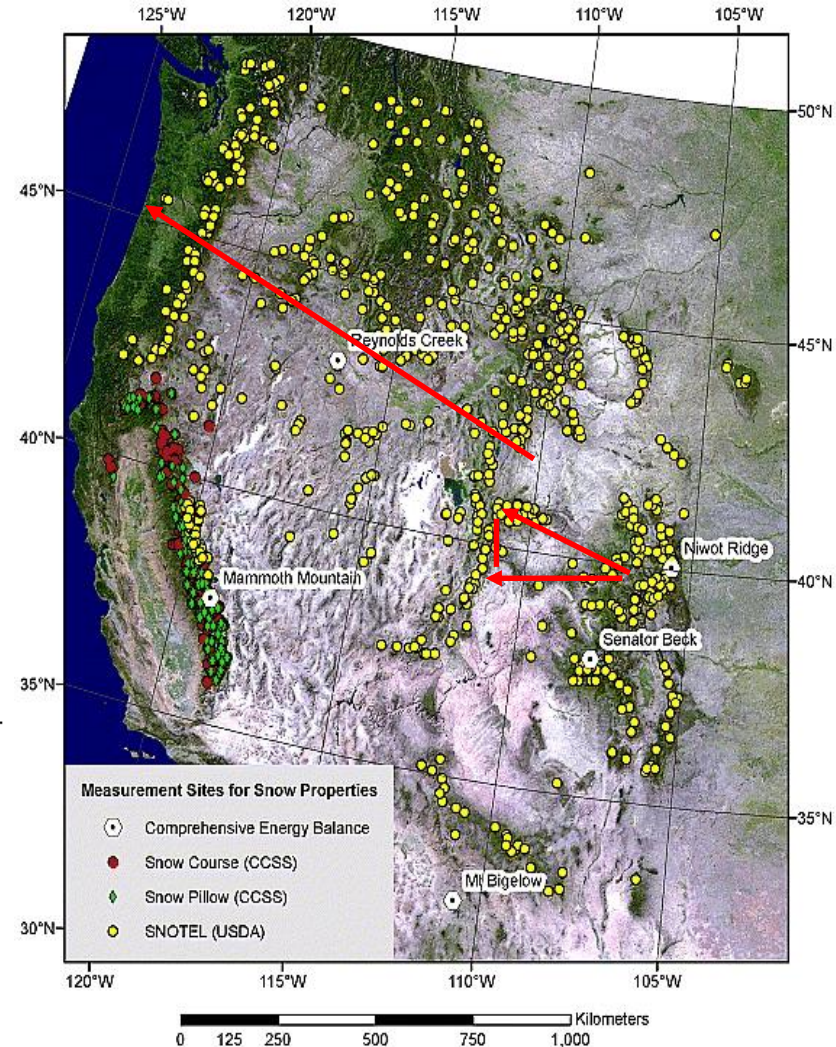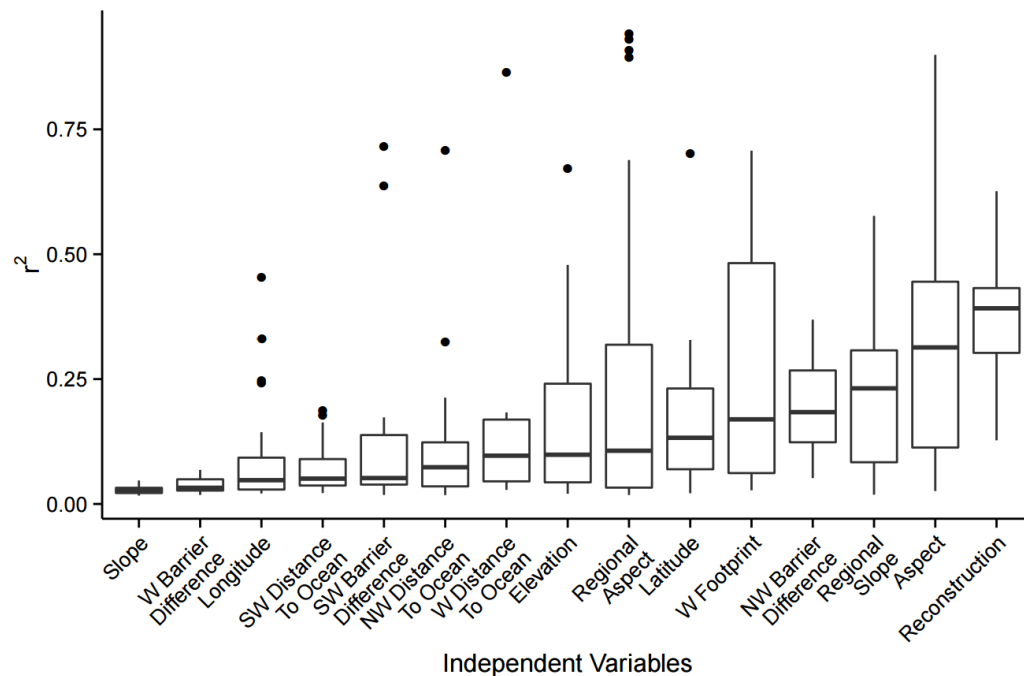

daily snowmelt, cm

0   1.6   3.2

Cline et al., 1998a,b; Liston, 1999; Molotch et al., 2004b; Molotch & Bales, 2005;2006; Durand et al., 2007; Molotch, 2008.

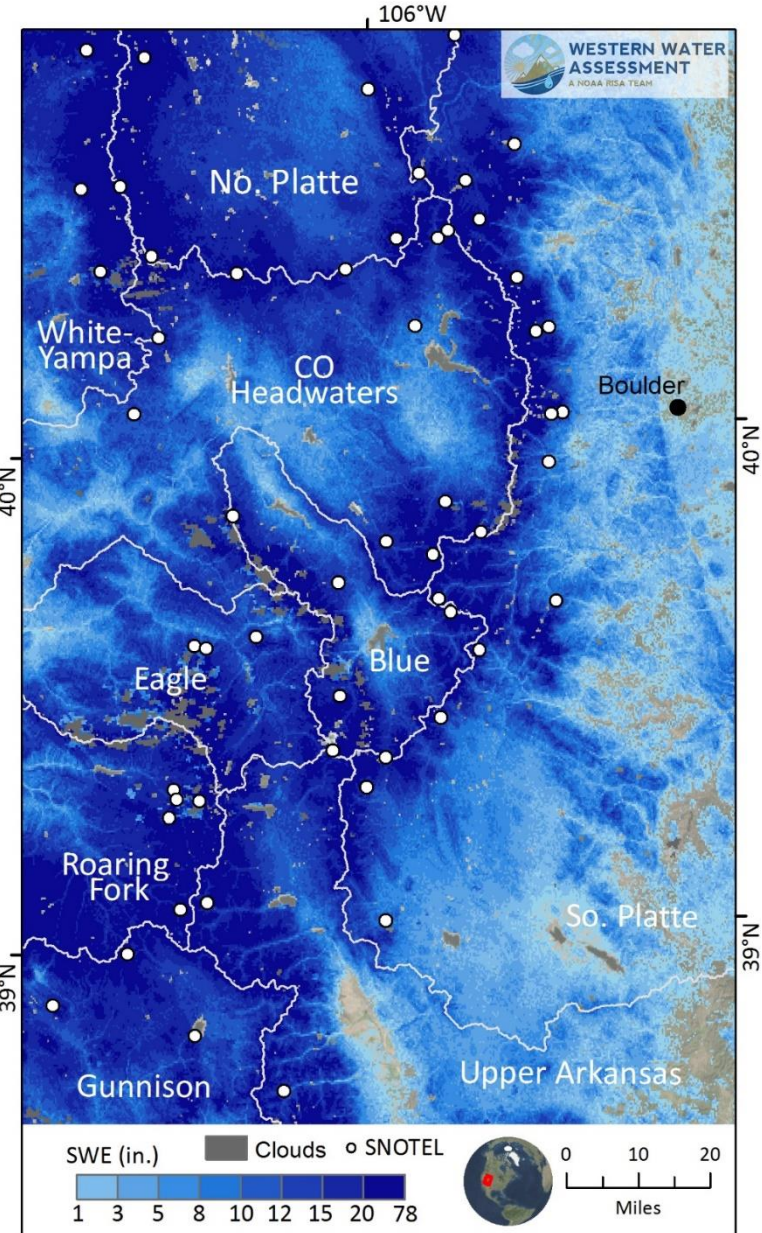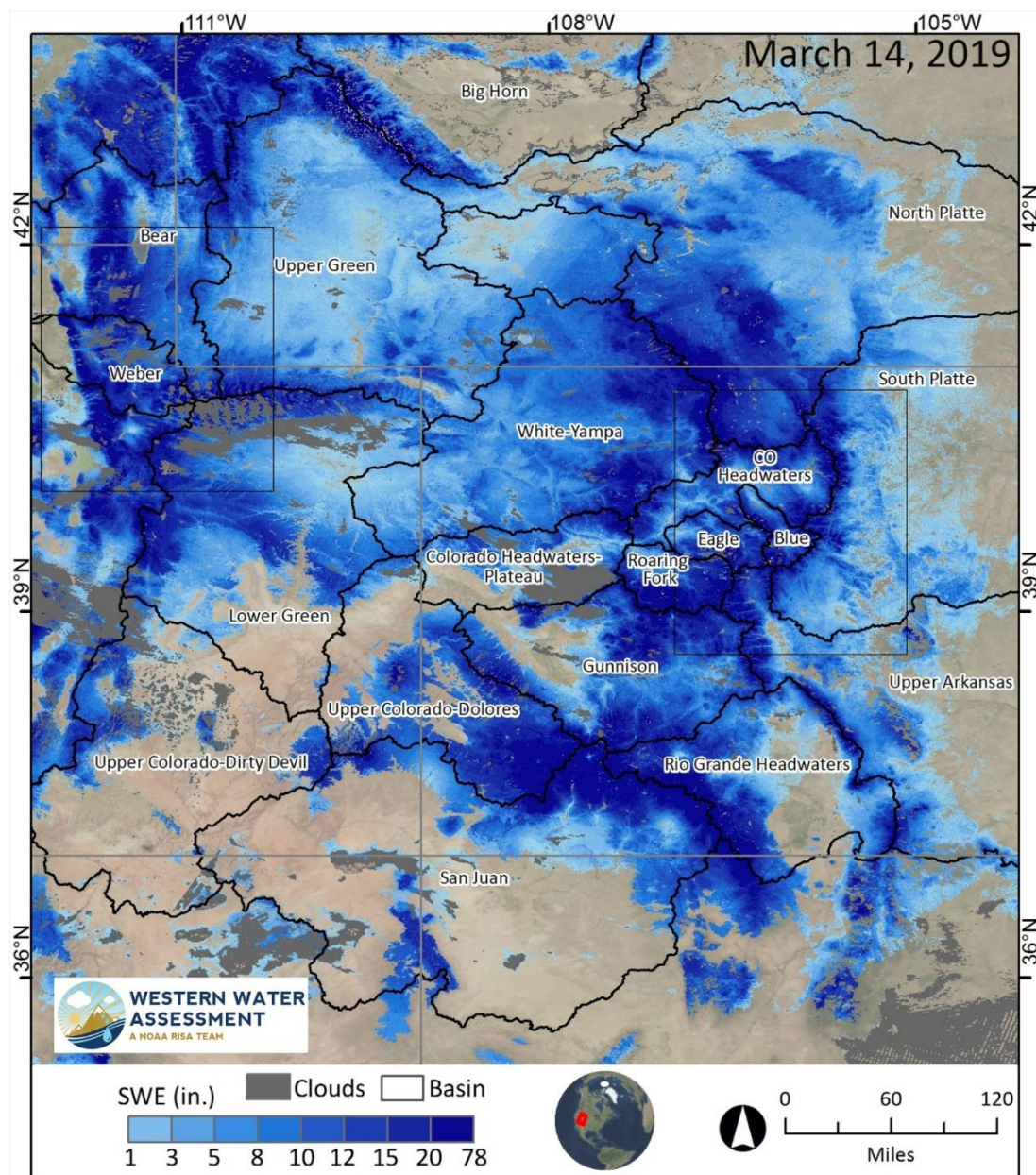# Historical Colorado River Basin Snowpack

Correlation between SNOTEL SWE & Single Variables

April 1, 2010 - 2015

# Real-time SWE for the Southern Rockies

SWE by Watershed

Basin	3/14/2019 % 3/14 Avg	3/14/19 SWE (in)	3/14/19 % SCA	3/14/19 Vol (af)	Area (mi2) > 5000'	3/14/19 SNODAS* (in)
Blue	138.8	15.6	96.2	579,238	698	13.9
Colorado Headwaters	140.0	12.9	98.0	2,046,714	2,985	11.4
Colorado Headwaters-Platea	141.2	11.4	66.2	787,437	1,298	12.6
Eagle	133.7	14.3	94.0	716,792	941	14.2
Gunnison	148.6	13.0	94.0	4,481,017	6,470	14.6
Lower Green	150.4	13.1	81.5	3,550,576	5,066	11.4
North Platte	145.6	11.3	99.5	6,850,046	11,367	7.2
Rio Grande Headwaters	>175†	8.8	81.1	3,632,293	7,722	7.0
Roaring Fork	128.1	19.1	98.2	1,462,607	1,435	17.5
San Juan	>175†	12.7	83.7	4,486,272	6,632	9.6
South Platte	>175†	7.6	99.0	2,461,913	6,072	5.0
Upper Arkansas	>175†	7.5	86.5	2,469,709	6,201	3.9
Upper Colorado-Dirty Devil	>175†	8.7	69.1	997,197	2,157	7.0
Upper Colorado-Dolores	>175†	16.3	96.2	3,041,575	3,500	12.9
Upper Green	131.5	9.1	97.7	5,097,186	10,446	7.3
White-Yampa	138.9	14.4	97.3	4,877,261	6,345	12.3

SWE by Elevation & Watershed

Basin	Elevation Band	3/14/2019 % 3/14 Avg.	3/14/19 SWE (in)	3/14/19 % SCA	3/14/19 Vol (af)	3/14/19 Area (mi2)	3/14/19 SNODAS* (in)
Blue	7000-8000'	137.5	4.5	96.4	8,544	36.0	3.1
	8000-9000'	146.8	8.6	99.6	49,018	106.8	7.2
	9000-10,000'	152.4	10.2	98.2	70,249	129.1	12.0
	10,000-11,000'	152.3	14.6	98.4	151,548	194.4	16.9
	11,000-12,000'	131.2	22.0	93.4	193,512	165.0	18.4
	12,000-13,000'	132.3	29.7	89.7	97,095	61.4	15.0
	13,000+	145.6	31.2	79.4	9,274	5.6	8.3
Colorado Headwaters-Plateau	7000-8000'	161.2	8.1	69.3	224,317	516.1	7.9
	8000-9000'	141.5	10.8	65.3	270,052	470.3	12.0
	9000-10,000'	137.0	16.0	65.1	143,061	167.7	18.2
	10,000-11,000'	125.8	19.1	59.5	139,828	137.1	22.4
	11,000-12,000'	90.6	29.7	95.9	10,178	6.4	30.4
Colorado Headwaters	7000-8000'	149.4	6.0	99.4	151,047	469.1	3.0
	8000-9000'	141.9	9.4	98.0	449,516	898.7	7.5
	9000-10,000'	150.7	12.8	99.0	529,854	773.5	12.3
	10,000-11,000'	139.0	17.4	97.5	552,805	597.3	19.6
	11,000-12,000'	125.0	26.6	94.3	307,770	216.8	19.1
	12,000-13,000'	129.2	34.8	90.5	55,438	29.8	12.5
	13,000+	120.8	38.2	66.7	284	0.1	10.5
Eagle	7000-8000'	146.1	7.1	100.0	65,271	172.0	3.6

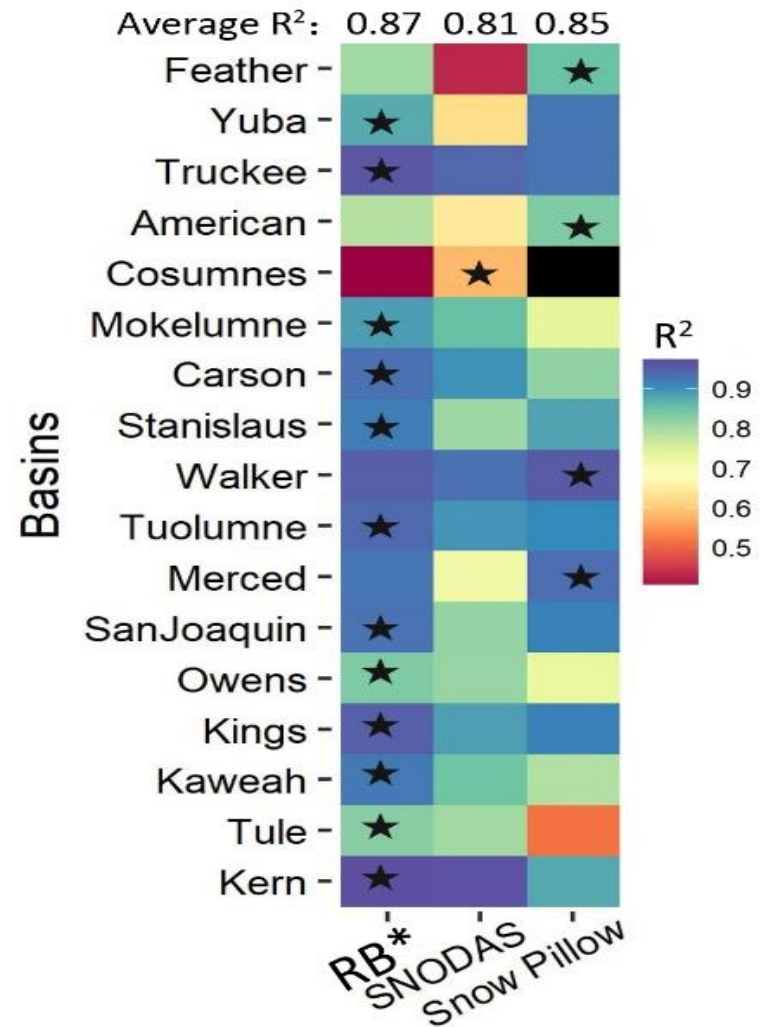# SNODAS VS REGRESSION PRODUCT
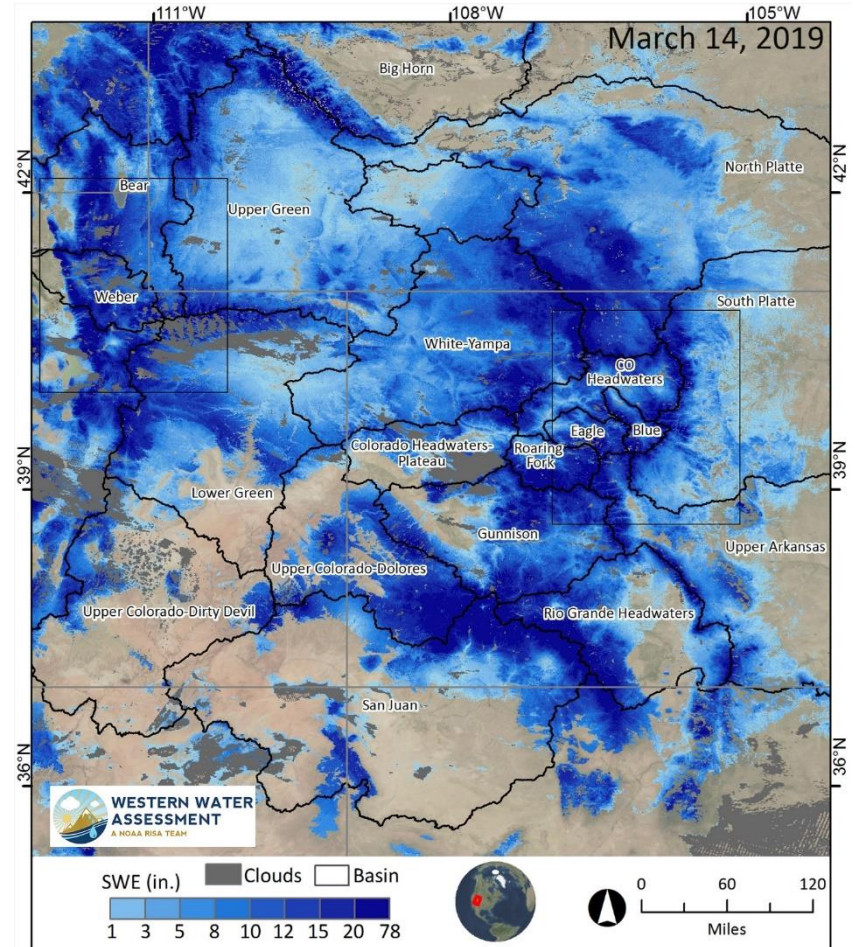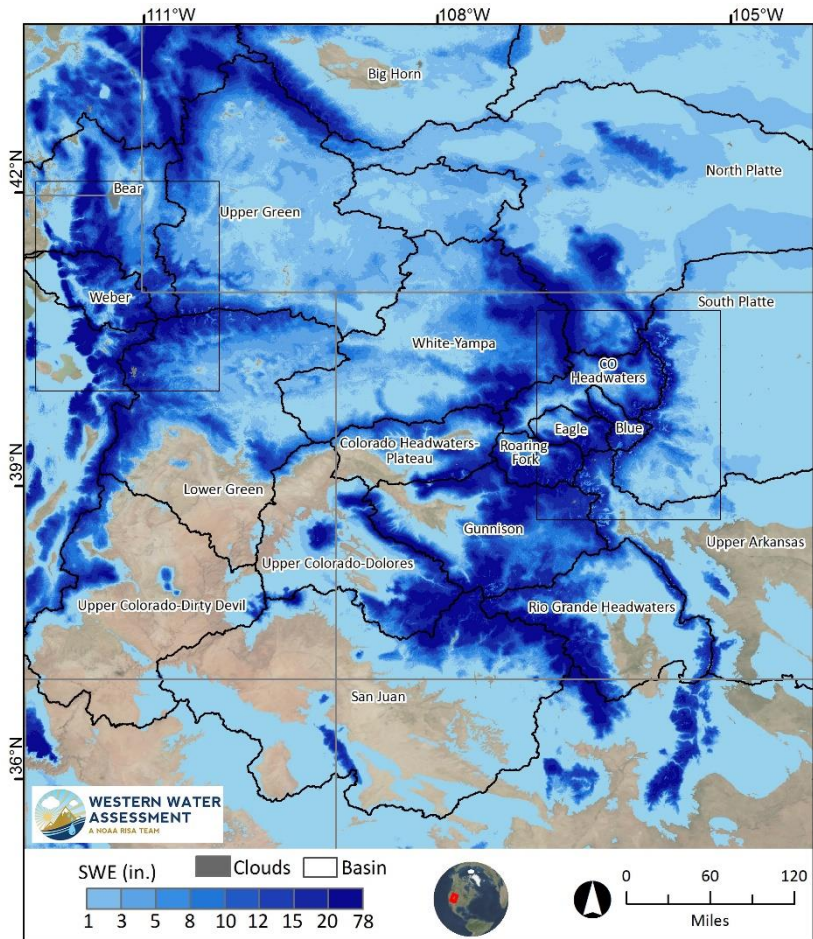
SWE Difference w/ SNODAS
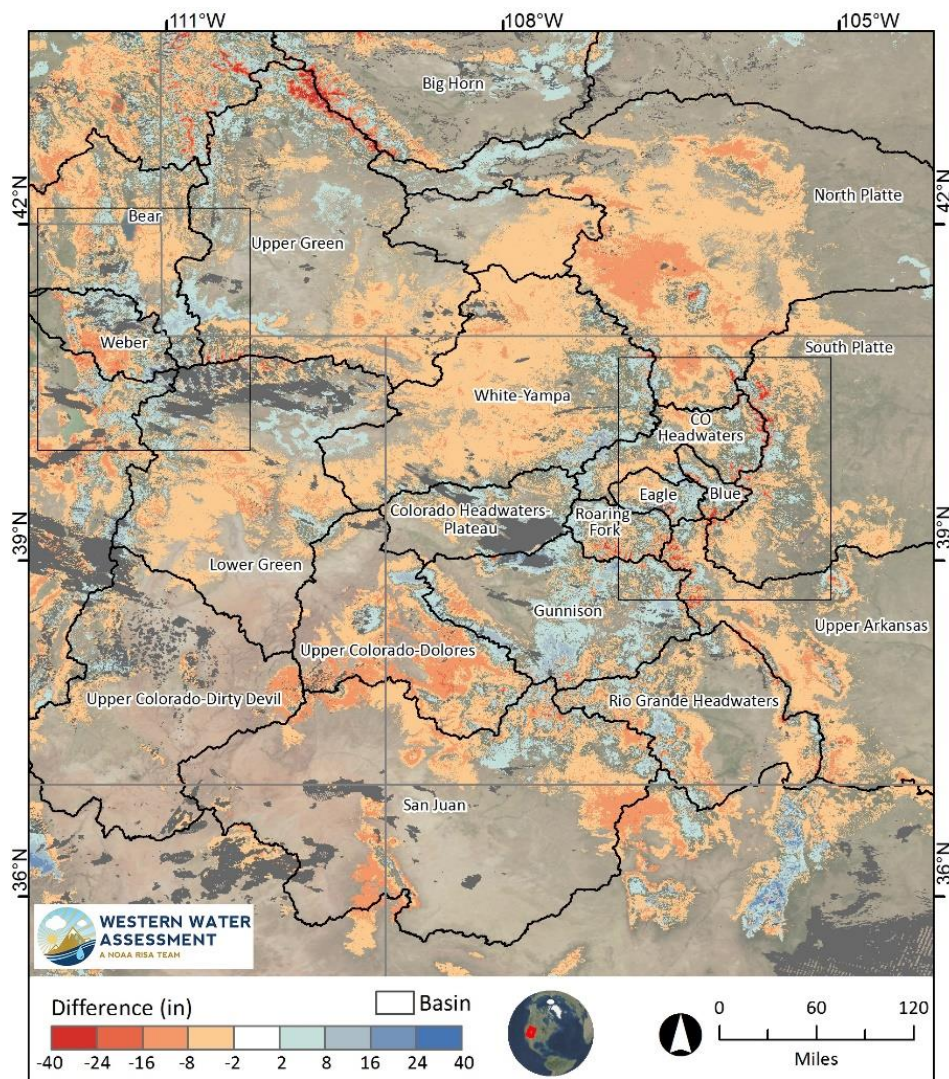
- Regression SWE is slightly greater across large areas of the Yampa & North Platte

- Regression SWE shows significantly greater high elevation SWE above treeline.

Correlation w/ Full Natural Flow

- Regression-based estimates show greater correlation than SNODAS in 17 of 18 watersheds.

- Regression-based estimates show greater correlation than Snow Pillows in 14 of 18 watersheds.

Conclusions & Future Work

- Regression Spatial SWE estimates provide valuable information for augmenting point data and SNODAS.

- Products are used by CA Department of Water Resources to adjust statistical forecasts.

- Approach can be applied in conjunction with airborne snow measurements in context of validation and / or temporal change analysis.

Contact Us

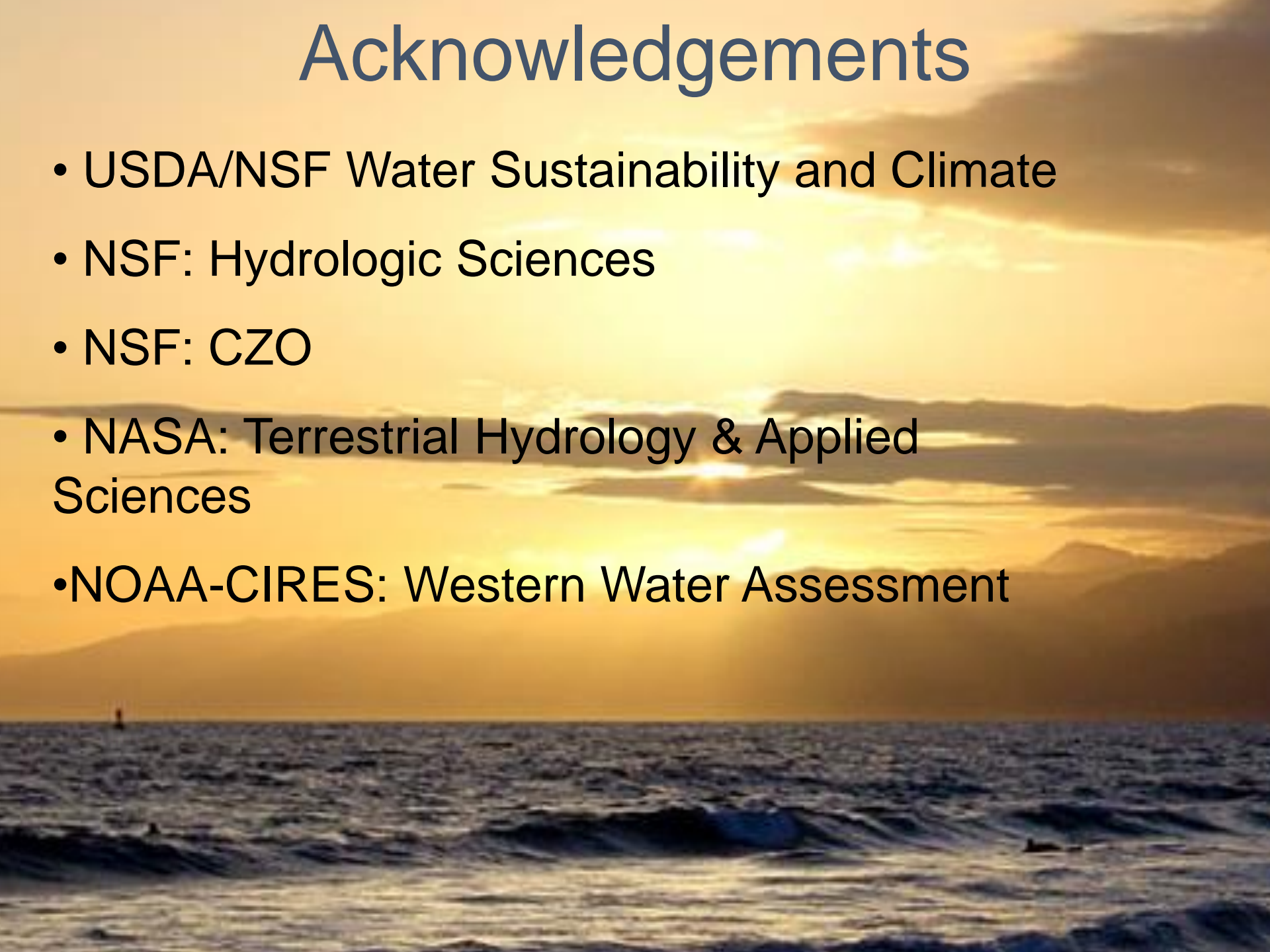We are looking for new partners to tailor SWE reports for local needs.

Noah Molotch: noah.molotch@colorado.edu
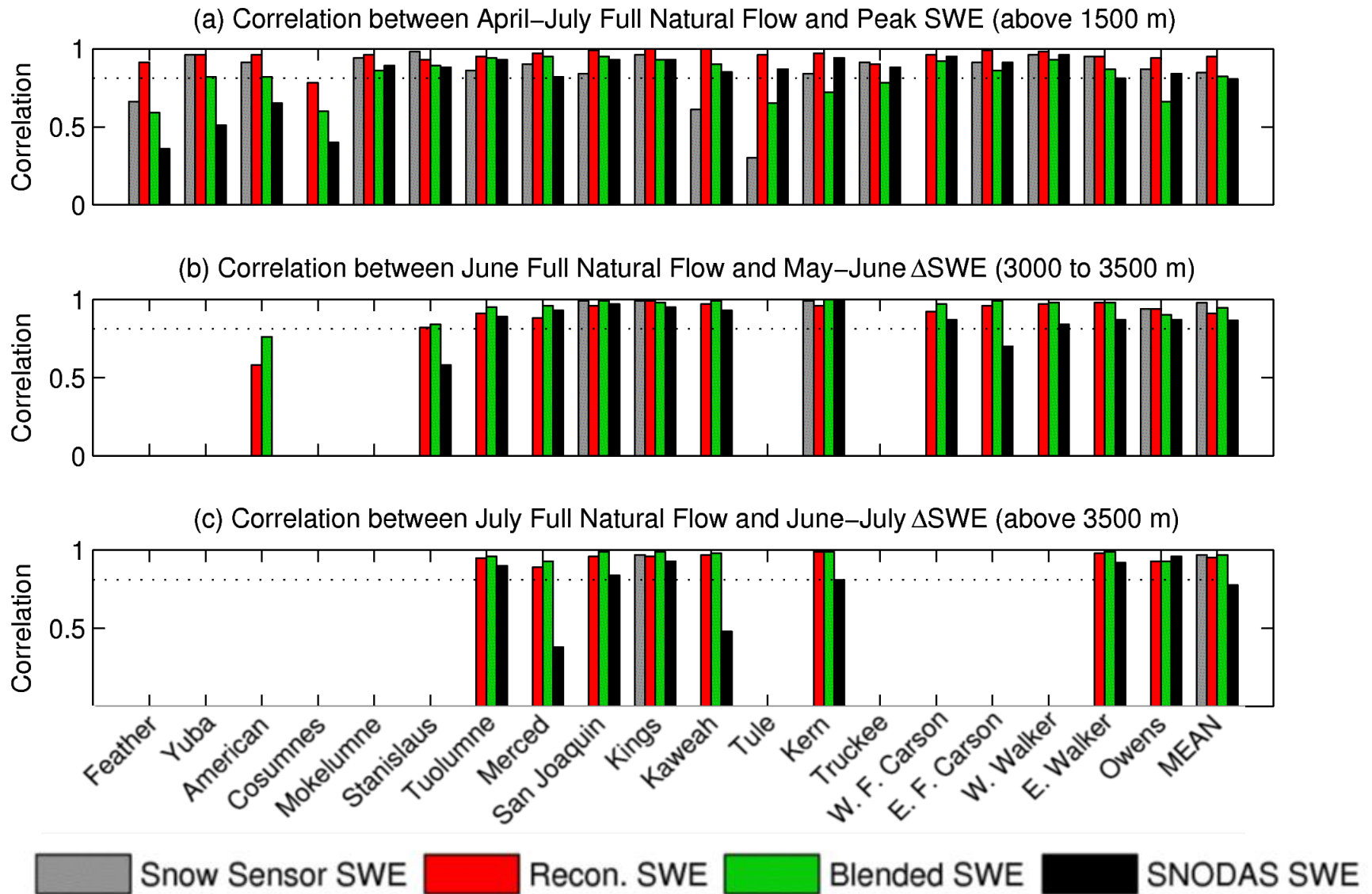

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Center for Water, Earth Science and Technology
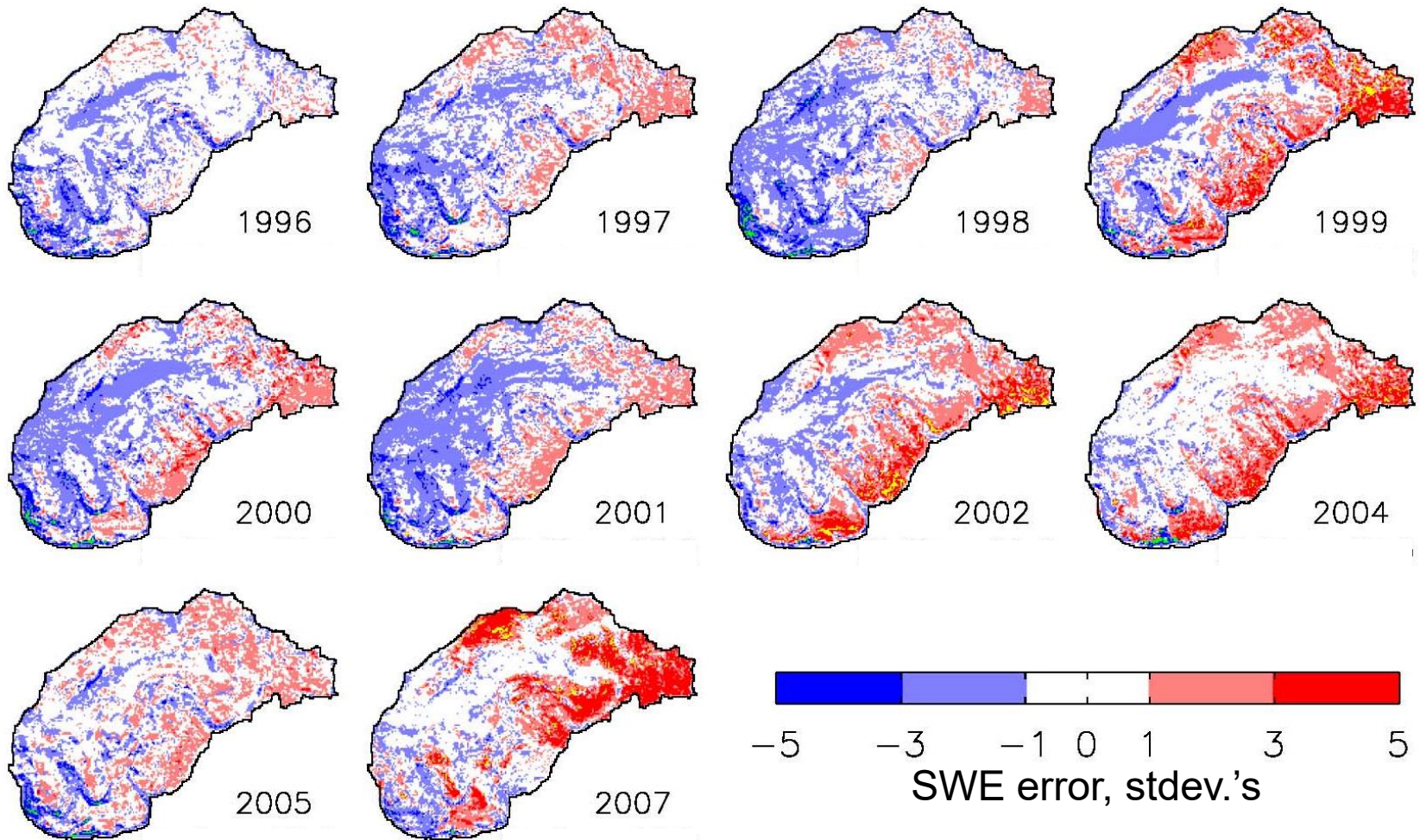
Acknowledgements

Correlation of SWE with Streamflow

(a) Correlation between April–July Full Natural Flow and Peak SWE (above 1500 m)

(b) Correlation between June Full Natural Flow and May–June ΔSWE (3000 to 3500 m)

(c) Correlation between July Full Natural Flow and June–July ΔSWE (above 3500 m)

Feather, Yuba, American, Cosumnes, Mokelumne, Stanislaus, Tuolumne, Merced, San Joaquin, Kings, Kaweah, Tule, Kern, Truckee, W. F. Carson, E. F. Carson, W. Walker, E. Walker, Owens, MEAN

Snow Sensor SWE   Recon. SWE   Blended SWE   SNODAS SWE

Guan et al., 2013 - WRR

Model Validation

1996 1997 1998 1999

2000 2001 2002 2004

2005 2007

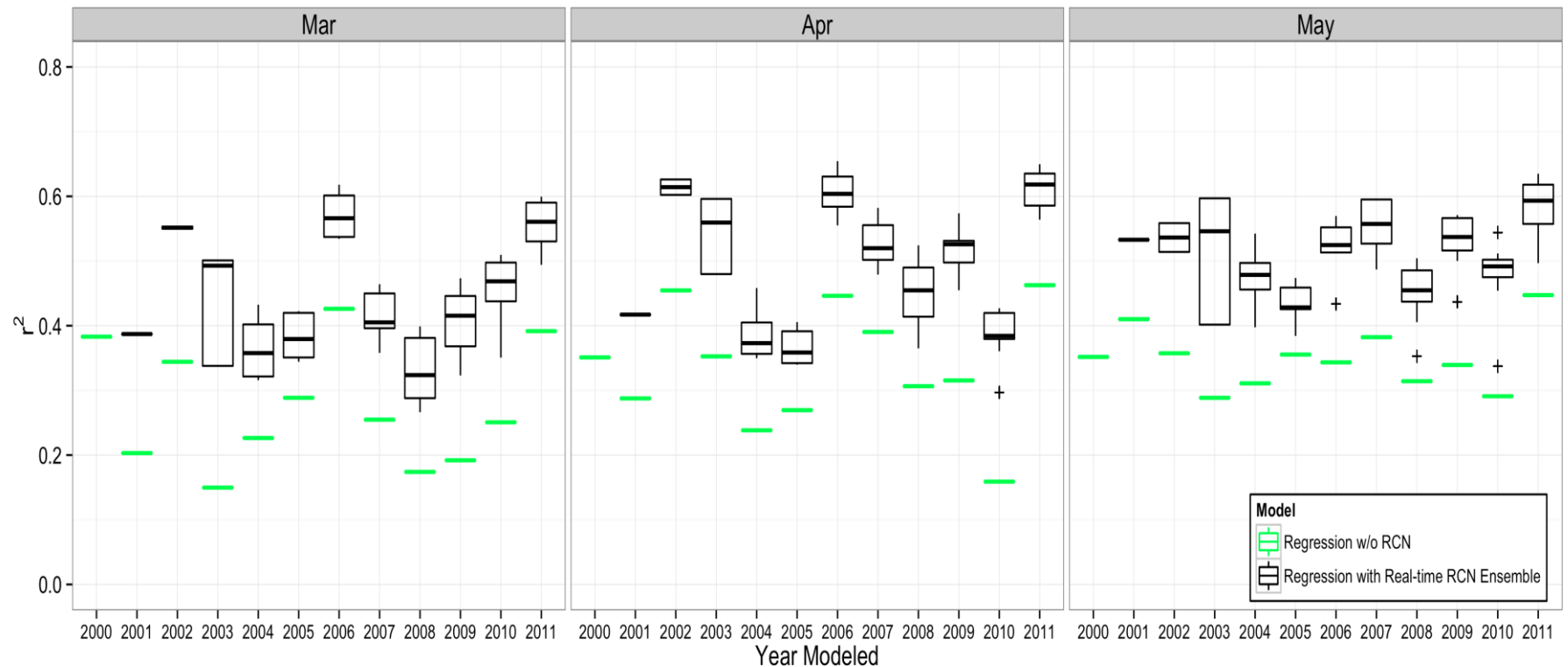SWE error, stdev.'s

−5 −3 −1 0 1 3 5

Jepsen et al., 2012 - WRR

Correlation of SWE & Independent Variables: With and Without Reconstruction

Upper Colorado River Basin Domain, 2000 – 2011.
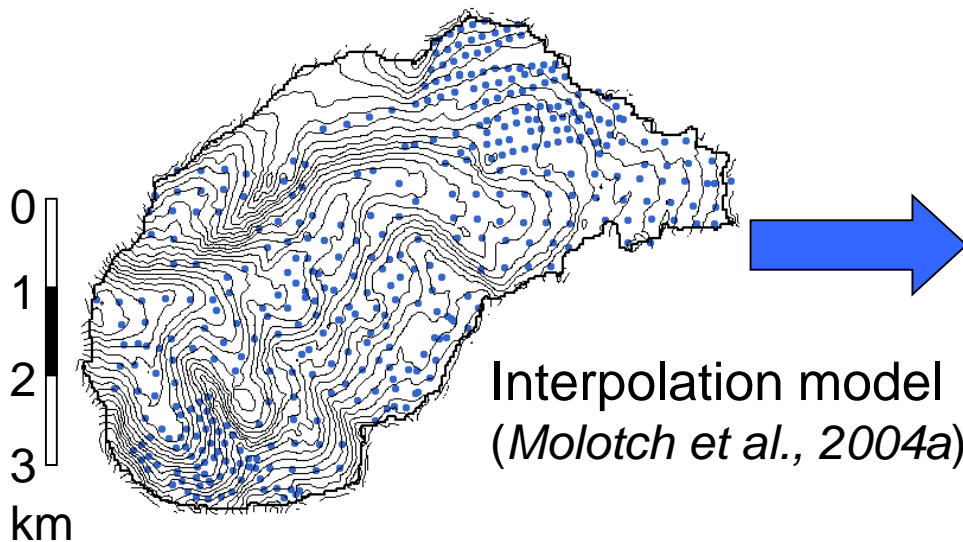
Model Validation
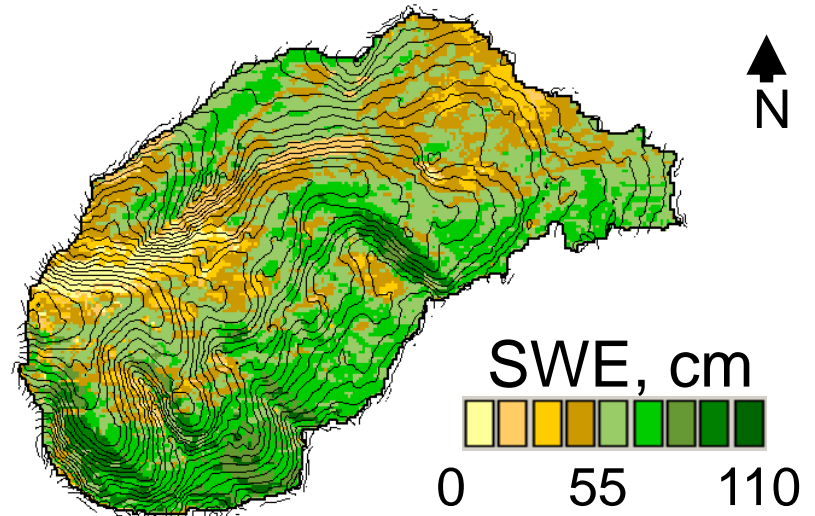
snow depth

6 people
8 days

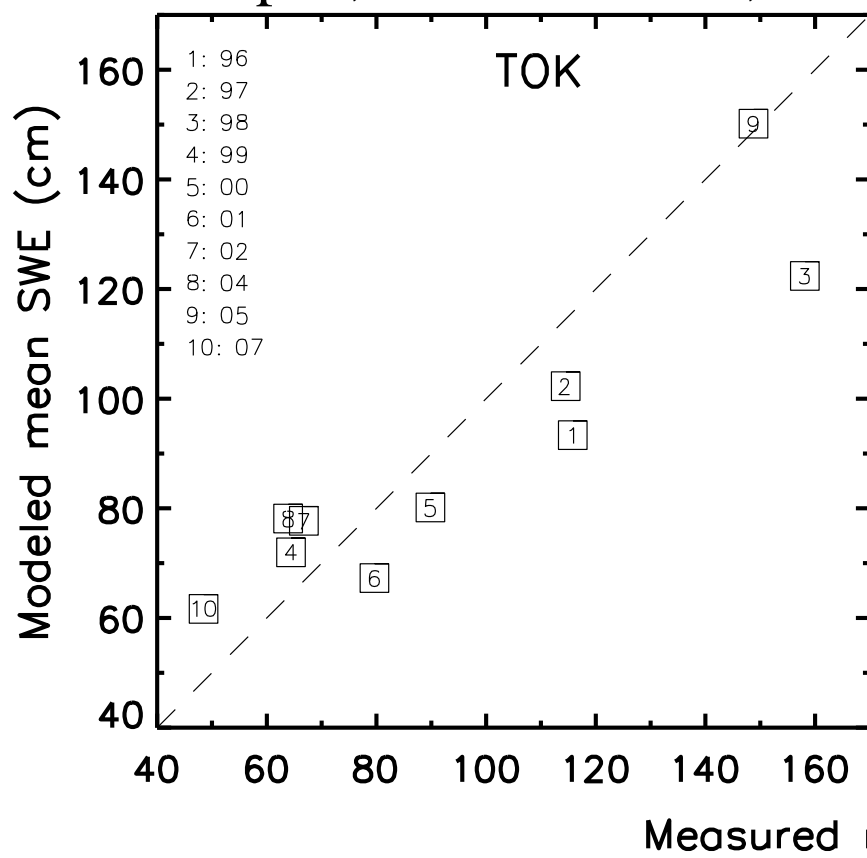snow density

● 400+ measurements

0
1
2
3
km

Interpolation model
(*Molotch et al., 2004a*)

N

SWE, cm

0   55   110

Model Evaluation: Sierra and Rockies

Tokopah, Sierra Nevada, CA

Green Lakes Valley, CO Rockies

Jepsen et al., 2012 - WRR