Snowpack Change from 1982-2016 over Contiguous United States

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Motivation

Snowpack includes snow water equivalent (SWE), snow depth, and snow cover.

It affects the energy cycle (via albedo), water cycle (via snowmelt), land-atmosphere coupling (via insulation of ground), and hence affects weather, climate, and water prediction.

Recommendation from U.S. National Academies Decadal Survey (2017):

Snow depth and SWE as one of seven to compete for three medium-size instruments and satellite missions

Existing SWE and snow depth datasets

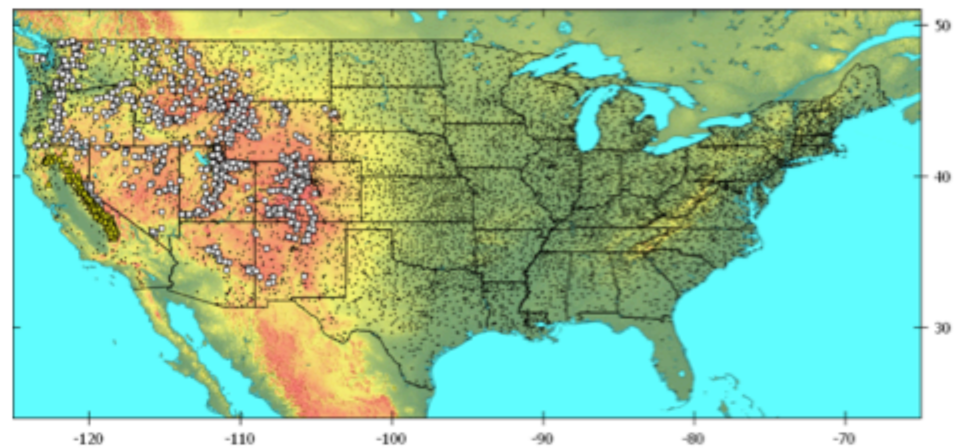
- Global operational analysis, re-analysis, GLDAS
  coarse resolution (10-100 km), relatively poor quality
- Global satellite (e.g., AMSR-E) and merged products
  coarse resolution (10-100 km), relatively poor quality
- In situ point measurements (e.g., SNOTEL)
  accurate but difficult to upscale to area averages
- Airborne measurements (e.g., ASO)
  excellent snow depth measurements, but areas and periods are limited
- Field campaigns (e.g., SnowEx)
  excellent snow depth and SWE measurements, but areas and periods are very limited

What is needed: regional SWE and snow depth datasets (to serve as a bridge between accurate, high resolution in situ data and coarse resolution global products)

Daily 4 km SWE product over ConUS from Oct 1981-Sep 2016 (Broxton et al. 2016a,b; Dawson et al. 2016, 2017)

a) Input data:

- SNOTEL SWE/snow depth sites, NWS COOP snow depth sites,
- PRISM daily 4 km precipitation and temperature data



b) Innovative data assimilation

- Point-area interpolation
- A new snow density model to combine SWE and snow depth measurements

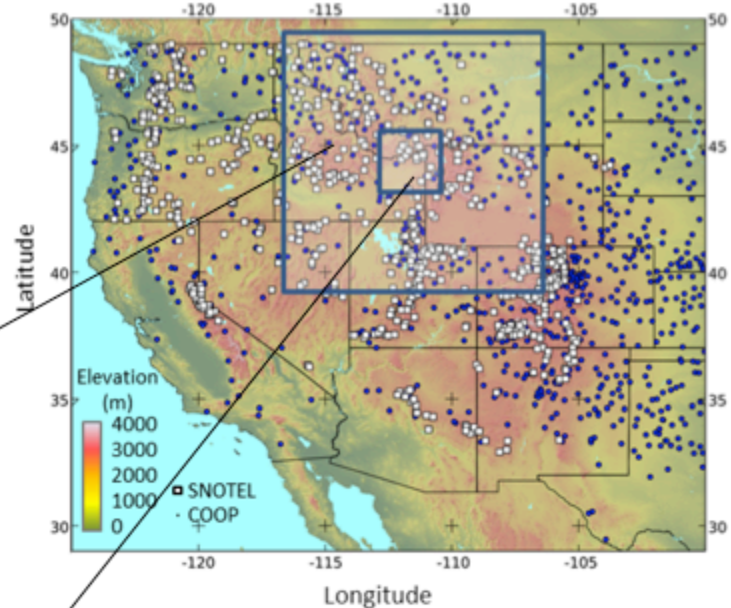
c) Four rigorous tests:

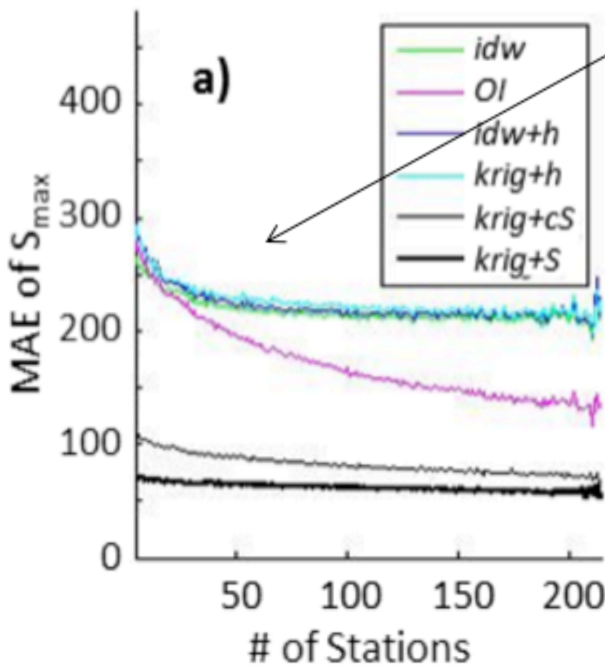
d) The dataset will be released this year after the overview paper (Zeng et al. 2018) is accepted.

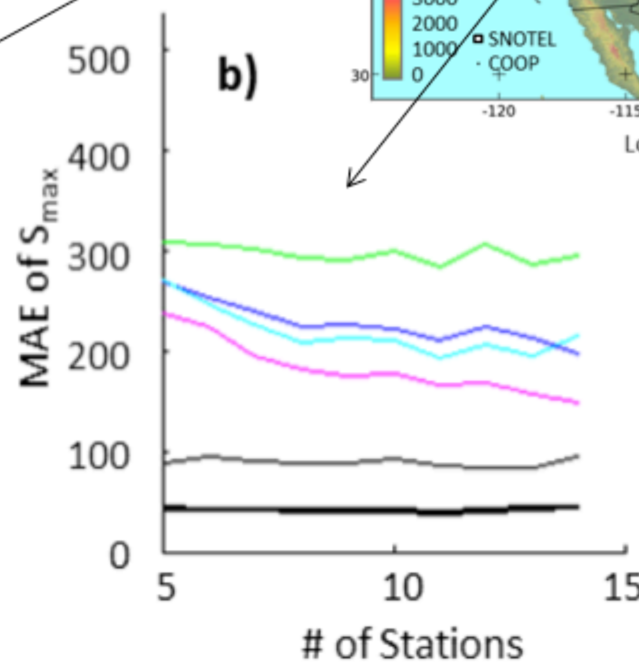
Note that we don't use any snow cover data – which are used for independent evaluations

Test #1: Interpolation from point to point

Q: How good is our method of spatial interpolation of normalized SWE compared with interpolation methods that use SWE itself?



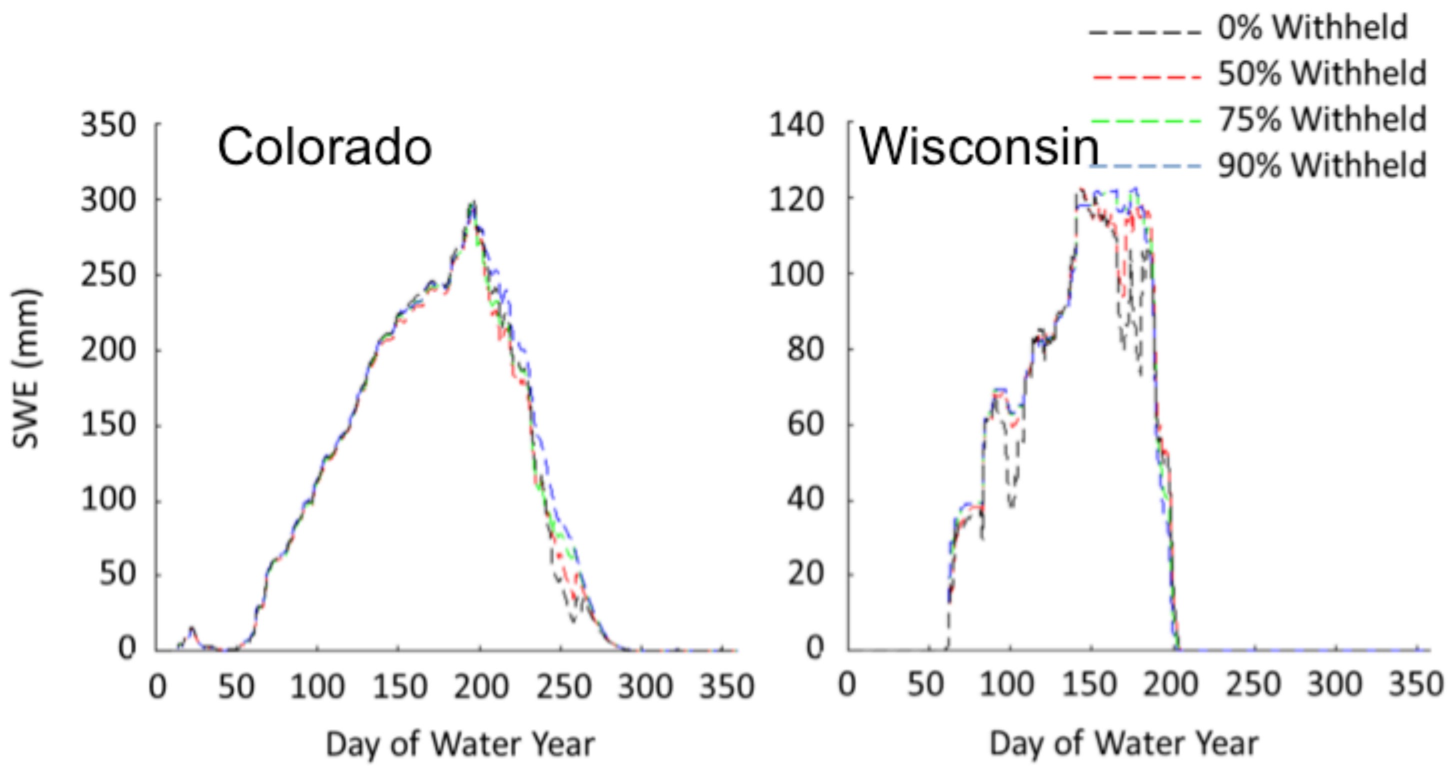




Our method has a much smaller error.

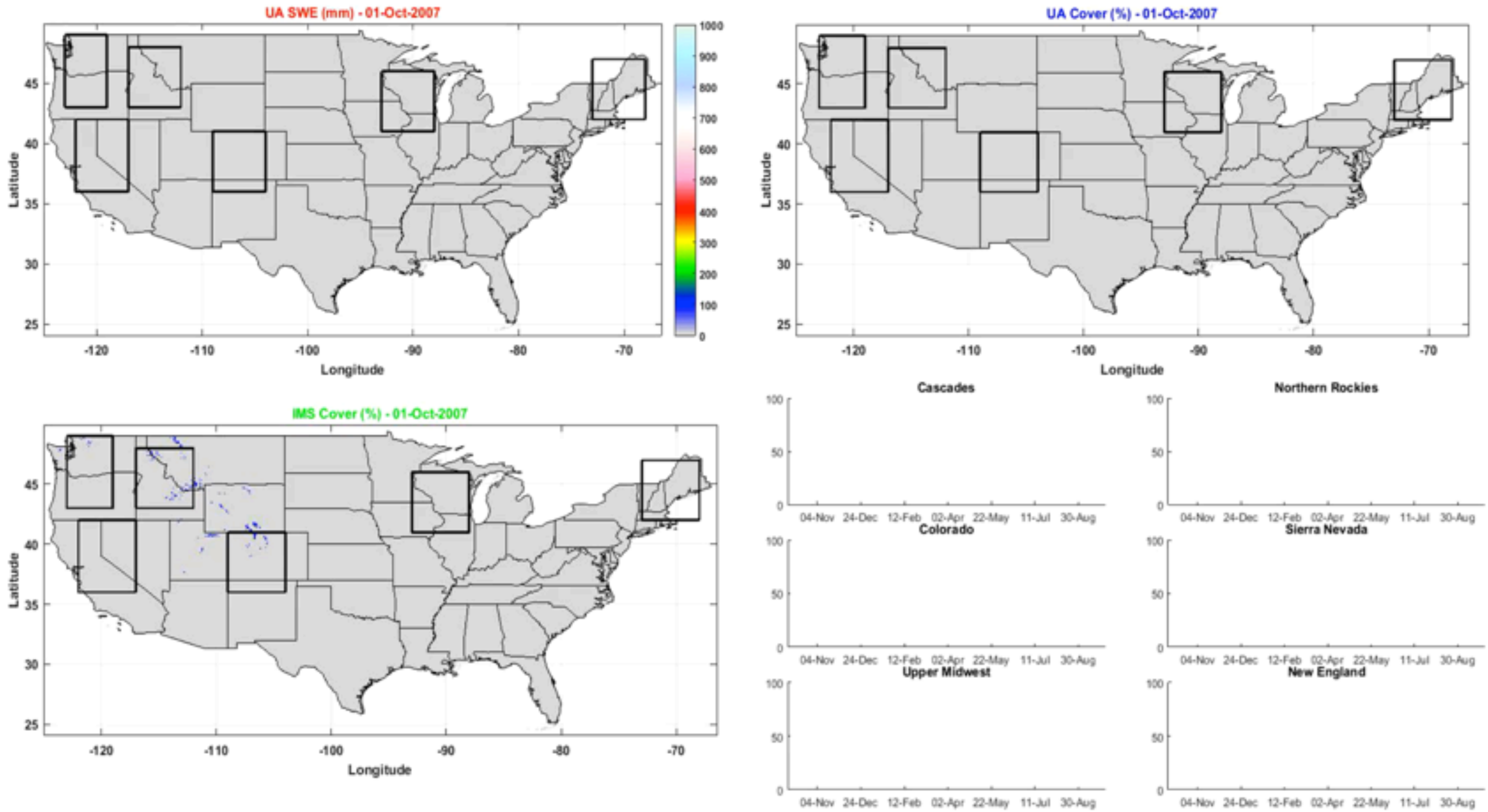
Our method is very robust, as the errors are nearly the same if we use 5%, 10%, 30%, or 90% of the sites for interpolation

Test #2: Compare the average SWE over a $2^o x 2^o$ area when 0%, 50%, 75%, and 90% of the station snow data are withheld during the generation of the UA data.



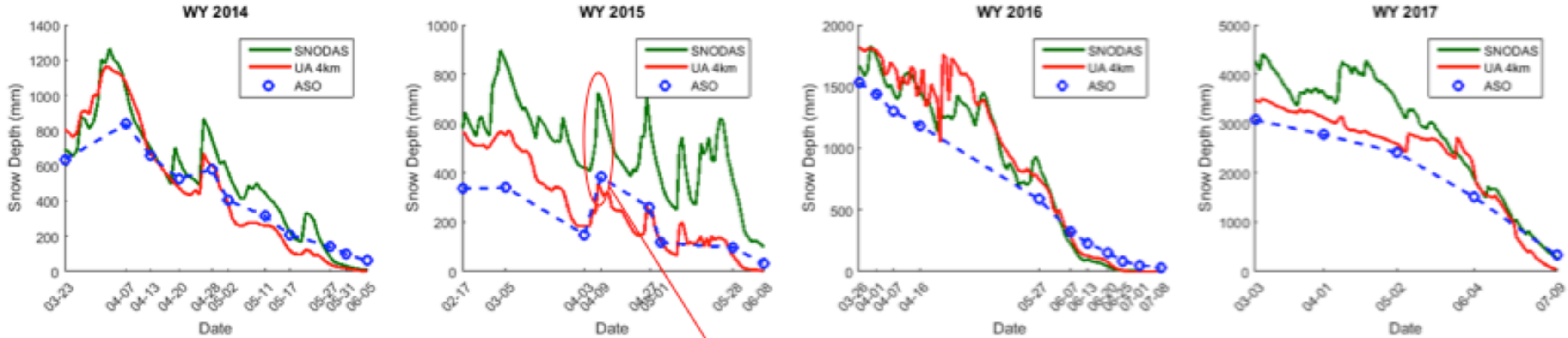
Our results are very robust, as using 10%, 25%, 50%, and 100% of the sites gives very similar area-averaged SWE seasonal cycle

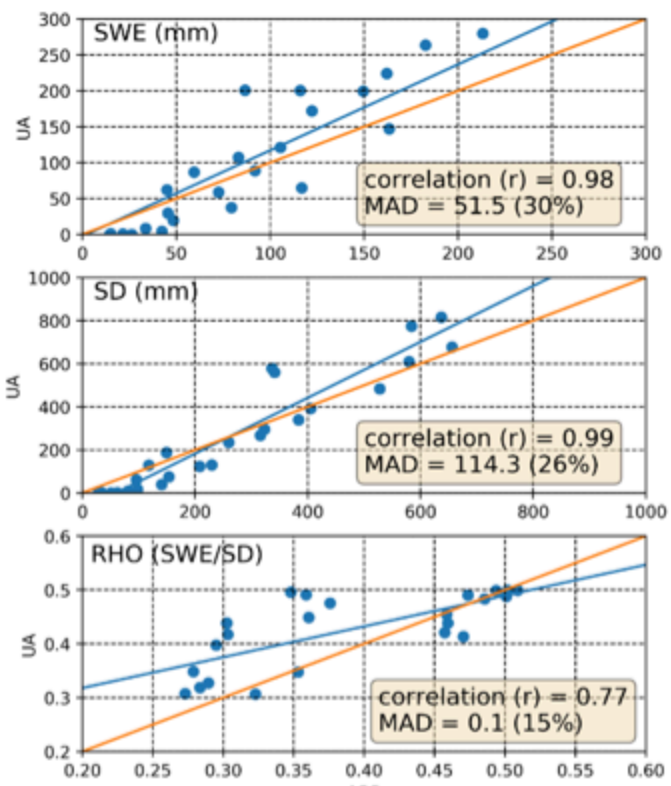
Test #3: Compare daily UA snow cover (SWE > 3 mm) with NOAA IMS product (Dawson et al. 2018, accepted with revision)

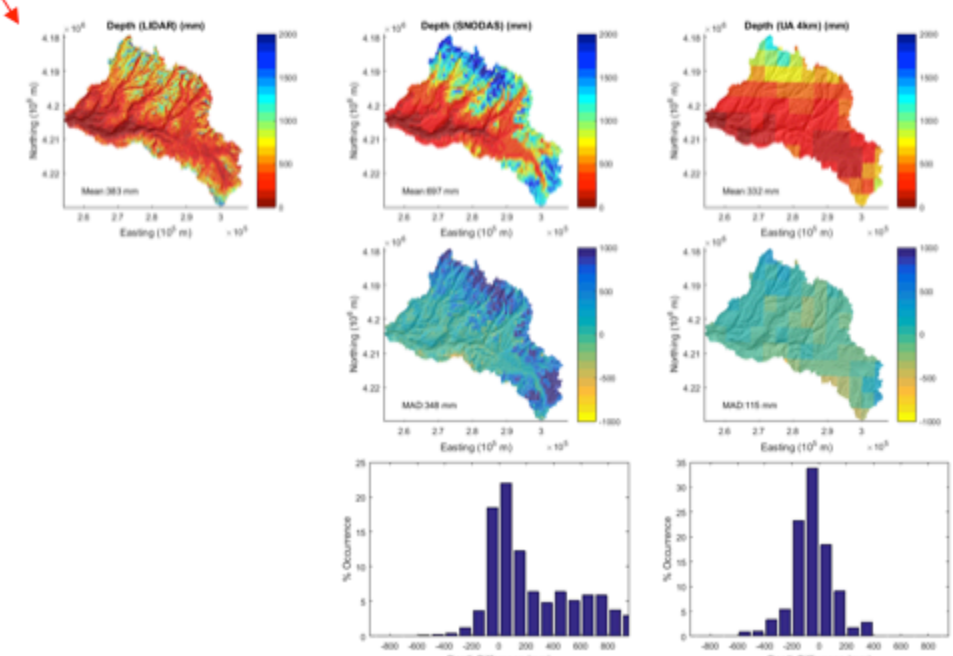


Overall, UA and IMS snow cover data agree with each other very well, though some inconsistencies in areas with shallow snow / near edges

Test #4: Comparison with the ASO data over Tuolumne River Basin, CA (Dawson et al. 2018, accepted with revision)



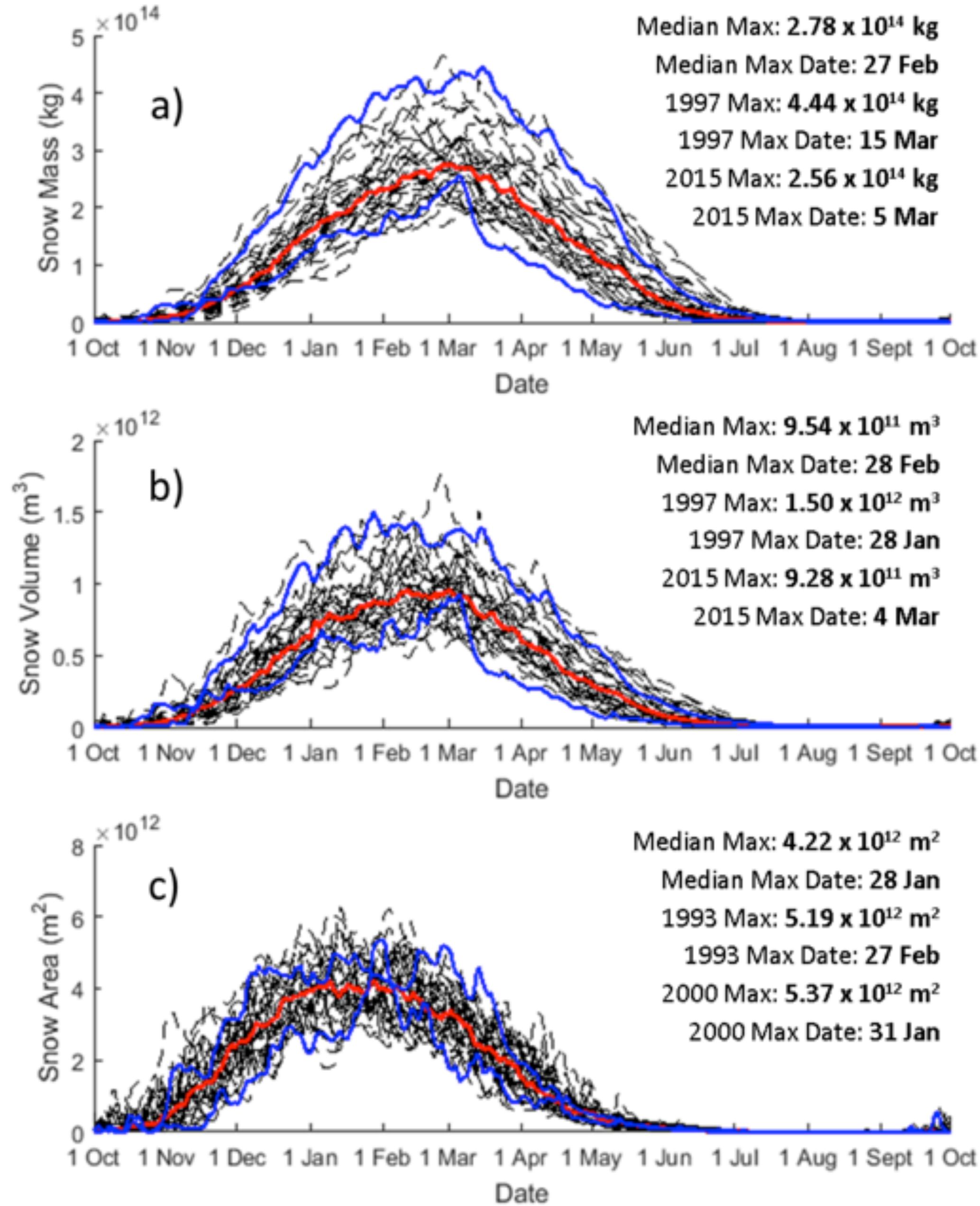




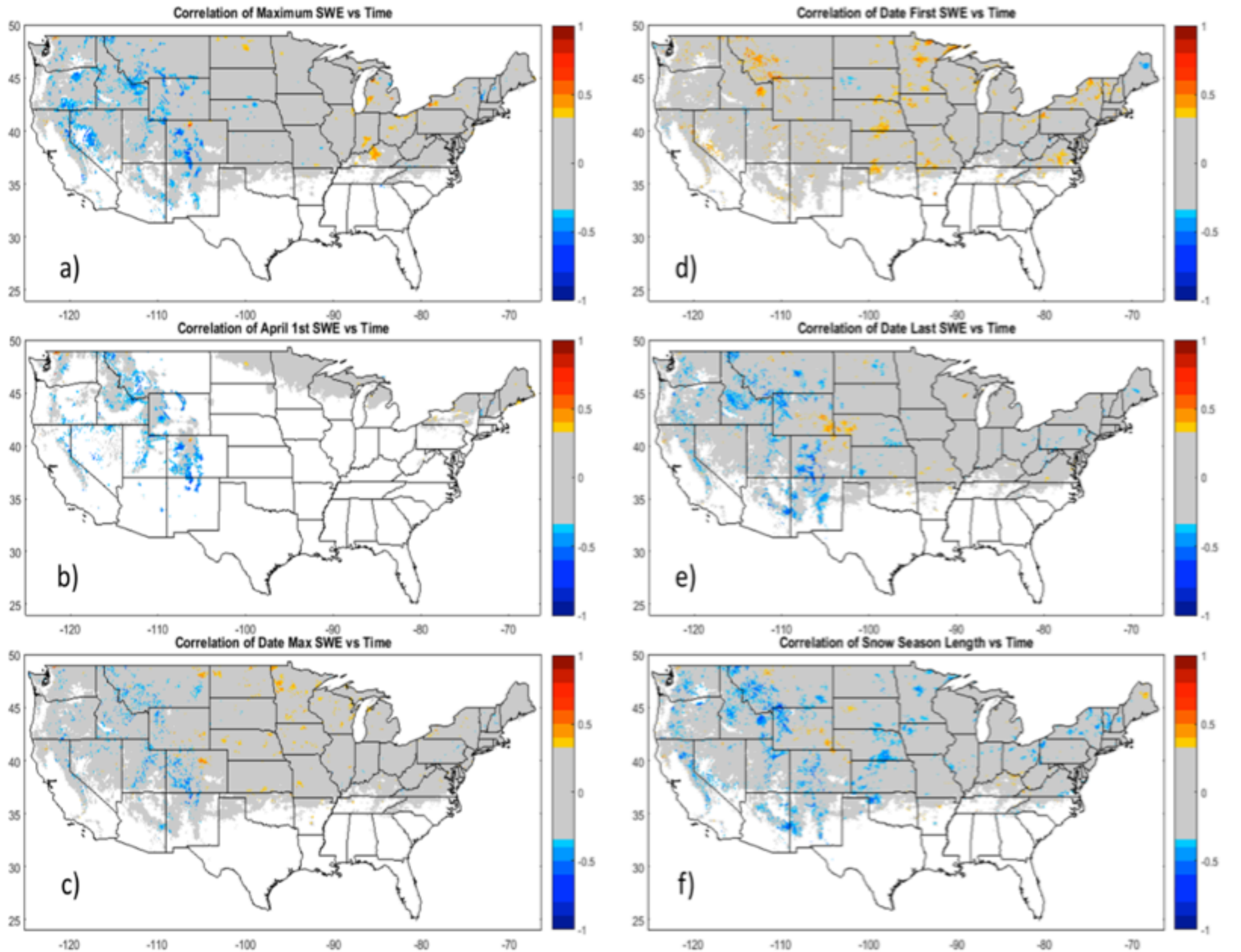
9 April 2015

Snowpack climatology over ConUS

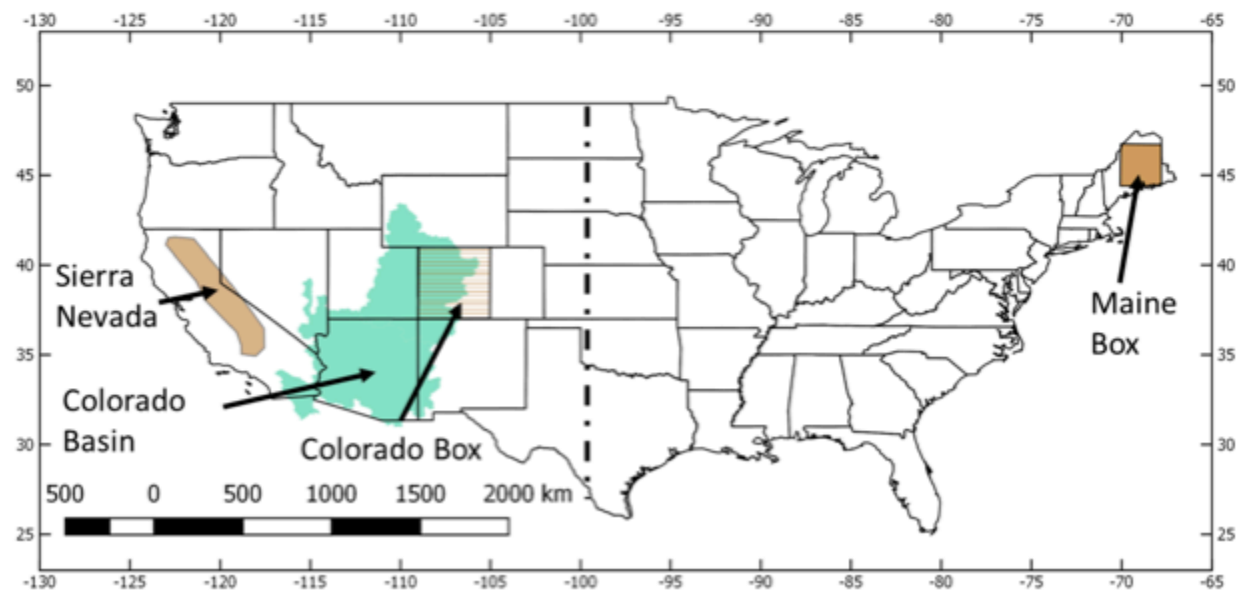
Zeng et al. (2018, submitted)



Correlation of variables with time in the linear regression



Max SWE (mm/yr)	Sierra Nevada	Colo. Basin	West ConUS	East ConUS	Entire ConUS	
	0.20	0.15	0.13	0.02	0.07	Percent of pixels
	-0.06	-0.13	-0.14	0.09	-0.10	Average trend
	-0.07	-0.17	-0.18	-0.08	-0.13	10^{th} percentile
	-0.01	-0.03	-0.03	0.01	-0.01	Median trend
	0.02	0.06	0.06	0.11	0.09	90^{th} percentile



Area (1000s of km^2)

	Sierra Nevada	Colorado Basin	Western ConUS	Eastern ConUS	Entire ConUS
High	12.7	67.5	191.4	0.0	191.4
Mid	39.6	296.5	1154.8	0.3	1155.0
Low	19.1	9.1	1029.9	2677.8	3707.7
All	71.4	373.0	2376.1	2678.0	5054.2

What is the driver of the SWE temporal variability?
Regression of 1 April SWE

		Sierra Nevada	Colo. Basin	Western ConUS	Eastern ConUS	Entire ConUS
Regression with T only	All	0.51	0.51	0.50	0.70	0.45
	High	0.42	0.47	0.41	-	0.41
	Mid	0.56	0.56	0.46	-	0.46
	Low	0.55	-	0.56	0.70	0.55
Regression with P+T	All	0.93	0.89	0.90	0.79	0.85
	High	0.97	0.91	0.94	-	0.94
	Mid	0.88	0.78	0.90	-	0.90
	Low	0.76	-	0.79	0.79	0.71
Regression with Eq. 1	All	0.91	0.87	0.88	0.80	0.84
	High	0.96	0.89	0.92	-	0.92
	Mid	0.87	0.76	0.88	-	0.88
	Low	0.77	-	0.75	0.80	0.72

Conclusions

1. Developed daily 4 km SWE and snow depth data over ConUS from Oct 1981 – Sep 2016. Our data assimilation method and dataset have passed four rigorous tests

2. 20%, 15%, and13% of the snowy pixels show significant (and mostly negative) trends of the annual max SWE over Sierra Nevada, Colorado River basin, and western ConUS

3. The temporal variation of 1 April SWE at low, mid- and high elevations can be mostly explained using Oct-Mar mean T and accumulated P, rather than using mean T alone (e.g., 81% versus 25% over western ConUS).

"First light" image released from GOES-R (GOES-16)