Daily 4 km snow water equivalent/depth/cover product over Continental U.S. from 1981

Xubin Zeng, Patrick Broxton, Nick Dawson
Department of Hydrology and Atmospheric Science
University of Arizona

xubin@email.arizona.edu

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THE UNIVERSITY OF ARIZONA.

Why am I here?

Snow affects four of the six NASA earth science focus areas (water and energy cycle, weather, climate, carbon cycle and ecosystem).

My group has worked on snow modeling and dataset development for the past 15 years:

- Global 5 km maximum albedo dataset of snow-covered land (Barlage et al. 2005) – implemented in NCEP operational weather/climate prediction models
- Improving snow processes in the Noah land model (Wang et al. 2010) - implemented in NCEP operational weather/climate prediction models
- Improving snow processes in the Community Land Model (CLM) (Wang and Zeng 2009) – implemented in the NCAR Community Earth System Model (CESM)

We have recently worked on snow data development, production evaluation, and snow impacts on weather/climate prediction – this talk

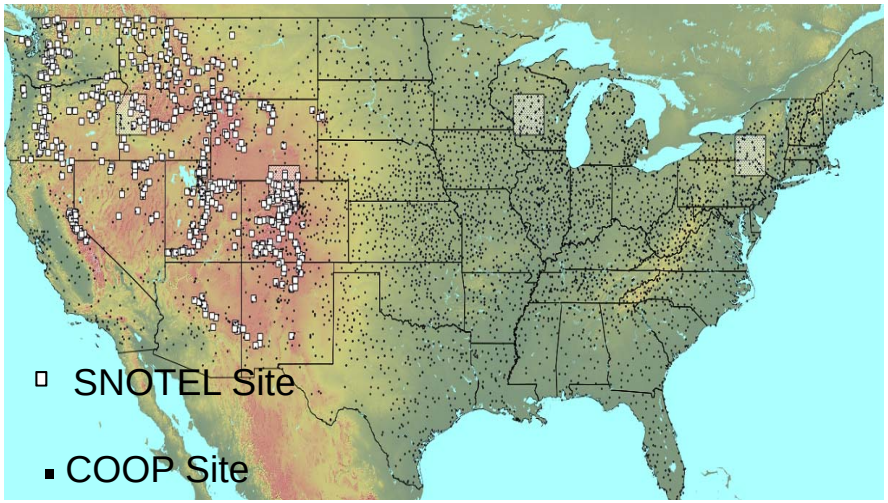
SWE and snow depth datasets

Snow water equivalent (SWE) and snow depth are challenging to measure, but various datasets are available:

- Global scale: Operational analysis, re-analysis, GLDAS, satellite (e.g., AMSR-E), and merged products – coarse resolution (10km - 100km) with a 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 and SWE computation depends on snow density estimation

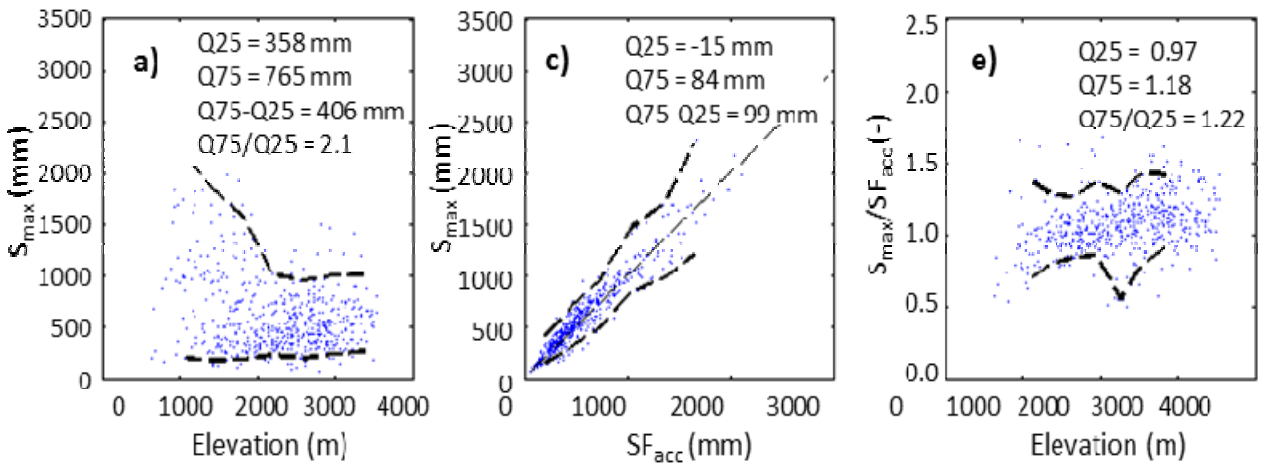
What is needed: regional SWE and snow depth datasets (to serve as a bridge between accurate, high resolution in situ data and coarse resolution global products)

Our method is based on SNOTEL SWE/depth measurements and COOP snow depth measurements.



Step 1: compute the ratio of SWE over (accumulated snowfall minus snow ablation)

Snowfall vs. rainfall is partitioned using a T_{2m} threshold based on SNOTEL data



Snow ablation is also computed using an empirical relation with T_{2m} based on SNOTEL data

Broxton et al. (2016a,b)

Q: How can we effectively use both SNOTEL SWE and COOP snow depth data?

Step 2: Develop a new snow density model to convert between SWE and snow depth (Dawson et al. 2017a):

- includes up to 10 snow layers
- is driven by snowfall and T_{2m}

Q: How do we upscale from in situ point measurements to area averages?

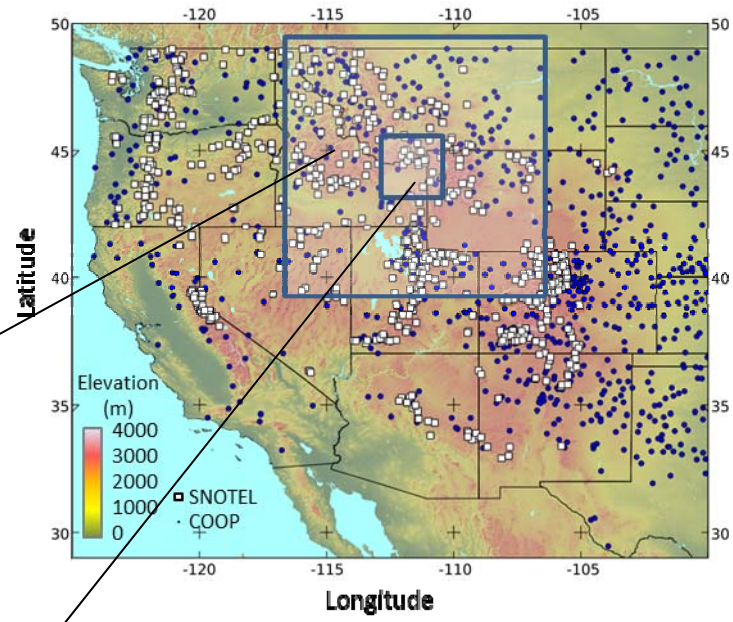
Step 3: Interpolate the in situ normalized SWE (from Step 1) to 4 km grids

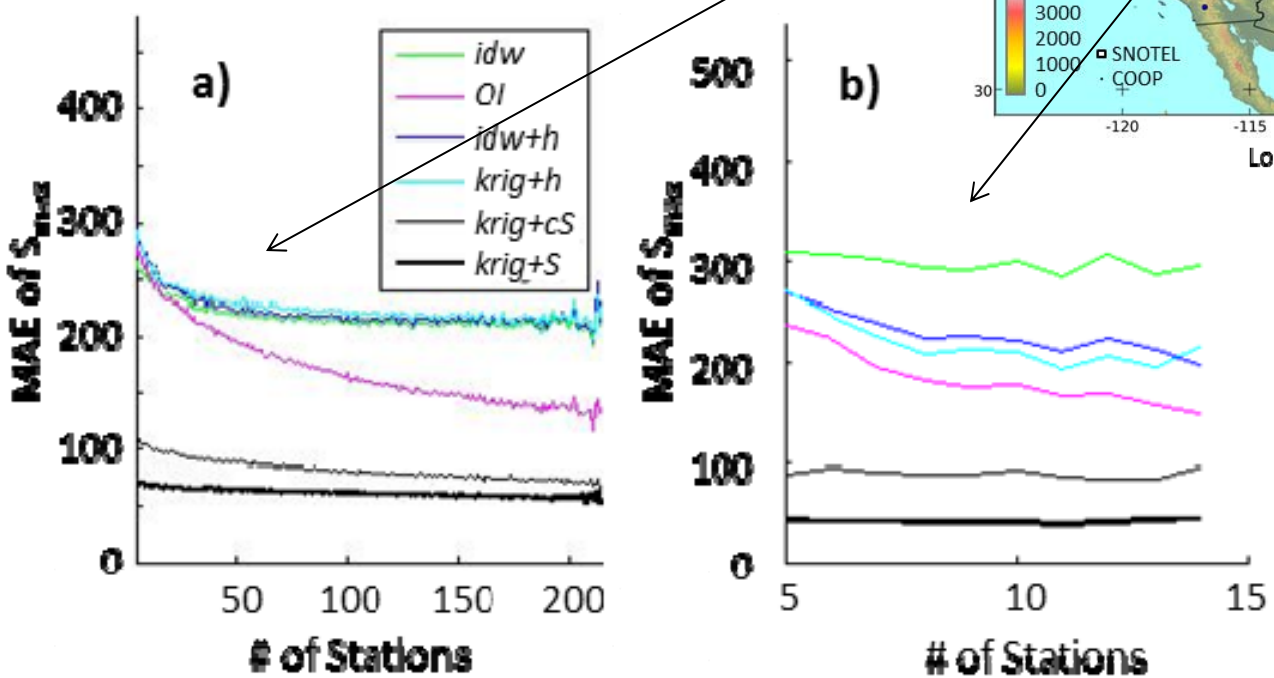
Step 4: Combine these values with the PRISM daily 4 km precipitation and T_{2m} products to obtain consistent daily 4 km gridded SWE and snow depth over ConUS

Note that we didn't use any snow cover data

Test #1: Interpolation from point to point

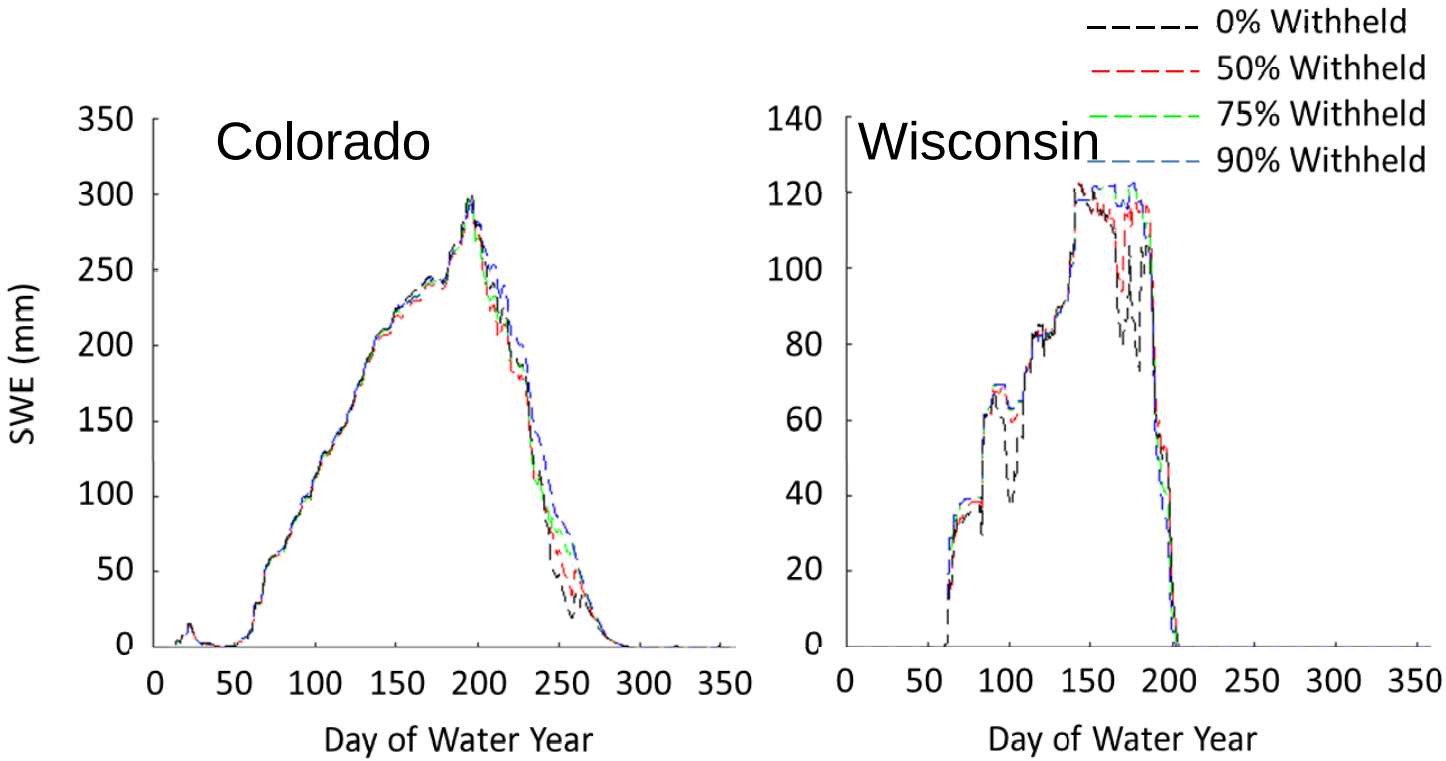
Q: How good is our method of spatial interpolation of normalized SWE compared with interpolation methods that use SWE itself?





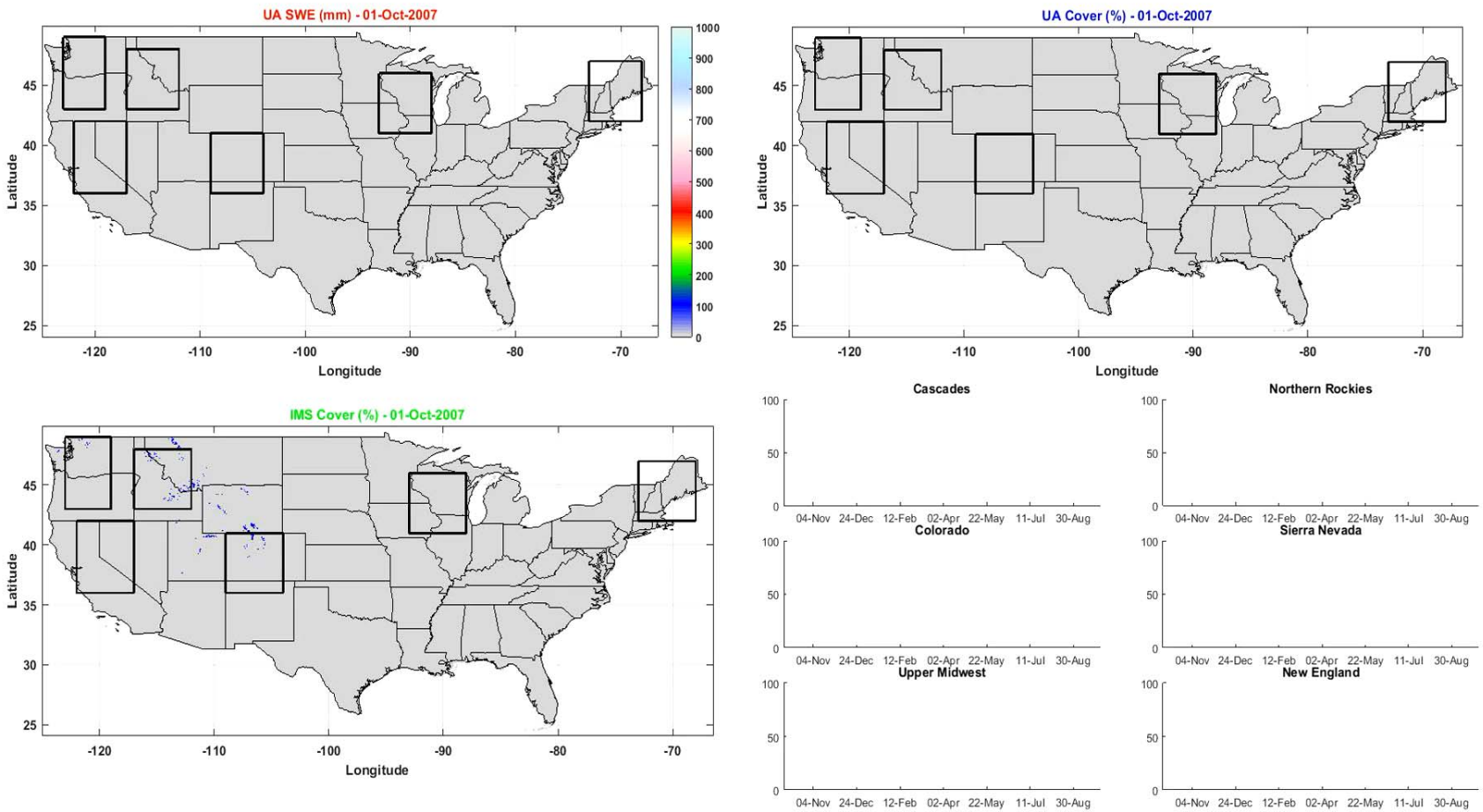
Our method has a much smaller error.
Our method is very robust, as the errors are nearly the same if we use 5%, 10%, 30%, or 90% of the sites for interpolation

Test #2: Compare the average SWE over a 2°x2° area when 0%, 50%, 75%, and 90% of the station snow data are withheld during the generation of the UA data.



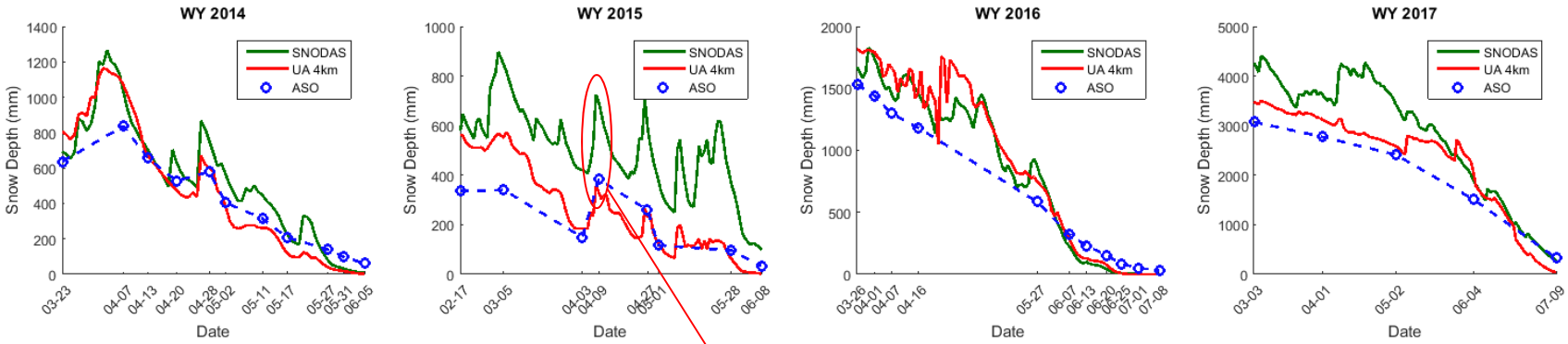
Our results are very robust, as using 10%, 25%, 50%, and 100% of the sites gives very similar area-averaged SWE seasonal cycle

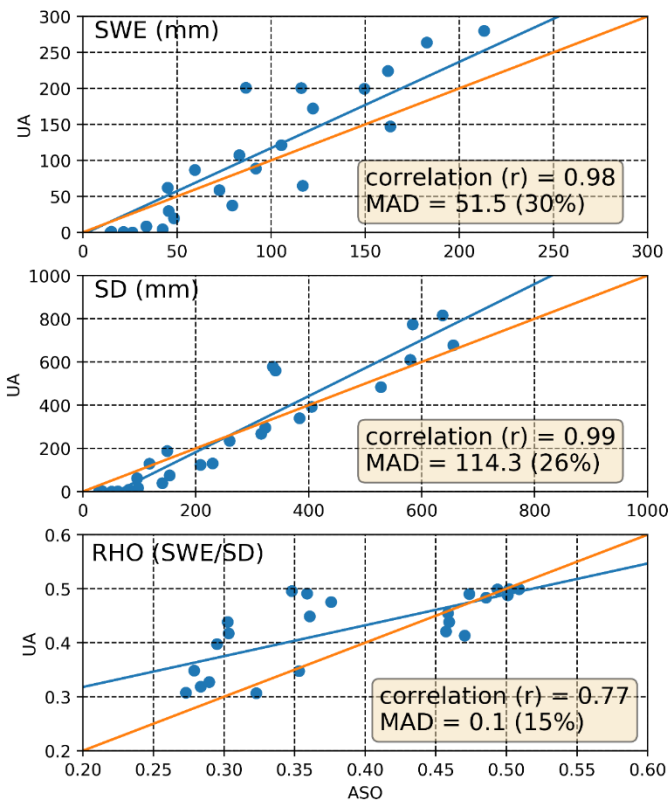
Test #3: Compare daily UA snow cover (SWE > 3 mm) with NOAA IMS product (Dawson et al. 2017b, in revision)

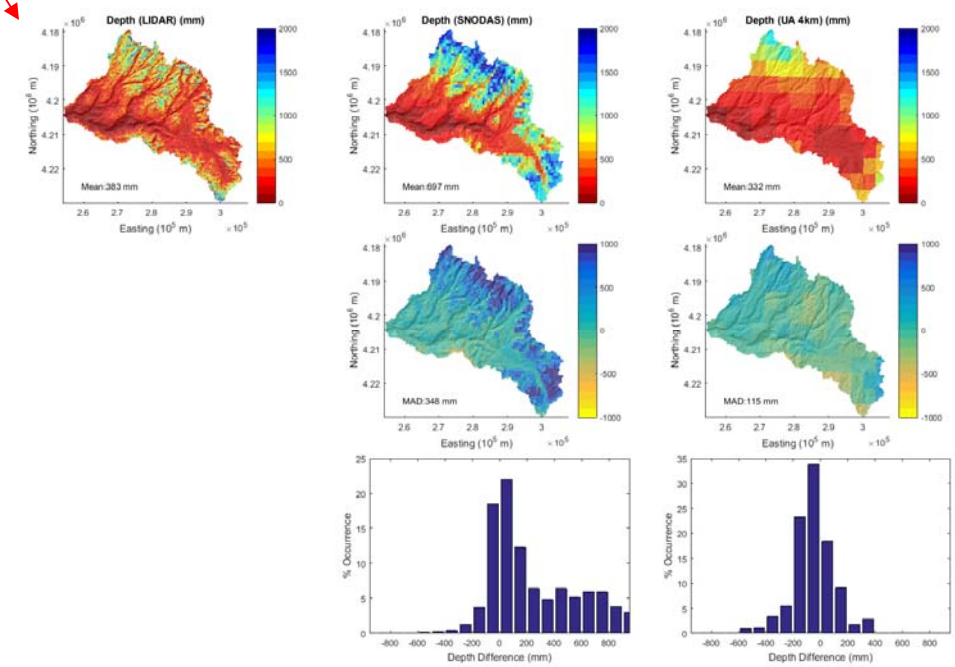


Overall, UA and IMS snow cover data agree with each other very well, though some inconsistencies in areas with shallow snow / near edges

Test #4: Comparison with the ASO data over Tuolumne River Basin, CA







9 April 2015

Summary of our recent snow studies

Broxton et al. 2016a (doi: 10.1002/2016EA000174): ideas for developing our snow product

Broxton et al. 2016b (doi: 10.1175/JHM-D-16-0056.1): reanalysis and LDAS snow is relatively poor and why; development of our daily 4km snow SWE/depth/fractional cover product over ConUS

Broxton et al. 2017 (J. Climate, accepted): suggest SWE initial state (rather than SST) as the primary source of seasonal prediction of T_{2m} over mid-and high-latitude land in NCEP CFS forecasting

Dawson et al. 2016 (doi: 10.1175/JHM-D-15-0227.1): USAF and NCEP snow initialization is relatively poor

Dawson et al. 2017a (doi: 10.1175/JHM-D-16-0166.1): a new snow density parameterization for snow data development and initialization

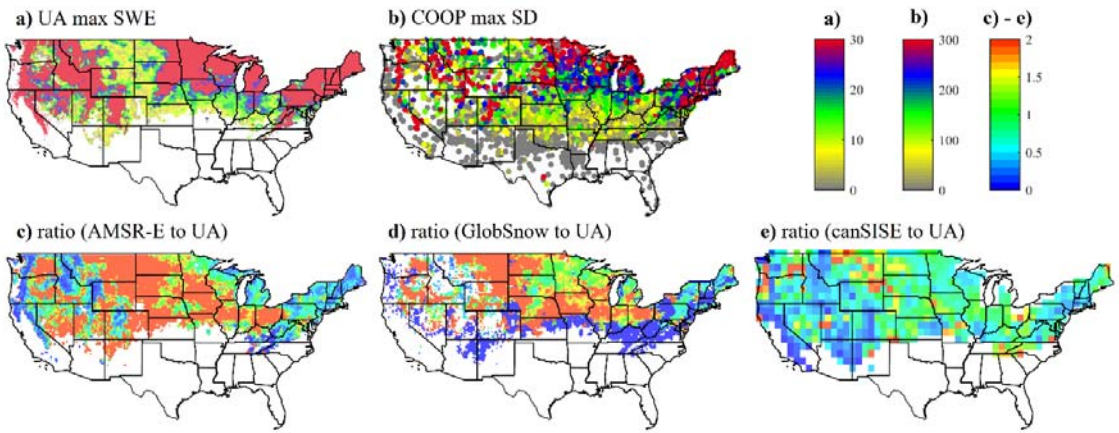
Dawson et al. 2017b (in revision): snow remote sensing product evaluations.

Zeng et al. 2017 (in preparation): quantifying and understanding the trend and variability of SWE, snow depth and cover over ConUS

What is the value of our daily 4 km SWE/depth/cover product over ConUS to SnowEx?

Field experiments (e.g., SnowEx) and airborne data (e.g., ASO) provide excellent SWE/depth measurements, but areas and periods are limited.

Recognizing the spatial variability of remote sensing retrieval, what is the strategy for SnowEx in Years 2-5?

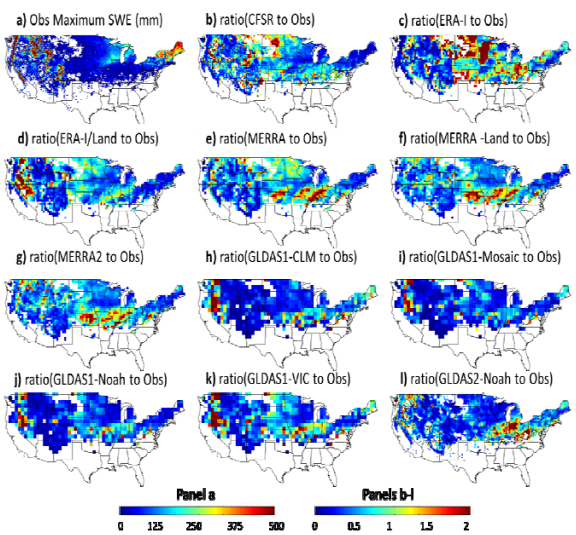
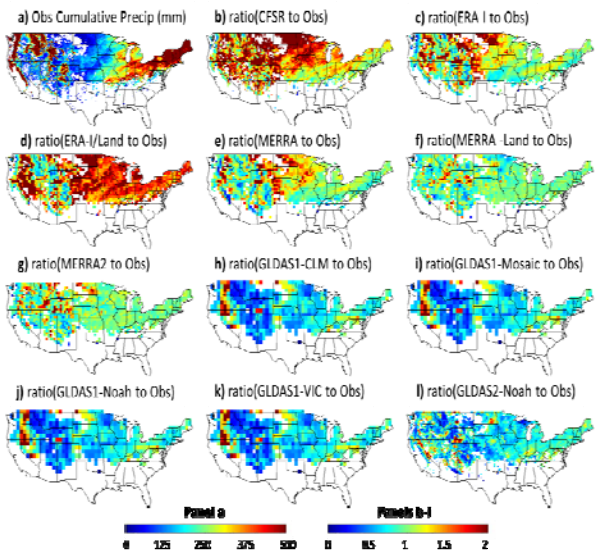


1. Same area in different years

2. Another area

3. Airborne measurements across ConUS, and the route is designed to align with in situ measurements planned by scientists in different regions.

What is the value of our daily 4 km SWE/depth/cover product over ConUS to future SWE/depth mission?

For future SWE/snow depth satellite mission, it is important

- to combine SWE measurement with snowfall/rainfall measurement to provide the mutual constraint,
- to integrate satellite measurements through data assimilation
- to evaluate its performance at specific areas and at continental scale,
- to have ~1 km resolution and 2-7 days revisit time as the **threshold requirement** (to benefit, and gain support from, weather, climate, and ecosystem focus areas; even the U.S. National Water Model uses 1 km grid size), and have this and 1-50 m high resolution as **baseline requirement**