NASA Science Mission Directorate
Earth Science Division
Applied Sciences Program

Assessing Water Resources in Remote, Sparsely Gauged, Snow-Dominated Mountains Basins

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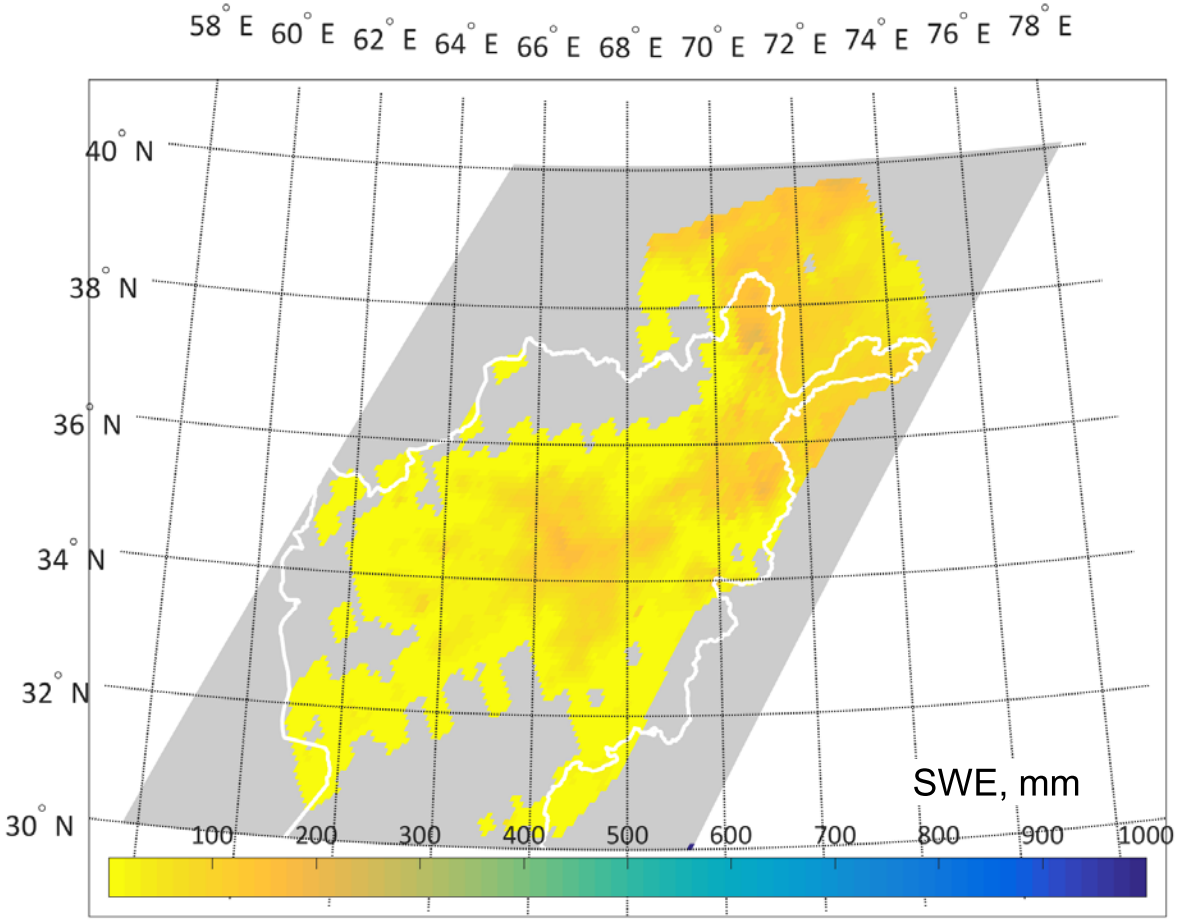
NASA Water Resources PI Meeting
April 26-28, 2016

News item from IRIN (UN)

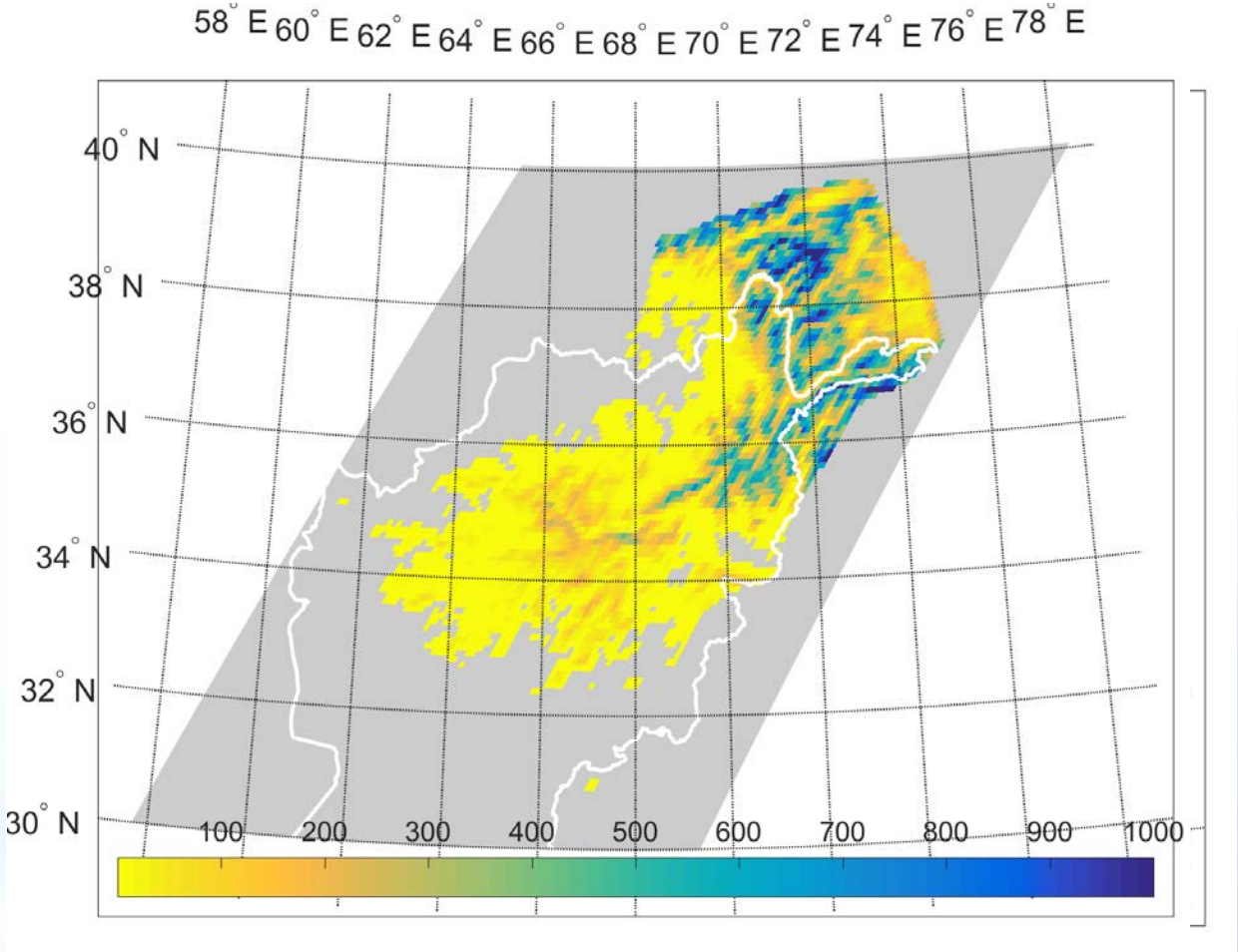
KABUL, 21 September 2011 – "The current dry spell sweeping across Afghanistan's northern, northeastern and western provinces could lead to a large-scale food crisis and the humanitarian community should act quickly to ensure this does not degenerate into a disaster, government and aid officials warn."

http://www.irinnews.org/Report/93781/Analysis-Afghan-drought-conditions-could-spell-disaster

Can we estimate SWE (snow water equivalent) from information available during the season?



2011-04-01, passive microwave SWE, 27 km³



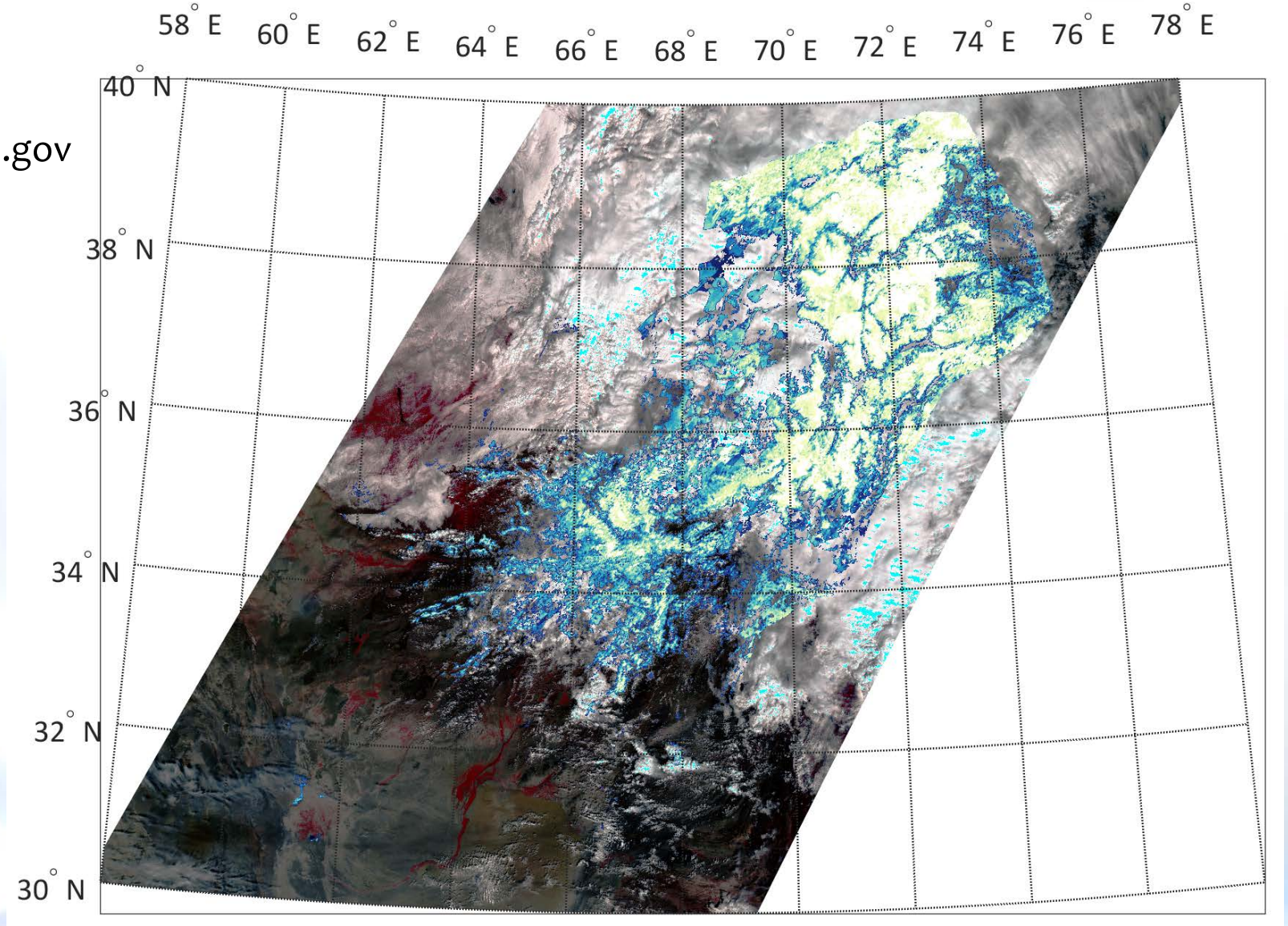
2011-04-01, reconstructed SWE, 68 km³

MODIS snow cover, 60,000 km²

Fractional snow cover from MODIS, 2015-04-01

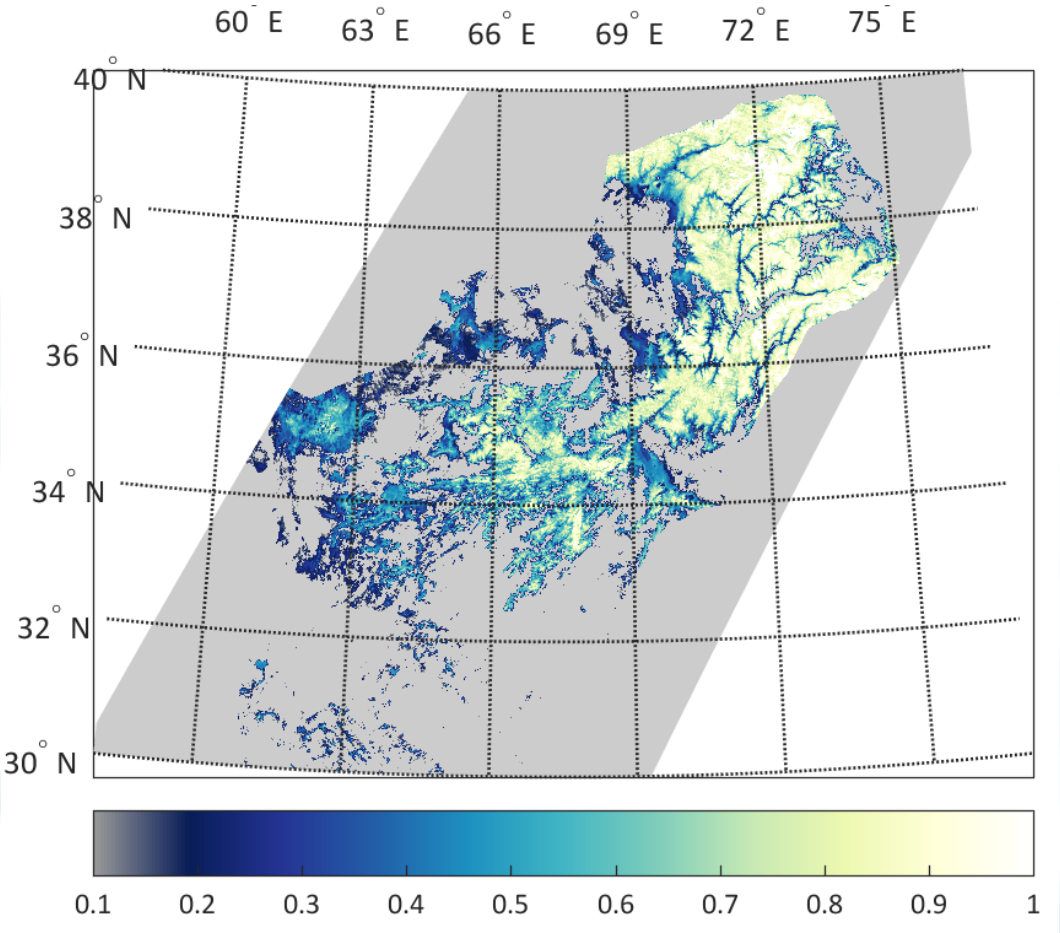
Data from http://snow.jpl.nasa.gov

$$R_\lambda = \epsilon_\lambda + \sum_{k=1}^{N} f_k R_{\lambda,k}$$

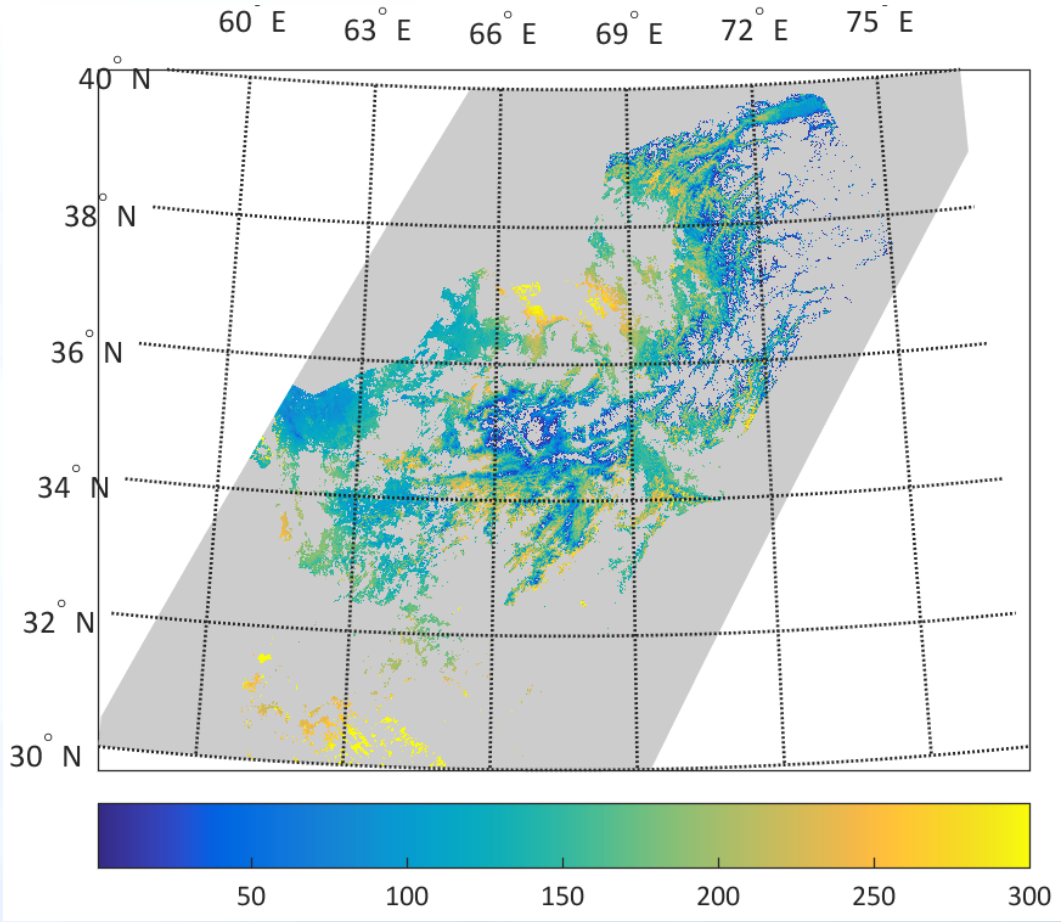


Steps in reconstructing SWE

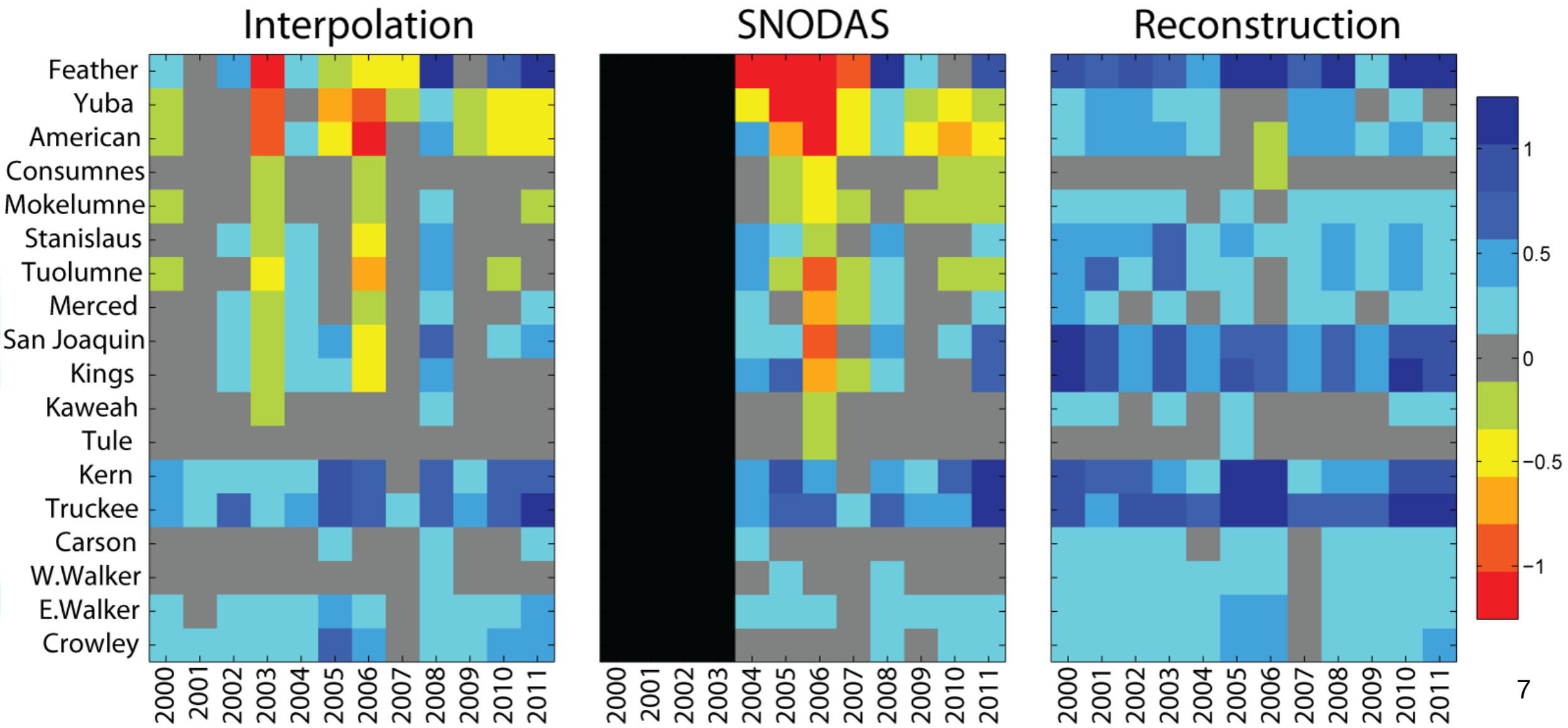
Fractional snow cover
MODIS image, 2014-04-01
(clouds removed)



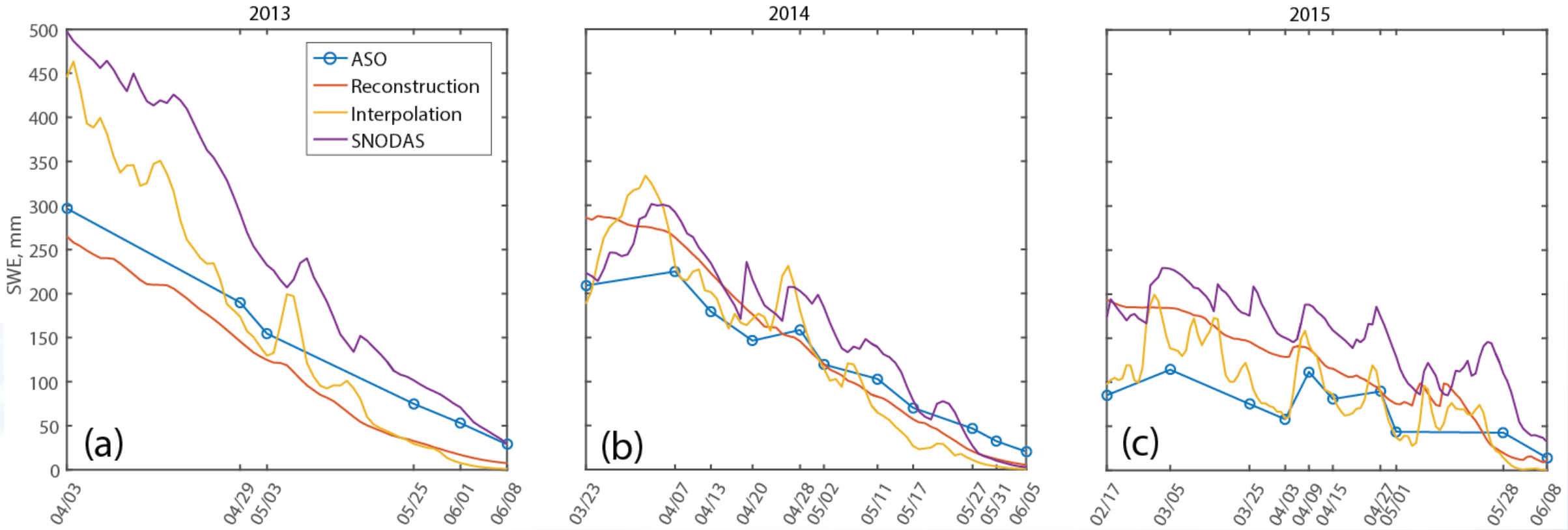
reconstructed SWE, mm
2014-04-01, 500m resolution

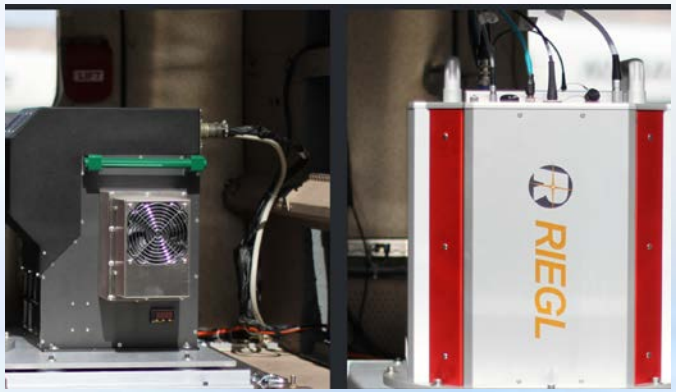


Water balance? $Q = P - ET \pm \Delta S$
Over a year $\Delta S \approx 0$, so is $P - Q > 0$?

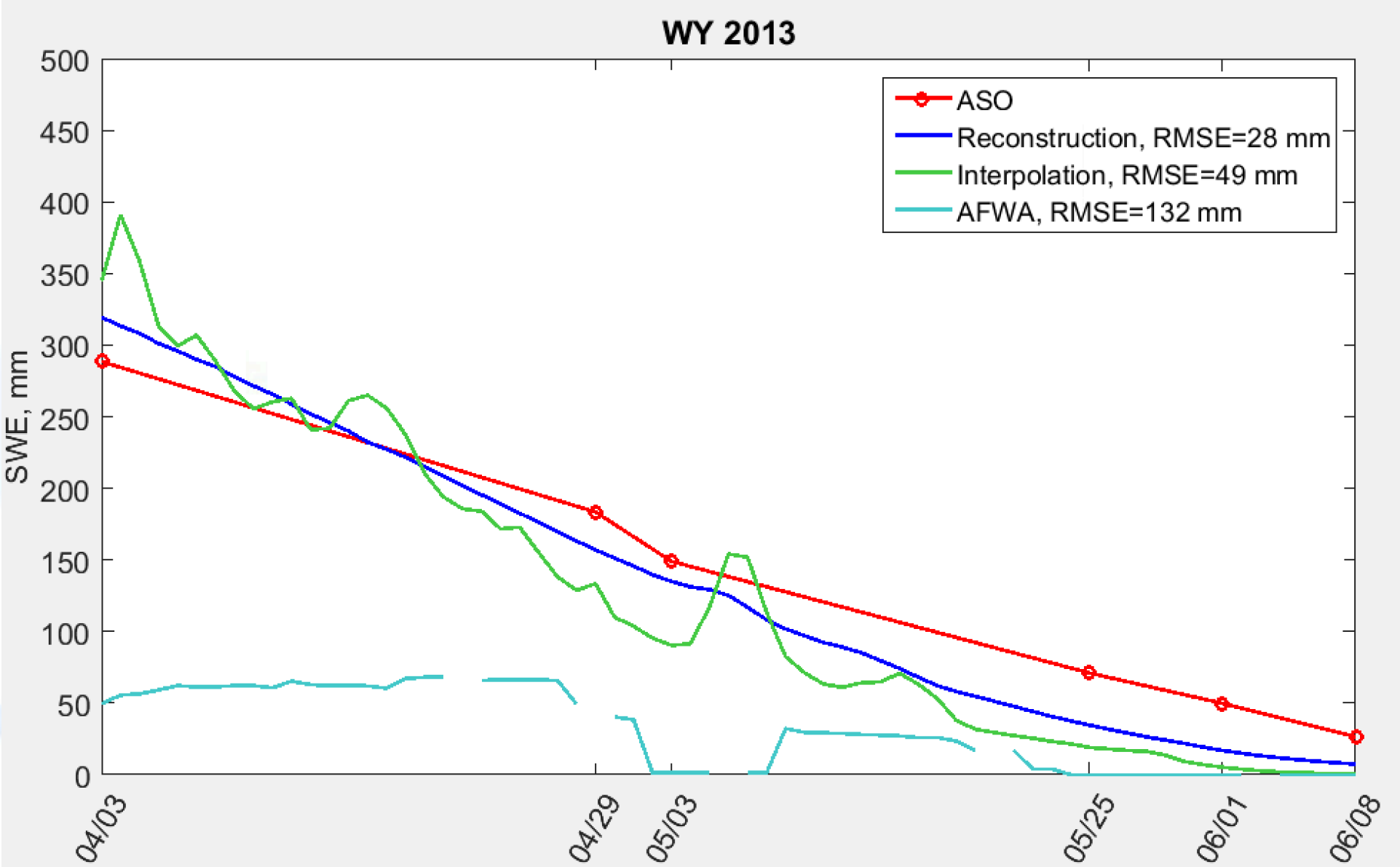


Comparison of reconstructed SWE with Airborne Snow Observatory





Comparison (2013): Reconstruction, ASO, Interpolation, AFWA



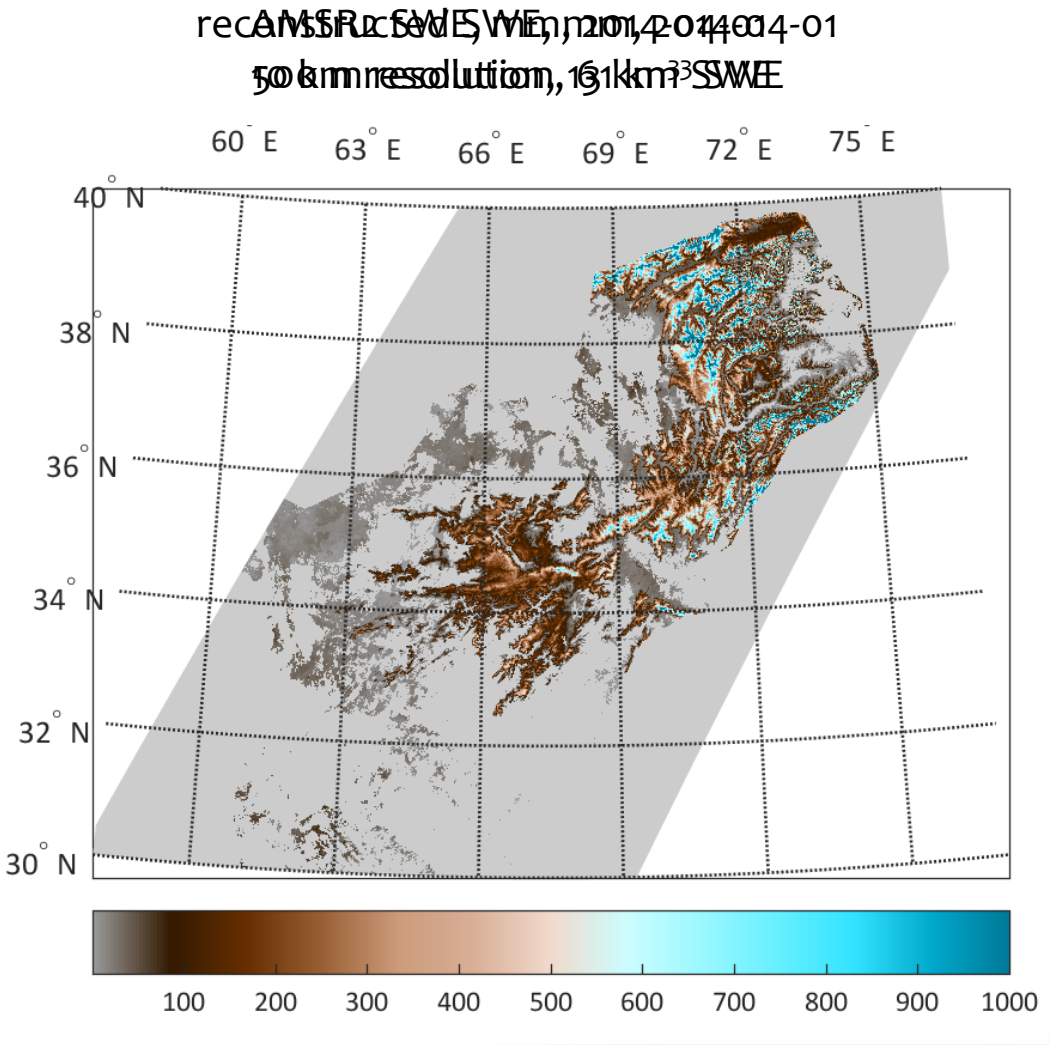
The problem

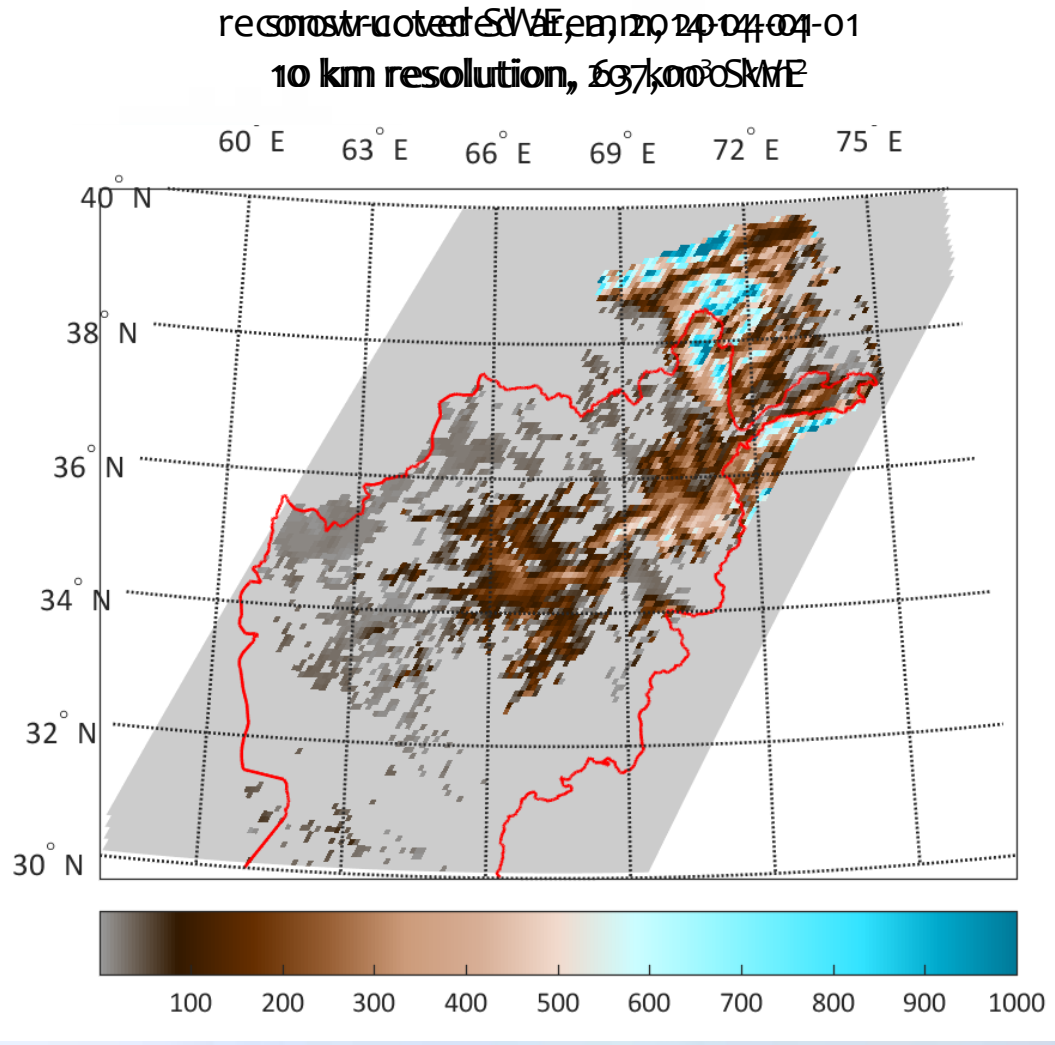
Discover a pattern that uses real-time data—passive microwave SWE and snow-covered area from optical sensor—to match reconstructed SWE, which is available only after the snow is gone

Approach

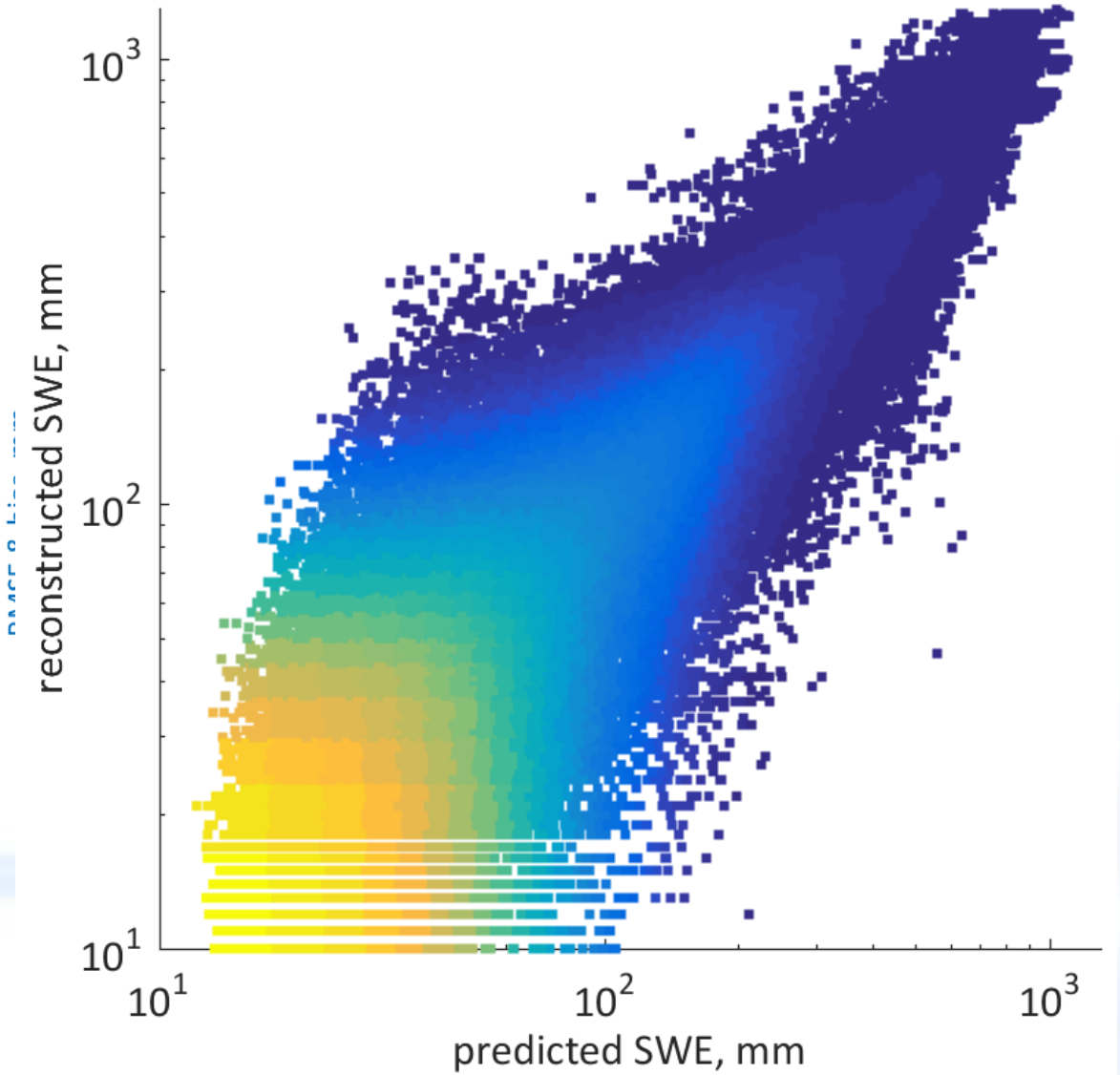
- Among the choices for machine learning methods, start with neural networks, regression-boosted decision trees, and bagged decision trees (bootstrap + aggregate)
- Develop a training set with 2003-2004 data; predict 2005, from March 1 to June 1
  - Then adapt 2005 results, and predict 2006
  - And so on

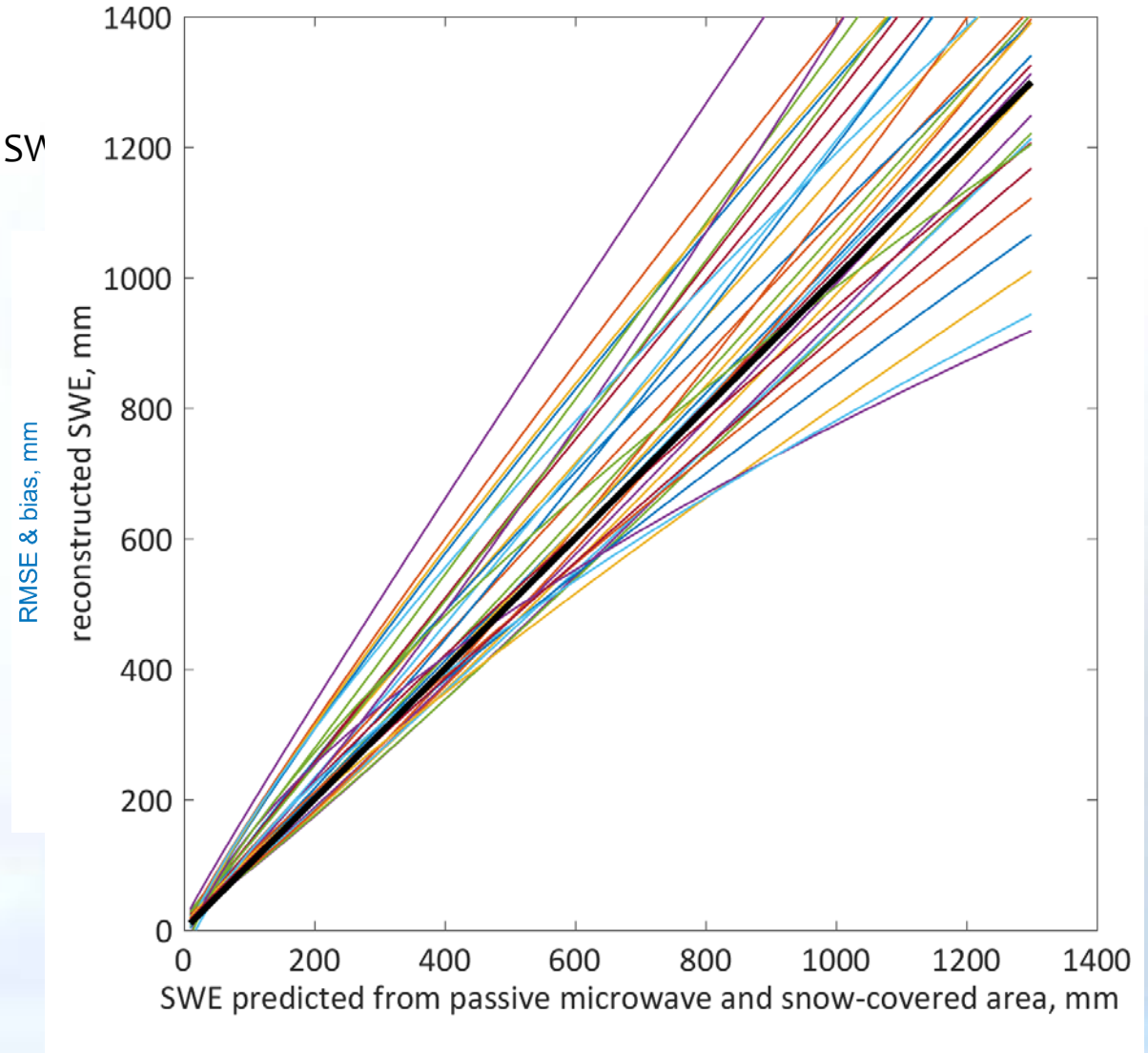
Can we estimate SWE from information available during the season?





Performance statistics on machine learning





Implications and future work

Can our partner, U.S. Army CRREL, use this?

- As it stands, the method provides a forecast that is much better than what they currently use
  - passive microwave, Air Force Weather Agency (AFWA)
- Combination of our code, MATLAB, fractional snow from JPL, MODIS imagery from USGS Land Processes DAAC, AMSR2 SWE from JAXA
  - Need to help CRREL with parallelizing, either on Microsoft Azure or their own hardware
- Machine learning could be improved to reduce bias and RMSE by incorporating other variables
  - Atmospheric circulation patterns (20 kPa geopotential height anomalies), possibly GPM estimates

Publications

Bair, E. H., J. Dozier, C. M. Vuyovich, K. Rittger, and R. E. Davis (2014), Snow water equivalent estimates in the Hindu Kush and the Sierra Nevada using passive microwave and reconstruction, *Proceedings, Western Snow Conference, 82,* 117-127.

Dozier, J., E. H. Bair, and R. E. Davis (2016), Estimating the spatial distribution of snow water equivalent in the world's mountains, *WIREs Water, 3,* 461–474, doi: 10.1002/wat2.1140.

Lettenmaier, D. P., D. Alsdorf, J. Dozier, G. J. Huffman, M. Pan, and E. F. Wood (2015), Inroads of remote sensing into hydrologic science during the WRR era, *Water Resources Research, 51,* 7309-7342, doi: 10.1002/2015WR017616.

Morriss, B. F., E. Ochs, E. J. Deeb, S. D. Newman, S. F. Daly, and J. J. Gagnon (2016), Persistence-based temporal filtering for MODIS snow products, *Remote Sensing of Environment, 175,* 130-137, doi: 10.1016/j.rse.2015.12.030.

Vuyovich, C. M., J. M. Jacobs, and S. F. Daly (2014), Comparison of passive microwave and modeled estimates of total watershed SWE in the continental United States, *Water Resources Research, 50,* 9088-9102, doi: 10.1002/2013WR014734.

Bair, E. H., K. Rittger, J. Dozier, and R. E. Davis, Validating snow water equivalent reconstruction using Airborne Snow Observatory measurements in the Sierra Nevada, *Water Resources Research,* in review.

Rittger, K., A. Kahl, E. H. Bair, and J. Dozier, Spatial estimates of snow water equivalent from reconstruction, *Advances in Water Resources,* in review.