SUPPORT OF MISSION PLANNING AND OPERATIONS IN SNOW-IMPACTED REGIONS

Methods to robustly assess the snow water resource in remote mountains

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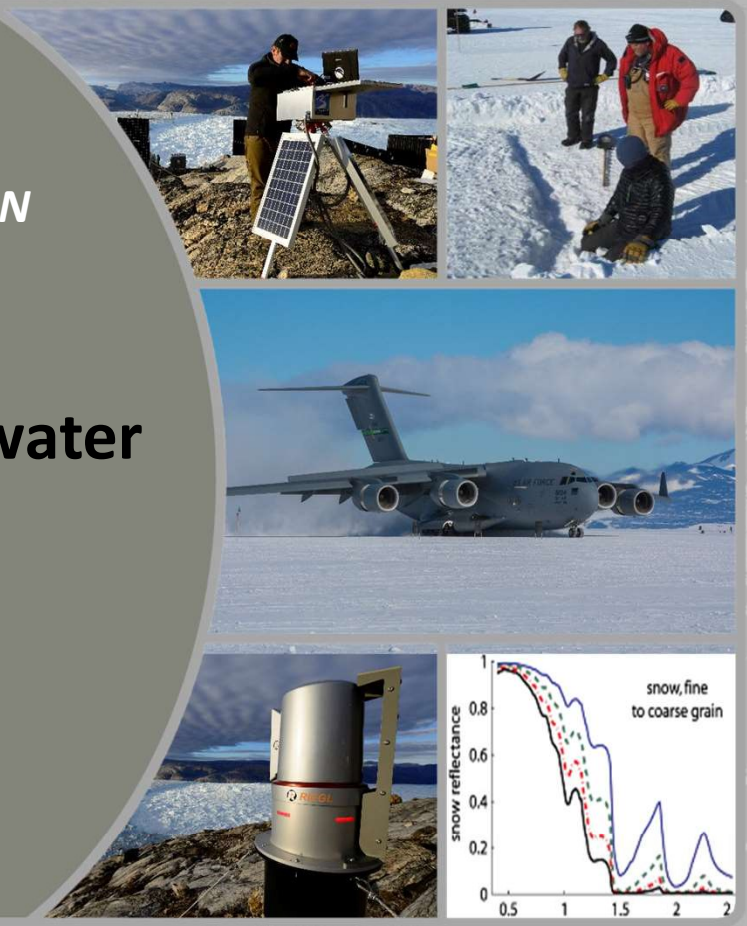

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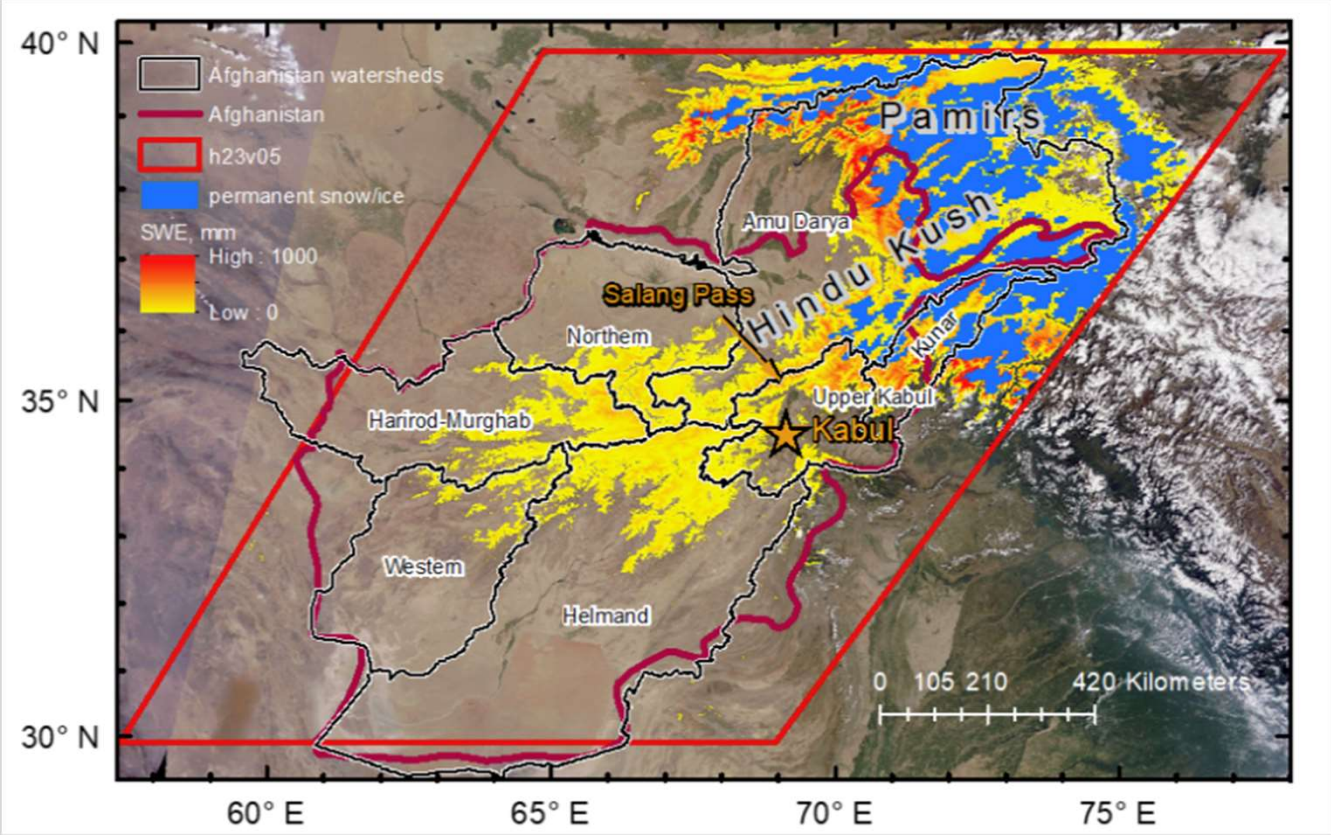
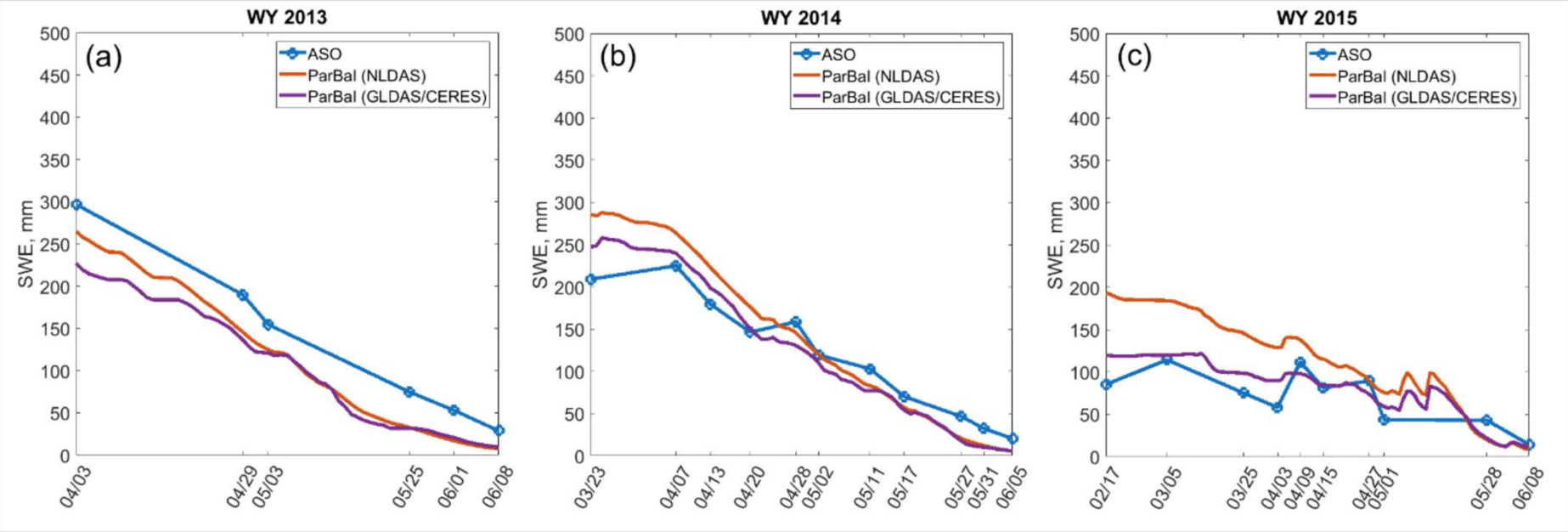
Reconstruction of snow water equivalent (SWE)

- Using remotely-sensed data on radiation and temperature, we build the snowpack in reverse with energy balance components to create historical maps of SWE
- Advantage: Can be done in areas with no ground-based measurements
- Limitation: Can only do this retrospectively after snow melts out



SWE Reconstruction works well in the Sierra

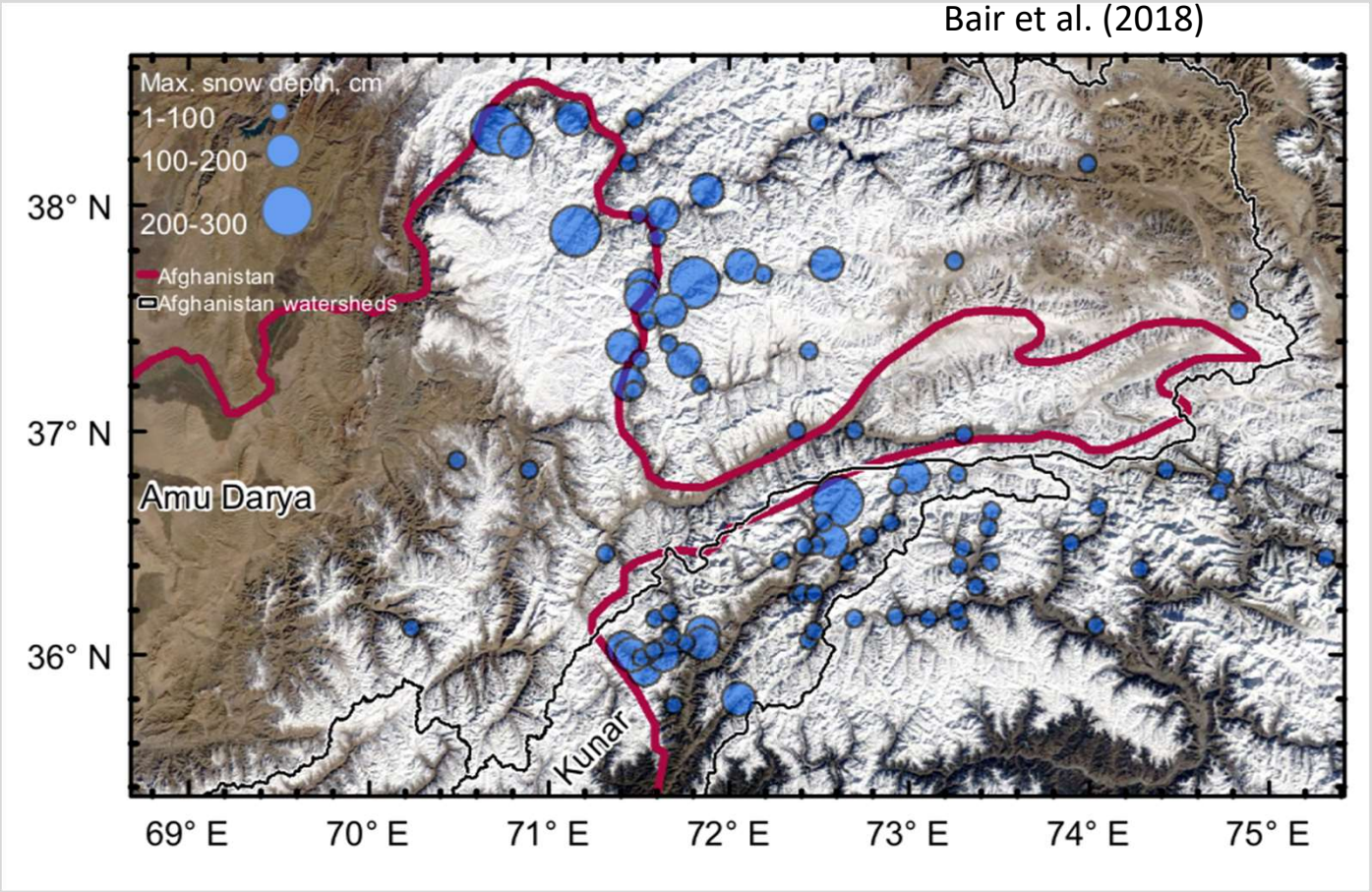
- 22% Mean Absolute Error using GLDAS/CERES and MODSCAG/MODDRFS forcings in the upper Tuolumne for 2013-2015.



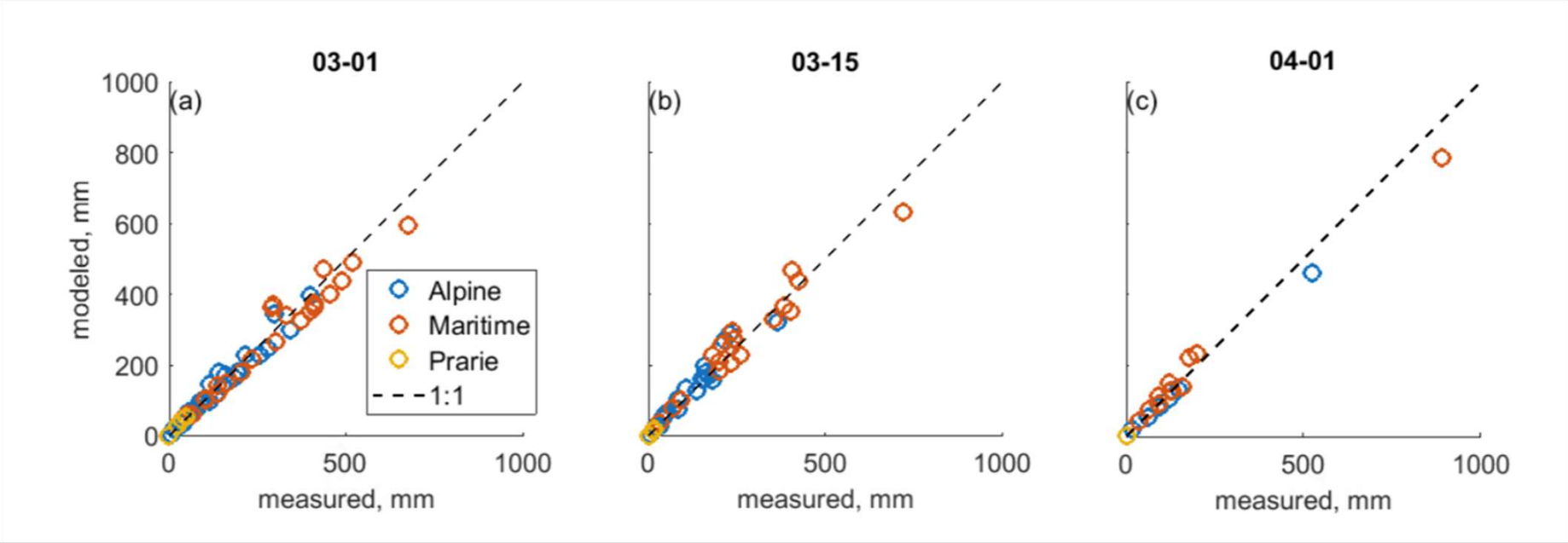
Snow measurements in Hindu Kush supported by Aga Khan Agency for Humanity

- It has been difficult to get recent snow measurements for validation in remote, inhospitable regions
- The Aga Khan Agency for Humanity (AKAH) provided daily snow measurement from 88 stations for model validation (Chabot and Kaba, 2016)

Bair et al. (2018)

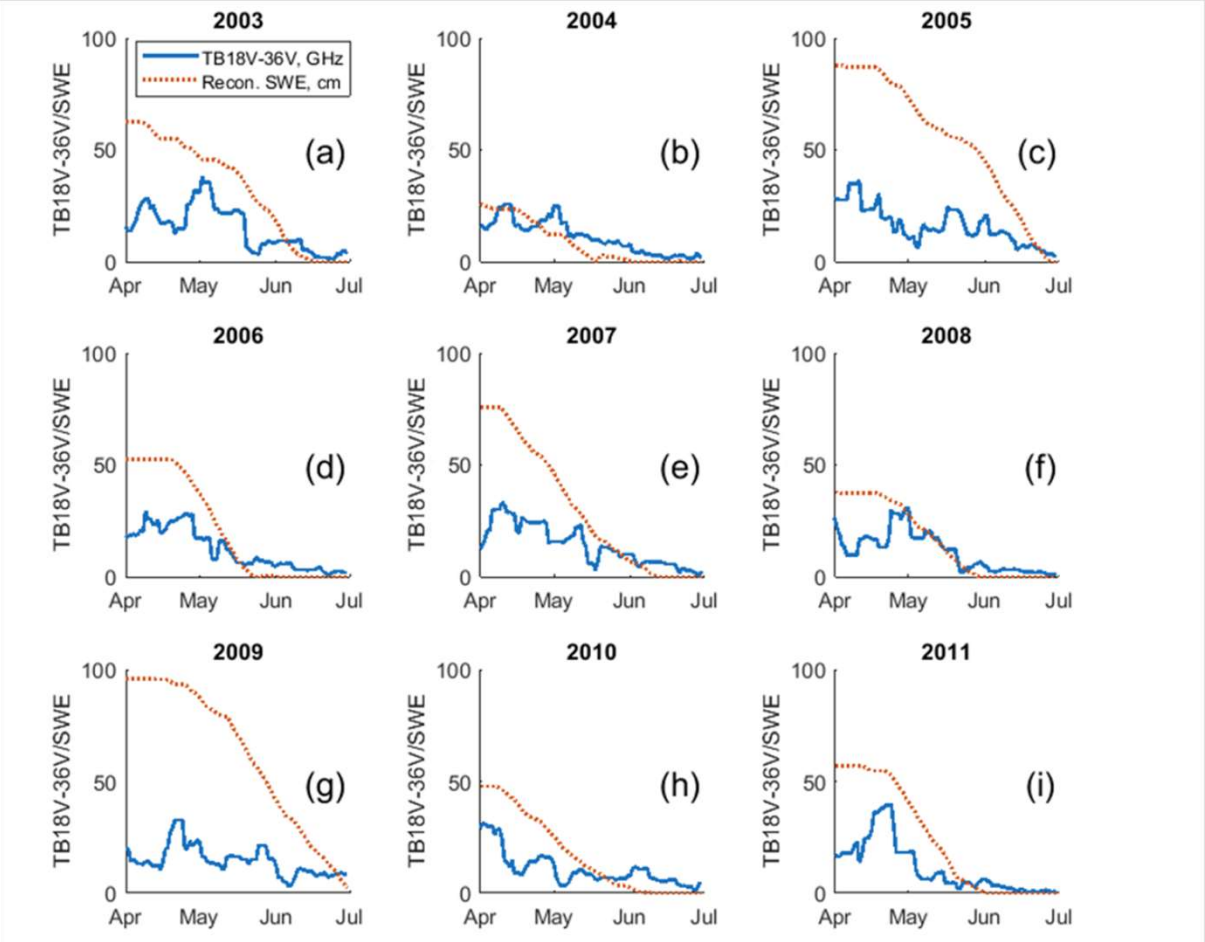


SWE Reconstruction works well in Afghanistan (2017)



- Catch is that only snow depth is measured, so density had to be modeled based on snow climate (Sturm et al. 2011), yielding -12 to +26% uncertainty in SWE. Graphs above show the best-case given that uncertainty in density.

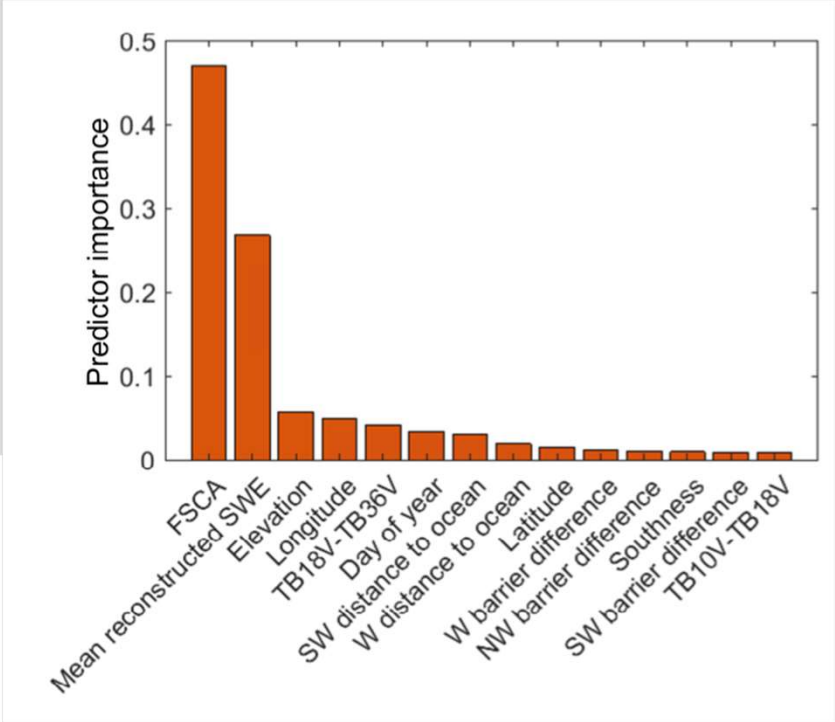
Problems with passive microwave snow assessment in mountains

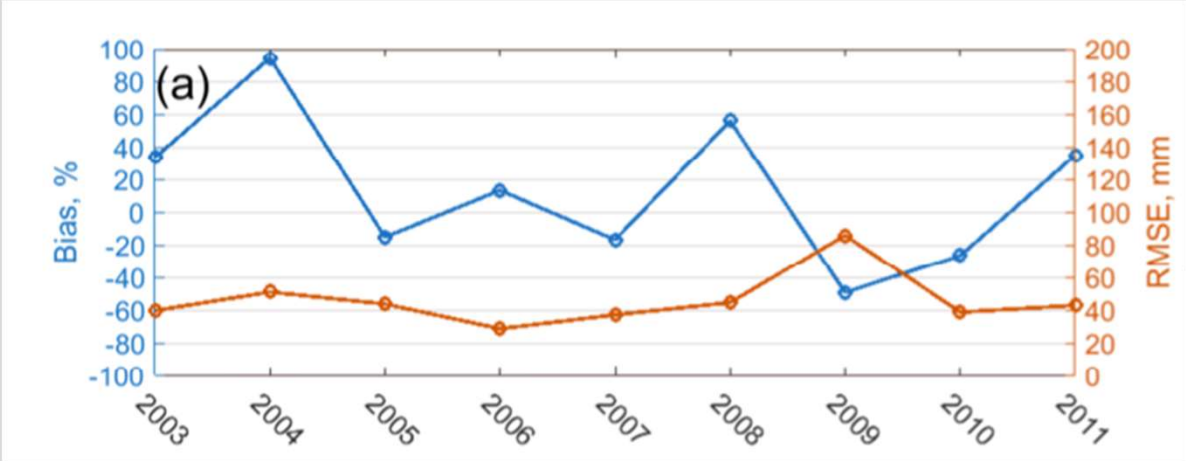


- Aggregated over large basins in Afghanistan, our reconstructed SWE values agree well with passive microwave estimates on April 1 (Daly et al. 2012)
- But on April 1, many areas are snow-free or have shallow snow cover, which masks errors in volume
- Passive microwave, even at enhanced (3 km) resolution, fails to capture the correct magnitude or rank for deep snow areas, such as Salang Pass (left)
- It also saturates at about SWE=200 mm

SWE prediction in Afghanistan using machine learning

- Use reconstructed SWE to train machine learning models that use predictors available during the snow season
- Specifically, bagged trees (random forests) and neural networks were used
- Those models were used to predict seasonal SWE throughout Afghanistan
- 20% of training data (reconstructed SWE) was held out for validation
- Nash-Sutcliffe efficiency is 0.68 for all years, indicating substantial improvement over currently used forecasts from Air Force Weather





Ongoing work, supported by U.S. Army

- 4 year effort through September 2020, now in Year 2
- We are at ARL 6 (System/subsystem model or prototype demonstration in a relevant environment). From the DOD *Defense Acquisition Guidebook*, we fit the ARL 6 example of "testing the prototype in a simulated operational environment"

Task Name	Description	Product/Deliverable	Dates
1) Improvements to ParBal and Reconstruction	e.g. improve f_{SCA}, snow cloud discrimination, albedo, and radiative forcings	Code and peer reviewed publication on new spectral unmixing (f_{SCA}) appraoch	ParBal code on GitLab; publication in 2019; ongoing development
2) Machine learning	SWE prediction using machine learning	Code and peer reviewed publication on machine learning	Publication just completed (Bair et al., 2018); code on GitLab
3) Improvement to passive microwave retrievals	e.g. enhanced resolution passive microwave products	Use of enhanced resolution passive microwave as a predictor in machine learning	Used in machine learning publication (Bair et al. 2018); ongoing development
4) Hydrologic modeling	Not pursuing due to funding constraints	N/A	N/A

References

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D. Chabot photos of training for AKAH snow and avalanche observers