Estimating snow depth of alpine snowpack via multifrequency passive microwave airborne observations: Colorado, USA

Rhae Sung Kim1(kim.2618@osu.edu), Michael Durand1, Dongyue Li2, Elisabeth Baldo2, Steven Margulis2, Marie Dumont3, and Samuel Morin3

1School of Earth Sciences and Byrd Polar Research Center, Ohio State University, Columbus, OH, USA
2Department of Civil and Environmental Engineering, University of California, Los Angeles, Los Angeles, CA, United States
3Météo-France – CNRS, CNRM – GAME UMR3589, CEN, Grenoble, France

1. Objective
- Seasonal snow cover plays a key role in the climate system. Passive microwave observations are available daily for three+ decades, but a coarse resolution. Much work has been done to develop retrieval algorithms.
- Using model-based estimation frameworks has emerged as a strategy to best use microwave measurements.
- In this study, we estimate snow depth in Colorado, USA by using multifrequency passive microwave airborne observations using a particle filter.

2. Hypotheses
- Single day airborne PM measurement could estimate snow depth correctly.
- Crocus could improve the accuracy of the prediction of snow state.
- A combination of multifrequency radiance has snow information and could help to estimate accurate snow depth.
- Particle filter approach outperforms the Kalman-based filter approach.

3. Study area and Data
- The Cold Land Processes Experiment 2002 (GAME UMR3589, CEN, Grenoble, France) project was provided by NASA New Investigator Program NNX13AB63G.
- Deployed Crocus-MEMLS coupled model with particle filter method.
- 10.7+18.7+37.0+89.0 GHz combination most accurately estimated the snow depths.
- Crocus and particle filter outperform SSib3 and EnKF, respectively.

4. Models and retrieval procedures
- Forcing data disaggregation model: to downscale all the forcing data to 120 m resolution (UCLA/Baldo & Margulis).
- Snowpack physical model: Crocus (CNRS/Dumont & Morin).
- Radiative transfer model: Microwave Emission Model of Layered Snowpack.

- 1. The forcing disaggregation model downscales the NLDAS-2 data to model resolution (120 m).
- 2. The snowpack evolution model (Crocus) prognoses snowpack structure from downscaled forcing data.
- 3. The radiative transfer model (MEMLS) simulates Tb from Crocus outputs.
- 4. The particle filter updates the predicted snow depth using observed Tb.
- 5. Estimated snow depths are validated with snow depth transects measurements.

5. Results
- Crocus: Simulates the physical snowpack processes and layering (stratigraphy) using up to 50 layers, capability to resolve melt-refreeze crusts.
- Microwave-depth relationships revealed by joint snowpack + microwave radiance simulations.
- Note that depths are far past typical values considered for “saturation”, and Tb vs depth correlation is positive, but the there is still some information in the airborne microwave measurements.
- Particle filter: proper to handle non-Gaussian PDFs and non-linear models.

6. Conclusions
- Particle filter estimates capture snow depth retrieval spatial Patterns constrained by airborne Tb.

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\text{Prior} & 19+37+89 \\ 
\text{GHz} & 0.44 (0.26) & 0.81 & 0.85 (0.94) \\
\text{RMSE} & 10+19+37+89 \\ 
\text{cm} & 25.26 (23.81) & 14.78 & 13.30 (8.10) \\
\text{Bias} & -4.42 (-6.35) & 7.99 & 4.45 (2.71) \\
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