

Improving snow properties retrievals thermodynamic snow models and satellite remote sensing

Langlois, A., and Royer, A.

¹Centre d'Applications et de Recherches en Télédétection, Université de Sherbrooke, Québec, Canada.

ABSTRACT: Snow cover plays a key role in the climate system by influencing the transfer of energy, gas and mass between the soil and the atmosphere. In particular, the amount of snow water equivalent (SWE) accumulated in a snowpack and the characteristics of the snowmelt (e.g. frequency, timing, and intensity) are of particular importance for hydrologic and climate processes. This is particularly true under the present warming climate with increasing occurrence of winter rain episodes and early snowmelt that could affect the avalanche risk.

Passive microwave has been extensively used in order to estimate snow water equivalent in northern regions. Although passive microwave are independent from daylight and atmospheric conditions, the coarse spatial resolution brings important uncertainties in the snow water equivalent (SWE) retrieval from space due to the important surface heterogeneity within one pixel. The lack of snow and meteorological stations is another source of significant uncertainties. In this presentation, we investigate the coupling of a thermodynamic multilayered snow model (SNOWPACK) with a passive microwave emission model (MEMLS) with the goal to improve the knowledge of the snowpack state evolution (layering, density, snow grain size, depth). The snow grain size predictions from SNOWPACK are evaluated and corrected using innovative short-infrared reflectance techniques with implications to snow mass retrievals algorithms (i.e. SWE through an assimilation scheme using passive microwave emission models) and avalanche risk assessment.

KEYWORDS: Snow, passive microwave, model, SNOWPACK, MEMLS, SWE, avalanche

1 INTRODUCTION

Snow cover plays a key role in the climate system by influencing the transfer of energy, gas and mass between the soil and the atmosphere. In particular, the amount of snow water equivalent (SWE) accumulated in a snowpack and the characteristics of the snowmelt (e.g. frequency, timing, and intensity) are of particular importance for hydrologic and climate processes. This is particularly true under the present warming climate with increasing occurrence of winter rain episodes and early snowmelt that could affect the avalanche risk. Passive microwave has been extensively used in order to estimate snow water equivalent in northern regions. Although passive microwave are independent from daylight and atmospheric conditions, the coarse spatial resolution brings important uncertainties in the snow water equivalent (SWE) retrieval from space due to the important surface heterogeneity within one pixel. The lack of snow and meteorological stations is another source of significant uncertainties.

2 METHODOLOGY

We coupled a snow thermodynamic model (SNOWPACK) driven by meteorological reanalysis data (NARR) with a layered snow emission model (MEMLS) to improve simulations of SWE which are completely independent of any surface observations. In order to evaluate the snow model, simulations were compared to in-situ measurements from two different field campaigns.

3 RESULTS

We first showed that the initial SWE simulations (without the use of any passive microwave measurements) contained large errors with a regression slope of 0.23 and a y-axis offset of 109 mm. The initial R2 and RMSE were measured 0.27 and 79 mm respectively (Figure-1).

Corresponding author address: Alexandre Langlois, Université de Sherbrooke
tel: +1 819 821 8000; fax: +1 819 821 7944;
email: a.langlois2@usherbrooke.ca

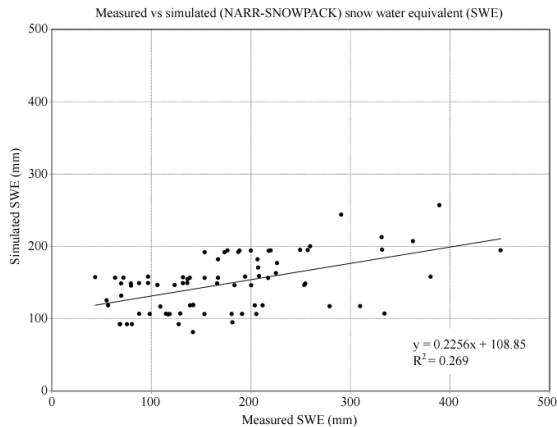


Figure 1: Comparison between initial modeled SWE values from NARR-SNOWPACK (without remote sensing) and measured values

In order to improve this result, we coupled the snow model output to a layered microwave emission model. First, the poor grain characterization by the snow model was corrected using an iteration scheme where the simulated snow grain was modified (correction factor, ϕ) until a minimum difference in brightness temperatures (ΔT_b -MIN) was found between measured (radiometers) and modeled (MEMLS) data. The most appropriate correction factor was found to be 0.1 for all sites, which was then applied to the snow model output. SNOWPACK output data (with corrected snow grains using ϕ) was again coupled to MEMLS for a second iteration on SWE (i.e. modifying SWE until ΔT_b -MIN was found). A correction factor on SWE (β) was found for all sites together (minimum RMSE) at 1.35. However further improvement occurred when using two β values for respectively underestimated and overestimated SWE values, which produced significant improvement on the slope, y-axis intercept, R^2 and RMSE between simulated SWE with correction factors and measured SWE (Table-1).

Table-1: Summary of initial and corrected SWE simulations statistics compared to field measurements.

SWE simulations	Slope	y-axis offset (mm)	R^2	RMSE (mm)
Initial	0.226	108.85	0.269	79.4
β fixed	0.532	121.13	0.447	54.9
β adjustable	0.891	23.474	0.404	65.4

Validation using an independent snow survey dataset and AMSR-E satellite observations over tundra with strong local-scale variability

showed promising results with a RMSE of 49 mm. This RMSE is comparable to other SWE retrieval studies using satellite. We showed that our method can be applied and be statistically significant over a wide range of SWE values (45-260 mm) (Figure-2).

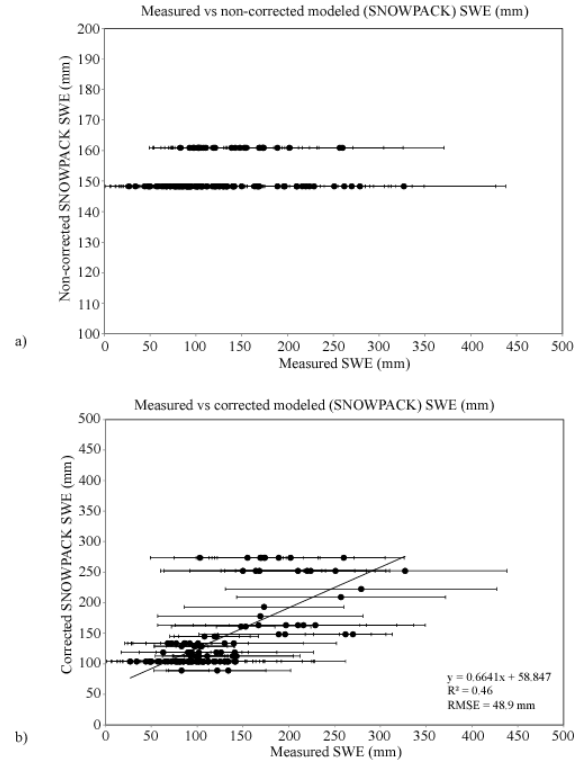


Figure 2: Comparison between simulated and measured SWE a) before and b) after the iteration on measured brightness temperatures. Measurements are from a transect line near the Puvirnituk Inuit community (POV on Figure 1). In a), data span across two NARR pixels (two NARR SWE values). Horizontal lines correspond to the standard deviation on averaged in-situ SWE values.

Furthermore, most studies are using satellite passive microwave data, which are less sensitive to surface roughness, spatial variation in thickness and micro-variability in snow thermophysical properties, especially snow grains. The airborne-derived brightness temperatures used in this paper are indeed generally more sensitive to such micro-scale analysis, increasing the challenge of SWE retrieval. On the other hand, this increased sensitivity to snow properties allowed the correction of poor grain simulations by the snow model (ϕ), which represents a main step forward for future assimilation schemes (for future spaceborne retrievals). We showed that coupling a snow thermodynamic model with a microwave snow emission model without

accounting for poor grain parameterization leads to very large errors, with RMSE > 100K in brightness temperatures. A simple two-step iteration procedure (first iteration on snow grains, second on SWE) driven by meteorological reanalysis and without any in-situ snow information allows improved or similar SWE retrieval accuracy when compared to an assimilation scheme that requires in-situ snow information.

3 CONCLUSION

The next intuitive step is to extend the validation of the method using a multi-scale approach that also includes satellite passive microwave radiometer measurements. The differences in errors observed at the various scale using the same field SWE reference measurements averaged at the different scales will explain the potential source of errors at the satellite scale. The proposed simplified approach could also be applied regionally with a snow model or within the land surface scheme of a Regional Climate Model to potentially improve snow monitoring.