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Simulations of a Canadian snowpack brightness temperatures using SURFEX-Crocus for Snow Water Equivalent (SWE) retrievals

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In Quebec, the water associated to snowmelt represents 30% of the annual electricity production so that the snow cover evaluation in real time is of primary interest. The key variable is snow water equivalent (SWE) which describes the evolution of a global seasonal snow cover. However, the sparse distribution of meteorological stations in northern Québec generates great uncertainty in the extrapolation of SWE. On the contrary, the spatial and temporal coverage of satellite data offer a source of information with a high potential when considered as an alternative to the poor spatial distribution of in-situ information. Thus, this project aims to improve the prediction of SWE by assimilation of satellite passive microwave brightness temperatures (Tb) observations, independently of any ground observations. The snowpack evolution is simulated by the French snow model SURFEX-Crocus, driven by the Canadian atmospheric model GEM with a spatial resolution of 10 km. The bias of the atmospheric model and the impact of initialization errors on the simulated SWE were quantified from our ground measurements.

To assimilate satellite observations, the multi-layered snow model is first coupled with a radiative transfer model using the Dense Media Radiative transfer theory (the DMRT-ML model) to estimate the microwave snow emission of the simulated snowpack. In order to retrieve simulated Tb in frequencies of interest (i.e. sensitive to snow dielectric properties), the snow microstructure needs to be well parameterized. It was shown in previous studies that the specific surface area (SSA) of snow grains is a well-defined parameter to describe the size and the shape of snow grains and which allows reproducible field measurements. SURFEX-Crocus estimates a SSA for each simulated snow layer, however, the snow microstructure in DMRT-ML is defined per layer by monodisperse optical radius of grain ($\sim$ 1/SSA) and by the stickiness which is not known. It thus becomes necessary to introduce an empirical factor (noted φ) due to the simplification of the representation of snow as non-sticky spheres of ice in the model. In other words, the measured and simulated SSA has to be converted in an effective snow grain metric by optimizing this scaling factor to minimize the root-mean-square error between the measured and simulated brightness temperatures. The φ factor scaling the Crocus simulated SSA was estimated using ground-based radiometric measurements made during several field campaigns in the James Bay territory, Nunavik (in 2013 and 2015), and Churchill, Manitoba in 2010. This new parameterization, adapted to the Canadian arctic and subarctic snowpack, represents an essential step to optimize SWE maps in this remote region which have yet to be proven accurate.