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Evaluation of sub-kilometric numerical simulations of C-band radar backscatter over the French Alps against Sentinel-1 observations

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Snow plays a key role in surface energy and mass budgets of mountainous regions. Due to its spatial and temporal variability and the low spatial density of in-situ observations, remote sensing is a powerful method to monitor variations of snow conditions. Copernicus Sentinel-1 satellites offer a unique tool to monitor the snowpack using a C-band Synthetic Aperture Radar (SAR) with a high spatial resolution (20m) and with a revisit frequency of 6 days over the French mountains. C-band SAR is particularly sensitive to the soil properties and the thermal state of the snowpack, in particular the presence/absence of liquid water in snow.

In this study, we use the Microwave Emission Model of Layered Snowpacks (MEMLS, Proksch et al., 2015), a radiative transfer model which we interfaced with the physically-based snow evolution model Crocus (Brun et al., 1992; Vionnet et al., 2012) implemented in the land surface scheme ISBA, to simulate backscatter coefficients year-round over a wide alpine area in the Northern French Alps. Our study area is about 2500 km^2 with an effective resolution of 250 meters for both the simulations and the observations. Meteorological forcing data from the SAFRAN reanalysis downscaled to the resolution considered were used to drive ISBA-Crocus. To simulate the ground signal with the best accuracy, we fitted the simulated reflectivity at the snow/ground interface according to snow-free observations from Sentinel-1. We also used high resolution land cover products to mask the forest areas. Simulated backscatter coefficients were then evaluated by comparing them with 45 observation scenes from Sentinel-1 for two snow seasons, 2014-2015 and 2015-2016. We evaluate the capacity of the model chain to reproduce the observed microwave signal and we investigate the impact of some relevant snow/soil properties on the simulated and observed microwave signals. We use the ratio between backscatter signal of snow and snow-free situations, in simulations and in Sentinel-1, as a way to identify wet snow surfaces according to the Nagler et al. (2000) algorithm. Such surfaces are also compared to Sentinel-2 snow cover extent products (https://theia.cnes.fr). Those products indicate the snow presence or absence on the land surface with a 20 m resolution.

Our investigations have made it possible to develop and evaluate observation operator relating backscatter coefficients to ground and snow physical properties, opening the way to assimilation of C-band radar data into this model chain.