Measurement of Tundra Arctic Snow Microstructure and Improved Microwave Radiometry Modelling

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ABSTRACT

Arctic snow has the peculiarity of being very dense near the surface, due to frequent blowing-snow events and sustained cold temperatures, while the bottom of the snowpack is typically less dense, with thick depth hoar layers formed through temperature gradient metamorphism. This leads to a combination of high thermal conductivity contrast, where the upper layers have higher conductivity than the bottom layers which contains more air. The result of this combination can significantly alter snowpack-insulating properties, as these layers develop through the winter. Currently, no land surface model is able to accurately simulate such a specific density stratigraphy. Snow models generally produce the reverse density stratigraphy, with low density at the surface and high snow density at the bottom since they are mostly based on compaction and ignore the water vapor fluxes from the ground as well as the vegetation interactions, both leading to depth hoar formation.

We show this issue can be resolved using passive microwave radiometry. From simulations based on the Snow Microwave Radiative Transfer (RT) model SMRT, we discuss how the arctic snow brightness temperature (TB) can depart from temperate and subarctic snow due to the different microstructures and stratigraphy of snowpacks. Based on new ground-based radiometric and snow microstructure measurements over Canadian Arctic tundra sites (Umiujaq, Nunavik, Trail Valley Creek, Yukon, and Cambridge Bay, Nunavut, Canada), we parameterize the snowpack microstructure profile using snow surface specific area, density and micropenetrometer-derived correlation length variations. We then discuss the best modelling and configuration approach among the RT models proposed in SMRT (DMRT-SHS, IBA-SHS and IBA-Exp). The presence of wind slab and ice crusts within the snowpack, which are now often observed over Arctic areas, also generates significant variation in TB.

These results suggest that improved tundra arctic snow modelling could lead to better estimates of snow insulating effects on the ground and thus reduces errors in estimates on winter soil temperature and permafrost evolution (Arctic snow feedback effect).

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