Simulating Transmissivity of Thin Snow with a Photon-Tracking Radiative Transfer Model

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ABSTRACT

The interaction between visible and near-infrared radiation and individual snow particles is well described by geometric optics theory. However, this interaction is complicated enormously when considering a snowpack in aggregate due to the intricate microscopic details of the snow in ways that are not sufficiently understood to accurately model and predict radiative transfer through a snowpack in all circumstances. This has important implications for quantifying the effect of snow cover on the Earth's energy balance, determining of snow properties via remote sensing, and detecting of objects under the snow, among others. Snow has an intricate microstructure and is a highly scattering medium. Yet, most radiative transfer models rely on simplified snow grain geometries and idealized particle-size distributions to parameterize the snowpack optical properties and therefore are not able to explore in detail the impact of the snow microstructure on bulk snowpack radiative properties. In this study, we aim to understand how snow microstructure, including grain and pore space arrangement, impact the radiative transfer properties of optically thin snow with a focus on transmissivity. To accomplish this we have developed the ERDC-CRREL snow radiative transfer model (RTM) based largely on the framework developed by Kaempfer *et al.* (2007), which applies a photon-tracking model that incorporates realistic snow microstructural elements from micro-computed tomography data as input. Our model modifies this approach such that it can be expanded to snowpacks of arbitrary depth. We present an initial evaluation of this model against snow reflectance and transmittance measurements collected over painted panels inserted at various depths throughout a snowpack in Vermont during the 2020-21 winter. Microtomography samples collected coincidently with the reflectance and transmittance measurements were used to drive the radiative transfer model. Preliminary results show good agreement between modeled and observed radiative properties. The model is able to successfully reproduce known relationships between grain size and albedo.

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