EGU24-17505, updated on 12 Feb 2025
https://doi.org/10.5194/egusphere-egu24-17505
EGU General Assembly 2024

Determining snow material properties from near-infrared photography

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It is well understood that snow is a complex, porous material, whose microstructural changes directly affect its physical properties. Therefore, – to gauge the snow's role within the climate system – it is of interest to accurately measure and characterize the spatio-temporal variability of snow surfaces and snowpacks.

On a local scale, for example inside a snowpit during a field campaign, snow measurements are often taken in a manual, point-like fashion resulting in single, one-dimensional profiles with a sampling resolution of a few centimeters. At this resolution thin layers are difficult to observe and spatial inhomogeneities of the snowpack are missed. State-of-the-art X-ray microtomography (μCT) scans of snow provide excellent spatial resolution,[1] however, the added experimental constraints prevent sampling extended spatio-temporal domains.

To address some of these limitations, we propose to use near-infrared (NIR) photography[2] with 940 nm illumination to determine the snow's specific surface area (SSA) and density. Our device – called SnowImager – achieves millimeter resolution and covers a spatial extent of a few square meters, such as the surface area of a snowpit wall. While the SSA is determined directly from the measured NIR image using the well-established asymptotic radiation transfer theory,[3–6] the density dependence is introduced by physically truncating the illuminating and back-scattered light. It results non-trivially from the lateral component of the sub-surface scattering process and enables us to recover density profiles that compare well to reference data from density cutter and μCT measurements. As a demonstration, we present the spatial variability of an Antarctic snowpack at an unprecedented level of detail, revealing an extremely high spatial variability of the snow microstructure.

Using near-infrared photography enables accurate and fast determination of snow material properties, whenever millimeter spatial resolution and a spatial extent of several square meters are required. It is thus ideally suited to simultaneously capture thin layers within the snowpack and spatial inhomogeneities over a centimeter to meter scale, which is relevant as ground truth measurement for climate research, remote sensing and avalanche forecasting among others.

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