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Snowpack characterization and depth estimates using UAS-mounted ground penetrating radar: A case study from Western Norway

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There is a visible link between climate change and increased frequency of natural hazards. Avalanches are of particular concern within mountainous and arctic regions. Local snow characterization and mapping is an important first step to forecasting a hazardous event and identify vulnerable regions during risk management assessment of critical infrastructure, such as roadways and tunnels. Information on snow cover and snow properties is also crucial for flood management, hydropower industry and glacier mass balance calculations.

Uncrewed aerial systems (UASs) play a critical role in safely and efficiently obtaining high-resolution data to characterize snow and ice for avalanche and glacier studies. UASs provide controlled flight altitude and speed and high positioning accuracy resulting in repeatable surveys. Surficial and subsurface information on the snow layers can be obtained depending on the sensor equipped onboard the UAS. Lidar measurements collected prior to and after snow accumulation provide a ground and snow surface maps from which an estimate is derived on snowpack thickness. However, the lidar method does not provide information on internal snowpack structure neither on snow properties. Ground penetrating radar (GPR) allows mapping of the snow surface and insight into subsurface snow layers, depending on the snow characteristics such as snow water equivalent (SWE) and density.

In March 2023, GPR measurements using a 1GHz antenna were acquired from a commercial off the shelf quadcopter at Fonnbu along the Grasdalen alpine valley, western Norway. Following in-house data processing workflow, two main interfaces are identified through 2D profile picking: rock to snow and snow to air. Intermittent layers are also identified increasing detailed understanding of the snowpack structure. Snow density and velocity are determined using local snowpit logs from which snow thickness is calculated. These snowpack depth estimates are compared with the lidar thickness estimates enabling a multi-scale and -parameter analysis of the Fonnbu snow study site. Methods developed in this study will be implemented for snowpack characterization using UAS-mounted sensors to other study sites within Norway.