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Mapping snow depth in complex alpine terrain with close range aerial imagery - estimating the spatial uncertainties of repeat autonomous aerial surveys over an active rock glacier

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Snow depth mapping in open areas using close range aerial imagery is just one of the many cases where developments in structure-from-motion and multi-view-stereo (SfM-MVS) 3D reconstruction techniques have been applied for geosciences – and with good reason. Our ability to increase the spatial resolution and frequency of observations may allow us to improve our understanding of how snow depth distribution varies through space and time. However, to ensure accurate snow depth observations from close range sensing we must adequately characterize the uncertainty related to our measurement techniques.

In this study, we explore the spatial uncertainties of snow elevation models for estimation of snow depth in a complex alpine terrain from close range aerial imagery. We accomplish this by conducting repeat autonomous aerial surveys over a snow-covered active-rock glacier located in the French Alps. The imagery obtained from each flight of an unmanned aerial vehicle (UAV) is used to create an individual digital elevation model (DEM) of the snow surface. As result, we obtain multiple DEMs of the snow surface for the same site. These DEMs are obtained from processing the imagery with the photogrammetry software Agisoft Photoscan. The elevation models are also georeferenced within Photoscan using the geotagged imagery from an onboard GNSS in combination with ground targets placed around the rock glacier, which have been surveyed with highly accurate RTK-GNSS equipment. The random error associated with multi-temporal DEMs of the snow surface is estimated from the repeat aerial survey data. The multiple flights are designed to follow the same flight path and altitude above the ground to simulate the optimal conditions of repeat survey of the site, and thus try to estimate the maximum precision associated with our snow-elevation measurement technique. The bias of the DEMs is assessed with RTK-GNSS survey observations of the snow surface elevation of the area on and surrounding the rock glacier. Additionally, one of the challenges with processing snow cover imagery with SfM-MVS is dealing with the general homogeneity of the surface, which makes is difficult for automated-feature detection algorithms to identify key features for point matching. This challenge depends on the snow cover surface conditions, such as scale, lighting conditions (high vs. low contrast), and availability of snow-free features within a scene, among others. We attempt to explore this aspect by spatial modelling the factors influencing the precision and bias of the DEMs from image, flight, and terrain attributes.