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Airborne Structure-from-Motion modelling for avalanche and debris flow paths in steep terrain with limited ground control

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The availability of consumer remotely piloted aircraft systems (RPAS) has enabled rapidly deployable airborne surveys for civilian applications. Combined with photogrammetric reconstruction techniques, such as Structure-from-Motion (SfM), it has become increasingly feasible to survey large areas with very high resolution, especially when compared with other airborne or spaceborne surveying techniques. A pair of case studies, using an RPAS-based field surveying technique for establishing baseline surface models in steep terrain, are presented for two different natural hazard applications.

The first case study involved a survey over the entire 1000-m length of a snow-free avalanche path on Sætreskarsfjellet in Stryn municipality in Norway. A terrain-aware, multi-battery flight plan was designed to ensure good photographic coverage over the entire avalanche path and 21 ground control points (GCP) were distributed evenly across the path and subsequently surveyed. More than 400 images were collected over a 0.5 km^2 area, which were processed using a commercial SfM software package. Two digital surface models were reconstructed, each utilizing a different ground control scenario: the first one with the full count of GCP, while the second used only a limited count of GCP, which is more feasible for a repeat survey when avalanche hazard is high. Comparison with data from a pre-existing, airborne LiDAR survey over the avalanche path revealed that the SfM-derived model that utilized only a limited number of GCP diverged significantly from the model that utilized all available GCP. Further differences between the SfM- and LiDAR-derived surface models were observed in areas with very steep slopes and vegetative cover. The same methodology can subsequently be applied during the winter season, after extensive snowfall and/or avalanche events, to deduce relevant avalanche parameters such as snow height, snow distribution and drift, opening of cracks in the snow surface (e.g. for glide avalanches), and avalanche outlines.

The second case study involved a survey over the entire 1000-m length of a debris flow path at Årnes in Jølster, Norway. The Årnes flow, which caused one fatality, was one of the largest of several tens of debris flows that occurred on July 30, 2019. The flows were triggered by an extreme precipitation event around the Jølstravatnet area. Like with the Sætreskarsfjellet avalanche path

case study, a terrain-aware flight plan was established and 24 GCP were distributed and surveyed along the debris flow path. Over 400 images were collected over a 0.3 km^2 area, which were used to reconstruct a high-resolution surface model. Like with the avalanche case study, the SfM-derived model was compared with a pre-existing LiDAR survey-derived digital terrain model. Altitude and volume changes, due to the debris flow event, were calculated using GIS analysis tools.

The utility of the RPAS survey technique was demonstrated in both case studies, despite difficult accessibility for ground control. It is suggested that a real-time-kinematic (RTK)-enabled workflow may significantly reduce survey time and increase personnel safety by minimizing the number of required GCP.

Keywords: Structure-from-Motion, photogrammetry, digital surface model, natural hazards, ground control.