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Studying ice dynamics of the Morteratsch glacier complex (Switzerland) with UAV acquired photography and structure from motion (SfM) algorithms

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Glacier variations are key indicators of climate change. Monitoring of glacier activity is mostly based on ground-based measurements and on satellite observations. However, these measurements lack the spatial and/or temporal resolution that is required for accurate interpretations. Therefore, Unmanned Aerial Vehicles (UAVs) are increasingly used to study glacier dynamics, bridging the gap between direct field observations and satellite images.

In this research, the usability of UAVs and SfM algorithms to study glacier dynamics was assessed and applied to reconstruct high-resolution digital surface models (DSMs) of the ablation area of the Morteratsch-Pers glacier complex in Switzerland. We performed annual field campaigns between 2014 and 2018 to assess the accuracy of UAV images and to calculate high resolution elevation differences.

The accuracy of UAV measurements was assessed in detail as a function of ground control point (GCP) density, GCP distribution, flight direction, visual content, and RTK positioning. We also compared the different reconstructed DSMs with each other and with DEMs created by SwissTopo in 2015 and 1991. Based on these comparisons, we found that the Pers glacier is thinning more rapidly than the Morteratsch glacier at the same elevation. In addition, the highest elevation differences were found for the front of the Morteratsch glacier with a decrease of almost 150 meters since 1991. For the almost stagnant front of the Morteratsch glacier, the elevation decrease goes up to -10 m/y which corresponds to the local surface mass balance as measured directly from a stake network. Different glacier features like ogives, surface melt channels and crevasses were detected and used for feature recognition. This allowed to calculate surface velocities that appeared to be very heterogenous for the glacier complex. We conclude that SfM algorithms applied on UAV images have great potential for studying glacier dynamics accurately at high resolution.