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Ground-based multi-view photogrammetry for the monitoring of landslide deformation and erosion

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Recent advances in multi-view photogrammetry have resulted in a new class of algorithms and software tools for more automated surface reconstruction. These new techniques have a great potential to provide topographic information for geoscience applications at significantly lower costs than classical topographic and laser scanning surveys. Based on several open-source libraries for multi-view stereo-photogrammetry and Structure-from-Motion, we investigate the accuracy that can be obtained from different processing pipelines for the 3D surface reconstruction of landslides and the detection of changes over time. Two different algorithms for point-cloud comparison are tested and the accuracy of the resulting models is assessed against terrestrial and airborne LiDAR point clouds. Change detection over a period of more than two years allows a detailed assessment of the seasonal dynamics of the landslide; the possibility to estimate sediment volumes, as well as the quantification of the 3D displacement at most active parts of the landslide. Compared to LiDAR point clouds, the root-mean squared error of the photogrammetric point clouds did generally not exceed 0.2 m for the reconstruction of the entire landslide and 0.06 m for the reconstruction of the main scarp. We show that at the slope scale terrestrial multi-view photogrammetry is sufficiently accurate to detect surface changes in the range of decimeters. Thus, the technique currently remains less precise than terrestrial laser scanning or differential satellite positioning systems but provides spatially distributed information at significant lower costs and is, therefore, valuable for many practical landslide investigations. Algorithm parameters and the image acquisition protocols are found to have important impacts on the quality of the results and are discussed in detail. Our findings suggest that a relative precision of 1:500 and better is possible. The results of the change detection show a strong seasonality of the landslide activity and point towards an increased sediment delivery and transport in spring; especially in years with intensive and prolonged winters. The quantified volume budgets lead to an average sediment yield of 426.9 ± 43.9 kg m^{-2} yr^{-1} for the monitoring period (2.5 years) which shows that the landslide scarp must be considered as an important point-source of loose sediments and a significant term in sediment budgets at the catchment scale.