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Close-range sensing and object-based analysis of shallow landslides and erosion in grasslands

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Close-range sensing methods for topographic data acquisition, such as Structure-from-Motion with multi-view stereo (SfM-MVS) photogrammetry and laser scanning from the ground or from unmanned aerial systems (UAS), have strongly improved over the last decade. As they are providing data with sub-decimetre resolution and accuracy, these methods open new possibilities for bridging the gap between local in-situ observations and area-wide space-borne or aerial remote sensing. For assessments of shallow landslides and erosion patches, which are wide-spread phenomena in mountain grasslands, the potential of close-range sensing is two-fold: Firstly, it could provide accurate reference data for assessing the geometric accuracy of a catchment or regional scale eroded area monitoring based on aerial or satellite remote sensing systems. Secondly, selected sites can be monitored at a very detailed local scale to reveal processes of secondary erosion or natural vegetation succession and slope stabilisation. Furthermore, high-resolution 4D data from multi-temporal close-range sensing make it possible to quantify volumes and rates of displacement at erosion features. In this contribution, we propose to exploit this potential of close-range sensing for landslide and erosion studies with object-based approaches for raster and 3D point cloud analyses. Assuming that erosion features can be discriminated from undisturbed grassland and from trees and shrubs, based on their morphometric and spectral signatures, we show how computer vision and machine learning techniques help to detect and label these features automatically as spatial objects in the data. We combine this object detection and labelling with 2.5D differential elevation models and with 3D deformation analysis of point clouds. This strategy addresses one of the key challenges of automatically analysing close-range sensing data in geomorphological studies, i.e. linking geometric information (such as the size and shape of erosion features or the surface change across a time series) with semantic information (e.g. separating vegetation from complex ground structures). In three case studies from recent projects in the Alps, where we acquired data by UAS, terrestrial laser scanning and terrestrial photogrammetry, we demonstrate the use of these new methodological developments. The methods tested can reliably detect changes with minimum magnitudes of centimetre to decimetre level, depending primarily on the specific data acquisition setup. By automatically relating these changes to erosion features of different scales (i.e. both at entire eroded areas and at their components, e.g. collapsing parts of the scarp), such analyses can provide valuable insights regarding process dynamics. In our tests, close-range sensing and automated data analysis workflows helped to understand both the development of new eroded

areas as well as their enlargement by secondary erosion processes or episodic landslide reactivation. Based on the experience from these case studies, we also discuss the main challenges and limitations of these methods for erosion monitoring applications.