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Landslide displacement vectors derived from multi-temporal topographic LiDAR data

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Information about slope geometry and kinematics of landslides is essential for hazard assessment, monitoring and planning of protection and mitigation measures. Especially for remote and inaccessible slopes, subsurface data (e.g. boreholes, tunnels, investigation adits) are often not available and thus the deformation characteristics must be derived from surface displacement data. In recent years, multi-temporal topographic LiDAR (Light Detection and Ranging) data became an increasingly improved tool for detecting topographic surface deformations. In this context, LiDAR-based change detection is commonly applied for quantifying surface elevation changes. Advanced change detection methods derive displacement vectors with direction and velocities of slope movements. To extract displacement vectors from LiDAR raster data (i) an approach based on feature tracking by image correlation and (ii) an approach based on feature tracking by vectors breaklines are investigated. The image correlation method is based on the IMCORR software (National Snow and Ice Data Center, University of Colorado, Boulder), implemented in a SAGA GIS module. The image correlation algorithm is based on a normalized cross-covariance method. The algorithm searches tie points in two feature rasters derived from a digital surface model acquired at different time stamps. The method assesses automatically the displacement rates and directions of distinct terrain features e.g. displaced mountain ridges or striking boulders. In contrast the vector-based breakline methods require manual selection of tie points. The breaklines are the product of vectorized curvature raster images and extracting the "upper terrain edges" (topographic ridges) and "lower terrain edges" (topographic depressions). Both methods were tested on simulated terrain with determined displacement rates in order to quantify i) the accuracy ii) the minimum detectable movement rates iii) the influence of terrain characteristics iv) the influence of input raster cell size and v) the influence of method parameter settings. Both methods were applied to investigate the development of an active rockslide in high mountain terrain. As a result, both methods yield reasonable data in order to differentiate between landslide areas and stable terrain as well as document the kinematic development of different sub-slabs within the landslide masses (featuring different movement directions and rates). Limitations are given for areas with large displacements and complex bedrock deformation, where automatic feature-tracking lead to wrong correlation results and tie points do not coincide with real displaced features. For complex deformation mechanism only the analysis method based on breaklines and manual tie point identification is suitable for vector extraction. Automated spatial analyses of topographic LiDAR data are a fundamental support to answer a variety of morphological-geological and monitoring questions.