Extending the integrated monitoring of deep-seated landslide activity into the past – preliminary results of the project EMOD-SLAP

JOHANNES BRANKE [1], THOMAS ZIEHER [1 2], JAN PFEIFFER [1 2], MAGNUS BREMER [1 2], MARTIN RUTZINGER [1 2]

Organisation(en):

[1] Institute of Geography, University of Innsbruck;

[2] Institute for Interdisciplinary Mountain Research, Austrian Academy of Sciences

johannes.branke@student.uibk.ac.at, thomas.zieher@oeaw.ac.at, jan.pfeiffer@oeaw.ac.at, magnus.bremer@oeaw.ac.at, martin.rutzinger@oeaw.ac.at

Abstract

The study presents the preliminary results of the project EMOD-SLAP, focused on assessing 3D displacements for the past movement activity of the deep-seated gravitational slope deformation below the Reissenschuh in the Schmirn valley (Tyrol, Austria). Therefore, historical aerial imagery is photogrammetrically processed using free and open-source software. Results show an area-wide 3D displacement of up to 30 m between 1973 and 2010 which corresponds to a mean annual movement rate of 80 cm/a.

In densely populated mountain regions all over the world landslides pose an imminent threat to settlements, infrastructure and agriculture. In recent years several incidents in the Alpine region attest the importance of an area-wide monitoring of the movement of mountain slopes. Particularly continuously moving deep-seated gravitational slope deformations (DSGSDs) have to be monitored carefully because their activity may change differently over several time scales. Especially long-term activity in the order of decades are often unknown since monitoring data are only sparsely or not at all available. Since June 2016, the activity of a DSGSD located below the Reissenschuh summit (2469 m a.s.l.) in the Schmirn valley (Tyrol, Austria) has been monitored using remote sensing and in-situ measurement techniques. Particular attention has been paid to a currently highly active slab of the landslide covering altitudes between 1700 and 2200 m a.s.l.. At lower elevation rock falls and debris flows occur as secondary processes of the DSGSD. Area-wide measurements include terrestrial laser scanning (TLS) and laser scanning based on an unmanned aerial vehicle platform (ULS). Furthermore, the position of observation points has been periodically measured using a differential global navigation satellite system (DGNSS). Based on this four-year time series of remotely sensed and in-situ data, the spatio-temporal activity of the landslide has been analysed in detail. However, up to now the past activity of the landslide remains unknown. In particular, it is unclear whether the landslide's movement rate remained constant in the long-term perspective. In the present study, the activity of the Reissenschuh landslide was re-analysed based on available historical aerial imagery processed with state-of-the-art photogrammetric techniques. Recent advances in photogrammetry and computational capacity allow to re-assess existing historical aerial imagery and to generate 3D point clouds representing the contemporary topography. Due to the computational expensive analyses, a highly automated workflow was developed for all processing steps based on free and open-source software. The workflow for the photogrammetric reconstruction based on the MicMac software tools (Rupnik et al. 2017) has been completed for the image acquisition campaigns in 1973, 2007 and 2010. The imagery includes scanned analogue aerial imagery (1973 and 2007) as well as digital photos (2010), provided by the Federal State of Tyrol, Division of Geoinformation. Further processing steps including the refinement of the georeferencing and scaling of the 3D point clouds based on available airborne laser scanning (ALS) data were conducted using CloudCompare (GNU General Public License). The workflow was automated using scripts written in the Python programming language.

Preliminary Results

With the help of the photogrammetrically reconstructed 3D point clouds, the existing monitoring time series have been extended into the past, allowing to re-analyse the activity of the Reissenschuh landslide. First, the positional uncertainty of the processed photogrammetric point clouds has been evaluated within assumed stable areas, considering an available ALS point cloud (Federal State of Tyrol, Division of Geoinformation) acquired in 2008 as reference. After the fine registration using the iterative closest point algorithm (Besl 1992), the positional uncertainty is less than 0.5 m (root mean squared error). Considering this uncertainty as detection limit for landslide-induced topographic changes, slope movements of at least 0.5 m can be assessed in a robust way. This detection limit corresponds to a mean annual movement rate of 1.4 cm/a. Results based on recently developed techniques for inferring area-wide 3D displacements from point clouds (Pfeiffer et al. 2018) in SAGA-GIS (Conrad et al. 2015) provide evidence for displacements of up to 30 m and even more between 1973 and 2010 (Figure 1). Furthermore, the results show that major parts of the DSGSD above the currently most active part of the slab move slowly at a rate between 2 and 4 cm/a. The currently observed mean annual displacement rates derived from TLS, ULS and DGNSS in the order of 0.9 m/a and the preliminary mean long-term rates (about 30 m within 37 years) are in general agreement for the most active slab. Areas where no information on displacement are either covered by a sparse larch forest (Larix decidua) or (currently) feature a markedly higher movement rate with secondary processes like rock fall (see areas highlighted in Figure 1), both prohibiting a sufficiently robust 3D displacement analysis. However, further analyses are required to get deeper insight into the spatio-temporal activity of the Reissenschuh landslide. The presented preliminary results have shown that based on historical aerial imagery the 3D displacement of DSGSDs of at least 0.5 m on slopes free of high vegetation can be efficiently assessed. Future work will focus on processing the aerial imagery of the first acquisition campaign in 1954 and integrating the photogrammetric point clouds with the recently acquired 3D monitoring data. Furthermore, the established workflow will be tested at further study areas affected by DSGSDs. Finally, the results of the project EMOD-SLAP will help to provide area-wide evidence for the (in)stability of mountain slopes.

Literature

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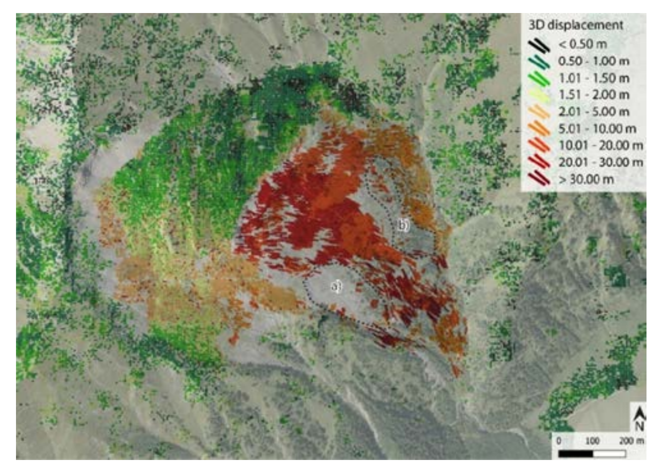

Figure 1: Classified 3D displacement vectors at the Reissenschuh landslide derived from 3D point clouds generated from historical aerial imagery from 1973 and 2010. Areas highlighted by the dotted polygons refer to data gaps related to secondary processes like rock fall (a) and/or high vegetation (b).