EVALUATING SYNERGY EFFECTS OF COMBINED CLOSE-RANGE AND REMOTE SENSING TECHNIQUES FOR THE MONITORING OF A DEEP-SEATED LANDSLIDE (SCHMIRN, AUSTRIA)

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INTRODUCTION

In the recent past, studies on the monitoring of deep-seated landslides included a multitude of measuring techniques. Direct and indirect methods are applied for displacement measurements at points, along lines or area-wise. In particular remote sensing has proven feasible for the detection of displacements featuring a high accuracy (range of cm to dm) while covering the whole area of interest. However, a combination of supplementing methods is preferable to confirm the observations and to overcome their individual drawbacks and limitations. In the present study, displacements of a deep-seated landslide situated in the Schmirn valley (Tyrol, Austria) are assessed by (i) image correlation of existing orthophoto series, (ii) multi-temporal data acquisitions using a terrestrial laser scanner (TLS) and (iii) repeated measurements with the help of a differential global positioning system (DGPS).

OBJECTIVES

The study focuses on evaluating the synergy effects of the tested methods in quantifying the landslide’s movement. Limitations concerning their spatial resolution and accuracy are addressed in specific detail. Altogether, the monitoring techniques shall support each other in order to confirm the observations and to overcome their individual drawbacks and limitations.

STUDY AREA

The Reissenschuh landslide is a deep-seated slope failure located on a south-facing slope in the Schmirn valley, Tyrol (Austria, Fig. 1). It moves in NW-SE direction and extends about 1 km in length and 0.5 km in width at an elevation between 1600 and 2200 m a.s.l. Mean annual rainfall amounts in the Schmirn valley are around 1100 mm with an emphasis in the summer season. The landslide’s substratum is characterized by highly fractured sandstone schists (Penicinum of the Tauern window. In the lower part of the landslide secondary processes (rock fall, debris flows) bear the potential of reaching the valley floor. The upper part of the landslide has been active for at least 65 years, as confirmed by available orthophoto series. The landslide’s activity is likely controlled by hillslope hydrology and its seasonality. Phases of enhanced movement are expected in the course of snowmelt and after exceptional rainfall events.

MATERIALS AND METHODS

Landslide displacements were monitored by means of:

1. Image correlation of available orthophoto series
2. Periodic DGPS measurements
3. Multitemporal LiDAR data

For the period from 2004 to 2015 four orthophoto series are available covering the entire study area. Displacement vectors in subsequent image pairs were derived using the image correlation technique IMCORR (Sambos et al. 1992) implemented in SAGA GIS. For the periodic DGPS measurements, 28 observation points were installed on large blocks located on the active and inactive part of the landslide. The position of the points were repeatedly measured with the Trimble Geo 7X receiver and Zephyr antenna. The measured DGPS positions were corrected in the post processing with data derived from the closest permanent station (SITPOS Sterzing/Vipiteno). The achieved final accuracy is in the order of 0.05 m. A point cloud was acquired by airborne laser scanning (ALS) in August 2008 area-wide. TLS point clouds have been acquired in May 2016 and 5 October 2016 from different scanning positions (Fig. 2a) with a long-range TLS (Riegl VZ 6000) operating with a wavelength of 1064 nm. The individual point clouds include about 300 million points each. To facilitate their registration, five square reflector targets were installed around the active part of the landslide. The IMCORR analyses cover a long time span, but are limited in the spatial resolution and accuracy. LiDAR data are assessed by (i) image correlation of existing orthophoto series, (ii) multi-temporal data acquisitions using a terrestrial laser scanner (TLS) and (iii) repeated measurements with the help of a differential global positioning system (DGPS). The results of the individual techniques can be combined in order to derive spatio-temporal information about the landslide’s activity.

RESULTS – DCGPS MEASUREMENTS

Observation points above the landslide’s crown do not show significant movement larger than the measurement accuracy (Fig. 4a). On the active part, significant displacements in NW-SE direction are evident (Fig. 4b). At one observation point, the DGPS measurements at the two installed marking nails disagree distinctly (observation point in the center of Fig. 4a). It is assumed that these uncertainties can be resolved by further measurements.

RESULTS – ALS & TLS

Comparing the digital terrain models (DTM) derived from the TLS data acquired in 2016 and the ALS data acquired in 2008, the active part of the landslide below the scarp is characterized by a loss in elevation while the lower part shows an increase (Fig. 5a,c). This pattern is less pronounced in the multitemporal TLS data (Fig. 5b,d). Vertical changes within three months of approximately ±10 cm are within the uncertainty of the long-range TLS. However, along the movement direction displacements in the order of 25 cm can be detected by comparing the representation of objects (e.g. blocks, trees and break lines) travelling on top of the landslide (Fig. 7).

RESULTS – IMAGE CORRELATION

The IMCORR results reveal mean annual displacement rates in the order of 0.75 m (a), (ii) uncorrected deviation, 3) Plots of enhanced displacements correspond to areas of higher landslide activity. Preliminary results suggest constant annual displacement rates from 2004 to 2015. However, the inter-annual dynamics of the landslide’s activity cannot be resolved.

CONCLUSIONS

The IMCORR analyses cover a long time span, but are limited in the spatial and temporal resolution. LiDAR data have a high positional accuracy and a fair spatial coverage. However, topographic LiDAR acquisitions are typically conducted in intervals of months to years. DGPS measurements feature the highest accuracy and can be conducted with a high temporal frequency, but cover only selected points in space. In combination, the applied techniques provide complementary information on the spatio-temporal displacement patterns.

Future research will focus on deriving three-dimensional displacement vectors from the multitemporal TLS data (e.g. Egy et al. 2015). Furthermore, displacements will be assessed by detecting, classifying and tracking objects moving with the landslide.