Geophysical Research Abstracts
Vol. 12, EGU2010-11209-3, 2010
EGU General Assembly 2010

Detection of precursory deformation using a TLS. Application to spatial prediction of rockfalls.

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Different applications on the use of Terrestrial Laser Scanner (TLS) on rock slopes are undergoing rapid development, mainly in the characterization of 3D discontinuities and the monitoring of rock slopes. The emphasis of this research is on detection of precursory deformation and its application to spatial prediction of rockfalls. The pilot study area corresponds to the main scarp of an old slide located at Puigcercós (Catalonia, Spain).

3D temporal variations of the terrain were analyzed by comparing sequential TLS datasets. Five areas characterized by centimetric precursory deformations were detected in the study area. Of these deformations, (a) growing deformation across three areas culminated in a rockfall occurrence; and (b) another growing deformation across two areas was detected, making a subsequent rockfall likely. The areas with precursory deformations detected in Puigcercós showed the following characteristics: (a) a sub-vertical fracture delimiting the moving part from the rest of the slope; (b) an increase in the horizontal displacement upwards, typical of a toppling failure mechanism (Muller 1968; Goodman and Bray, 1976). In addition, decimetric-scale rockfalls were observed in the upper part of the moving areas, which is consistent with the observations of Rosser et al., (2007).

TLS ILRIS 3D technical characteristics are as follows: high accuracy (7.2 mm at a range of 50 meters), high angular resolution (e.g. 1 point every few cm), fast data acquisition: 2,500 points/second; broad coverage; high maximum range on natural slopes: $\sim$600m. The single point distances between the surface of reference and the successive data point clouds were computed using a conventional methodology (data vs. reference comparison). The direction of comparison was defined as the normal vector of the rock face at its central part. We focused in the study of the small scale displacements towards the origin of coordinates, which reflect the pre-failure deformation on part of the slope. A nearest neighbour (NN) filtering technique was applied to the RAW datasets (Abellán et al., 2009), enabling the accurate detection of centimetric displacements.

The parameters of the precursory deformation correlated with the failure mechanism, lithology and volume of the rockfall: higher values of length and duration of the precursory deformation were found in the toppling failure mechanism, ductile materials and rockfalls that involved considerable volumes. These results are consistent with observations in the literature regarding rockfalls of higher magnitude and lower frequency (e.g.: Zvelebil and Moser, 2001; Crosta and Agliardi, 2004; Hungr et al., 2007). It is also important to mention that no precursory indicators were detected prior to each rockfall that occurred in the study areas. This could simply be due to infrequent data acquisition or insufficient instrument accuracy.

The application of TLS for the spatial prediction of rockfalls should be validated through: (a) the continuation of the TLS monitoring campaign at the areas which currently show ongoing deformation; (b) the selection of new case studies at different geomorphological sites with different lithologies; and (c) the selection of new case studies with different failure mechanisms (e.g. fall, slide). These tasks are of paramount importance to understand the pre-failure behaviour of rockfalls and to implement these findings in an early warning system.