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Understanding precursory rockfalls along cracks

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Little is known about the characteristics (magnitude, frequency, spatial location, etc) of precursory rockfalls leading to larger failures. In order to better understand this phenomena, we investigated the spatial location of precursory rockfalls and how these events tends to concentrate along the cracks that define the boundaries of the area were a larger failure will took place. Once a certain mass movement has started, the higher stress is concentrated around the limits between the moving and the stables parts of the slope, i.e. the limits between the ongoing rockfall and the rest of the slope. Since natural rock slopes do not allow too much deformation to be produced, the stress on the rock slope surface is expressed in surface by the occurrence of a series of rockfalls along time. Indeed, similar behaviour is observed in other geological events as earthquakes, which distribution is concentrated along the area of higher stress, i.e. along the tectonic plate boundaries.

We carried out a series of experimental tests on an analogue scale sandbox. We reproduced the geometry of a sedimentary natural cliff by using washed quartz sands (grain size < 2 mm Ø), being the verticality of the simulated cliff controlled by the water content (apparent cohesion). We studied slope evolution before, during and after its destabilization. During the experiment, we carried out a series of 3D measurements at a high temporal rate (∼45 sec) using a micro-Lidar (Konica Minolta Vivid 9i), computing the slope evolution (loss and gain of material) by a temporal comparison of 3D datasets. As a result, precursory indicators of larger failures as precursory deformation (see Carrea et al., in this conference) and small scale rockfalls were obtained. In order to automatically detect each precursory rockfall, we developed an algorithm to achieve a highly realistic surface modeling of the rockfall independently of the slope steepness and overhanging features. The method is based on cluster analyses allowing the automatic detection of shaped features not necessarily path connected. The workflow entails three main steps: (a) Features (i.e. clusters) detection and separation from noise using Nearest Neighbour (NN) Clutter Removal in combination with an EM algorithm (NN-EM); (b) Identification of single rockfall carried out by applying a hierarchical clustering function; (c) Volume computation for each rockfall. Once single rockfalls detected and properly identified, we analyzed its spatial location and its spatial proximity to the fracturing system.

Results of our experiment show a concentration of precursory rockfalls along the boundaries of future larger failures. Similar results were obtained in a natural cliff located at Puigcercós (Catalonia, Spain). Testing this method in new natural slopes will allow the creation of alternative early warning systems. Future perspectives include the study of the spatio-temporal evolution of precursory rockfalls and the study of failure prediction using precursory rockfall volumes.