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Using UAV's imagery and LiDAR to accurately monitor Harmalière (France) landslide evolution.

Sylvain Fiolleau (1,3), Laurent Borgniet (2), Denis Jongmans (1), Grégory Bièvre (1), and Guillaume Chambon (3)

(1) Université Grenoble Alpes, ISTerre, Saint Martin d'Hères, France (sylvain.fiolleau@univ-grenoble-alpes.fr), (2) Université Grenoble Alpes, Irstea, UR LESSEM, Saint Martin d'Hères, France, (3) Université Grenoble Alpes, Irstea, UR ETNA, Saint Martin d'Hères, France

Many regions of the world are exposed to landslides in clay deposits, which pose major problems for land management and population safety. The Harmalière landslide, located 30 km south of Grenoble in the French Alps, is an active landslide with reactivations episodes, which exhibits two types of mechanical behavior. In the upper part (head scarp), clay blocks slide along steep surfaces parallel to the headscarp with typical velocities of m/h. That corresponds to an earthslide mechanism according to the classification proposed by Hungr et al. (2014). In contrast, a flow-like mechanism with lowest velocities (m/day) is observed in the disorganized and degraded clayey material located in the central and lower part of the landslide. The understanding of the processes leading to this degradation and progressive solid- fluid transition is of crucial importance for hazard and risk assessment. In late June 2016, the Harmalière clayey landslide was suddenly reactivated at the headscarp after a 35-year long period of continuous but limited activity. Several sensors, including seismometers and GNSS stations, were installed at the rear of the headscarp in early July 2016. Since this event, several smaller reactivations occurred, mostly during winter periods (November 2016, January 2017 and January 2018). This continuous activity encouraged us to install 4 GNSS stations in the landslide for monitoring its kinematics. In addition to this terrestrial monitoring, different remote sensing methods have been applied to characterize the morphological evolution. First, we used aerial LiDAR scans performed before and after the reactivation of 2016, as well as correlations of satellite images over the 2015-2016 period. Then, multi spectral and LiDAR acquisitions were performed using unmanned aerial vehicles (UAV), which offer the advantages of low cost, flexible measurements, multi on-board sensors and frequent coverage. UAV's acquisitions were conducted on the Harmalière landslide from April to November 2018 with an average interval of 1.5 months. Field observations showed that the initial clay blocks are made of two materials (laminated clays and blocky clays) and that these blocks evolve more or less quickly into degraded mounds. This evolution is accompanied by a smoothing of the morphology and the deposition of eroded clay filling the depressions created between the blocks. Using very high-resolution ortho-images and DEMs, we characterize the evolution of the upper part of landslide surface, where the progressive degradation takes place, in terms of morphology and surface material type. Primarily, a first object-based classification was applied in order to extract the bare soil from vegetated and water-covered areas. Then, a second object- based classification was used to retrieve the proportion of the three main identified clay types in the active part of the landslide: laminated clay, blocky clay and filling clay. The comparison between all acquisitions allowed monitoring the evolution of the material types along the landslide. These results are compared to other data sets (moisture, displacement rates) obtained from ground-based and airborne techniques.

Hungr, O., Leroueil, S. & Picarelli, L. (2014) The Varnes classification of landslide types, an update. Landslides, 11, 167–194. doi:10.1007/s10346-013-0436-y