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In situ and remote long term real-time monitoring of a large alpine rockslide

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Large rockslides in alpine valleys can evolve into rock avalanches causing extraordinary hazards where morphological conditions and elements at risk occur. The evolution of these phenomena is controlled by lithological, structural, hydrological and meteo-climatic factors. As a consequence, their activity can be highly variable in time and subjected to acceleration and deceleration periods as a consequence of external factors. Snow melting and heavy rainfall are among the main agents triggering most of the annually recorded displacements in alpine environments. Suitable monitoring data are then required to constrain rockslide kinematics, establish correlations with triggering factors, and predict future displacements, velocities and accelerations, and eventually possible final collapses. Traditional monitoring activities have been based on topographic and ground-based geotechnical techniques. Although extremely useful to understand landslide behavior, these show limitations in terms of spatial description of rockslide displacements and kinematics, network implementation/maintenance, and suitability for early warning. Significant advances in remote sensing during the last decade have provided new opportunities to overcome these limitations. Here we analyze a long term monitoring dataset collected for a large rockslide (Ruinon, Lombardy, Italy). The rockslide (Crosta and Agliardi, 2003; Casagli et al., 2010) consists of a compound movement of about 13 Mm3 of phyllite along deep sliding surfaces, and after decades of activity entered a significant accelerating stage since 1997. Available data result from a ground-based monitoring network (wire extensometer, GPS, and distometric baselines) as well as from remote sensing techniques (PS-InSAR: Permanent Scatterers, GB-InSAR: ground based interferometry, data by ELLEGI-Lisalab) covering a 11-year time period. Ground-based data are densely spread over the rockslide and provide the longer and more continuous time series of displacements. Permanent scatterers data covers a total time window of about 18 years by exploiting different imagery (ERS1-2, Radarsat) and provides information for the slower slope sectors located at higher elevation and externally to the main active area. GB-InSAR measurements span over 5 years and cover about 50% of the rockslide area and a larger upslope sectors, allowing a comparison with PS-InSAR data. We analysed GB-InSAR data (image acquisition interval: about 14 minutes) in the form of multi-temporal maps of cumulative or incremental displacements. These portray displacement and displacement rate fields, and allowed to complete an initial rockslide zonation into homogeneous sub-domains with different displacement magnitudes and patterns. We refined this preliminary zonation through a multi-temporal geomorphological mapping based on photo-interpretation and field observations. Then we set up a virtual monitoring network by selecting about 200 slope locations considered representative of specific kinematic features of the related sub-domains. For each location, we extracted a time series based on about about 5500 images (one every 6 hours). 135 continuous time histories (i.e. covering the entire 5 monitoring years) have been validated against ground truth and analysed, allowing a further rockslide rezoning depending on: cumulative displacement and rate of displacement, sensitivity to and acceleration in consequence of specific meteo-climatic triggering events. In this way, we identified different behaviors for sectors characterized by outcropping bedrock, fine or coarse debris cover, or located close to large open fractures. Based on such spatially-distributed, improved information, we employed different modelling approaches to establish new velocity and displacement threshold for early warning purposes. We also discuss the advantages and limitation f the adopted data and approaches, and the suitability of different descriptors to predict landslide evolution to failure.

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Casagli, N., Catani, F., Del Ventisette, C., Luzi, G. (2010). Monitoring, prediction, and early warning using ground-based radar interferometry. Landslides, 7, 291–301.