

## **Use of statistical analysis of long term displacement rate time series for the definition of Early Warning thresholds. The case studies of the Ruinon and Mont de La Saxe landslides (N Italy)**

Stefano Alberti (1), Giovanni Battista Crosta (1), and Carlo Rivolta (2)

(1) University of Milan-Bicocca, Milan, Italy (s.alberti11@campus.unimib.it), (2) IEllegi s.r.l, Milano, Italy

Rockslides are characterized by complex spatial and temporal evolution. Forecasting their behaviour is a hard task, due to non-linear displacement trends and the significant effects of seasonal or occasional events. The displacement rate and the landslide evolution are influenced by various factors like lithology, structural and hydrological settings, as well as meteo-climatic factors (e.g. snowmelt and rainfall). The nature of the relationships among these factors is clearly non linear, site specific and even specific to each sector that can be individuated within the main landslide mass.

In this contribution, total displacement and displacement rate time series are extracted from Ground-based Interferometric synthetic aperture radar (GB-InSAR) surveys, monitoring of optical targets by total stations, a GPS network and multi-parametric borehole probes. Different Early Warning domains, characterized by different velocity regimes (slow to fast domains) and with different sensitivity to external perturbations (e.g. snowmelt and rainfall), have been identified in previous studies at the two sites.

The Mont de La Saxe rockslide (ca. 8 x 106 m<sup>3</sup>) is located in the Upper Aosta Valley, and it has been intensively monitored since 2009 by the Valle D'Aosta Geological Survey. The Ruinon landslide (ca. 15 x 106 to 20 x 106 m<sup>3</sup>) is located in the Upper Valtellina (Lombardy region) and monitoring data are available starting since 2006 and have been provided by ARPA Lombardia. Both phenomena are alpine deep-seated rockslides characterized by different displacement velocity, from few centimetres to over 1 meter per year, and which have undergone exceptional accelerations during some specific events.

We experiment the use of normal probability plots for the analysis of displacement rates of specific points belonging to different landslide sectors and recorded during almost ten years of monitoring. This analyses allow us to define: (i) values with a specific probability value expressed in terms of percentiles; (ii) values for which a specific change in behaviour is observed which could be associated to a specific type of triggering event (e.g. rainfall intensity, duration or amount; snowmelt amount) . These values could be used to support the choice of threshold values for the management of Early Warning System, by considering also the minimization of false alarms.

The analyses have been performed by using data averaged over different time intervals so to study the effects of noise on the threshold values. Analyses of false alarm triggered by the choice of different threshold values (i.e. different percentiles) have been performed and analysed.

This could be an innovative approach to define velocity thresholds of Early Warning system and to analyse the quantitative data derived from remote sensing monitoring and filed surveys, by linking them to both spatial and temporal changes.