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Integration of ground-based radar interferometry (GB-InSAR) and weather forecasts for real-time monitoring: kinematic evolution and early warning of the Sant'Andrea landslide (Eastern Italian Alps)

Filippo Catani, **Edoardo Carraro**, Antonio Galgaro, and Lorenzo Nava
University of Padova, Department of Geosciences, Padova, Italy (filippo.catani@unipd.it)

Early warning for complex landslides is a difficult task since their evolution could depend on the combination of various predisposing and triggering geological (e.g. rock type, water circulation) and climatic factors (e.g. rainfall, snowmelt). Depending on the type of phenomenon, the temporal evolution of a landslide can be monitored in several ways, from classical to recent advances in remote sensing and in-situ measurements. The potential of real-time monitoring by ground-based radar interferometry (GB-InSAR) is exploited here to improve the understanding of the kinematic evolution of a complex landslide in the Italian Alps. To this end, the integrated use of long-term, spatially distributed GB-InSAR data and of a classical Robotic Total Station (RTS) monitoring is analyzed and discussed for the Sant'Andrea landslide, located in the municipality of Perarolo di Cadore (Belluno, Italy), a rotational slide in heterogeneous materials. Due to the landslide features, the use of these two different techniques is complementary: GB-InSAR measures a continuous field of motion, although along LOS, that is suitable for detecting unstable sectors and quantifying the space-time variations of the kinematics on the entire slope, whereas RTS is able to acquire tridimensional displacement data, very useful to monitor single points and to correctly interpret the GB-InSAR data. The landslide position, just upstream of the village center, represents a relevant hydrogeological risk for the inhabitants. This complex mass movement involves a clay-calcareous debris mass overlying an anhydrite-gypsum dolomitic bedrock. The kinematic activity exhibits an alternation of slow displacements, as long-term creep, and episodic or seasonal accelerations, strongly related to rainfall triggering in response to both heavy and lasting events. Based on the intensity and duration of rainfall, the significant accelerations are followed by a relaxation period with a slow regression of the displacement rate, usually without returning to the previous values.
The analysis carried out by combining the mapping of 3D point-based displacements and LOS surface velocity fields allows distinguishing mechanisms and sensitivity of the landslide sectors to rainfall inputs, as well as to understand the wide range of mechanical behaviors shown by the slope during the monitoring period. Such information aims to quantitatively evaluate the trigger-response signals to rainfall events to predict accelerating trends of the landslide displacements as well as possible failures. The proposed monitoring and modelling framework will be soon implemented in an operational early warning procedure using real-time, high-frequency GB-InSAR data together with RTS and weather forecasts, in accordance with local authorities of Civil

Protection.