Long-term electrical resistivity data analysis for landslide monitoring: the case study of Rosano

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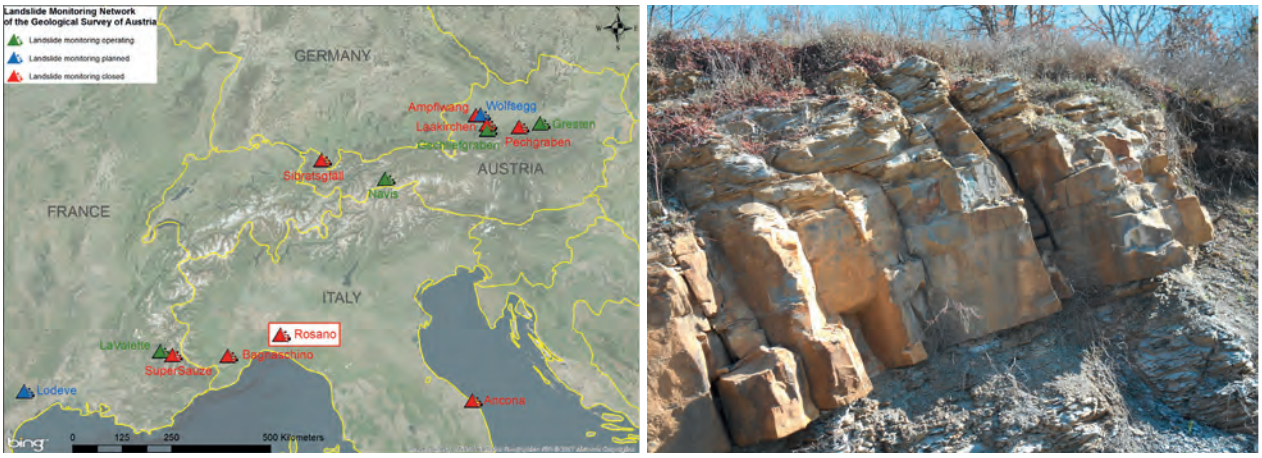
In the context of landslide monitoring, an integrated approach of several techniques is necessary to understand the mechanisms that control slope stability. Among the traditional monitoring techniques, the geoelectrical methods are currently employed for the investigation of the landslide body by means of high spatial resolution tomographic imaging. Temporal variations of the electrical resistivity can be correlated to changes in soil water content: modifications of slope saturation conditions are one of the most common precursors to landslide reactivation. This Master thesis presents and analyses the results of three years of monitoring data from a landslide in Rosano (44.662453 N, 9.104703 E, north-western Italy, Text-Fig. 1), collected with the GEOMON4D system, a geoelectrical permanent monitoring system developed by the Geological Survey of Austria (Guardiani, 2016).

The landslide reactivated in December 2004 due to heavy rainfall events and signs of structural failure on rural buildings were reported by the inhabitants of the hamlet. The elements at risk are the settlements in Rosano, which are located in two sectors that can be regarded as two geomorphological steps of the slope. This composite landslide has a general dynamic behaviour that can be regarded as a slow earthflow susceptible to intense and prolonged precipitations. The geological setting is quite heterogeneous: landslide debris covers a sequence of alternated layers of clayey-silt overburdens and calcareous rocks with different grades of alteration.

Electrical resistivity measurements were performed from July 2012 until April 2015 along a geoelectrical profile comprising 93 stainless steel electrodes, buried at a depth of approximately half meter and with a spacing of 2.5 m, for a total length of 230 m (Text-Fig. 2). One set of data includes 4,300 gradient-type measurements, which enables to achieve a good resolution of the tomographic images of the subsurface. The apparent resistivity data have been processed with two different approaches: 2D tomographic inversion for independent time-step processing and a 4D algorithm producing a time-space model of the electrical resistivity that is allowed to change continuously over time (Kim et al., 2009, developed within the cooperation between the GBA and the



Text-Fig. 1.
On the left side, the geoelectrical monitoring network of the Geological Survey of Austria (GBA) and location of Rosano (Bing maps); on the right, limestone formation outcropping along SP40 road in Cabella Ligure.

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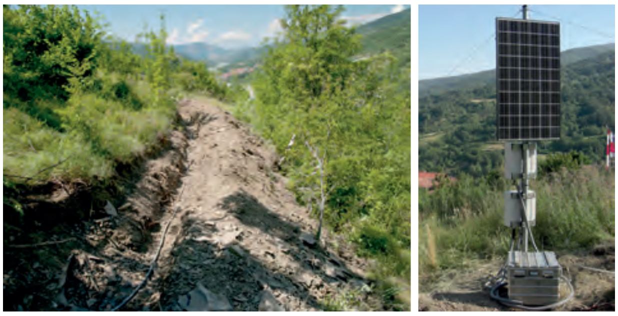

Text-Fig. 2.
Installation of the geoelectrical profile (left side); solar panel and methanol fuel cell (right side).

Korea Institute of Geoscience and Mineral Resources, KIGAM). The former method has been applied to the entire monitoring period and the comparison of Electrical Resistivity Tomography (ERT) results over time produced long-term electrical resistivity variations time series. Differencing 2D inversion results enabled to identify a clear dependence between the electrical response of the shallow subsurface and precipitation, with a significant decrease occurring within the shallow layers due to the saturation of the slope.

Then, the inversion processing was conducted with the 4D inversion algorithm, providing a space-time resistivity model that is allowed to change continuously over time. This method was used to analyse resistivity variations in a short-time scale, taking into account major intense rainfall events (Text-Fig. 3). This type of processing proved to be more representative of the spatial distribution of resistivity variations and thus more suitable for the interpretation of change in water content. Data filtering based on the raw signals (i.e. forward and backward current, signal-to-noise ratio) and electrode status assessment provided significant improvements to inversion results, by lowering the RMS error and reducing artefacts.

Acknowledgements

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Text-Fig. 3.
On the left, distribution of electrical resistivity in the subsurface [Ωm]:
(a) distribution of resistivity ratios ρt/ρ0 [-], (b, c) ERT images are compared to the reference time (a). On the right, graphic of hourly precipitation (turquoise) and 4D inverted resistivity time series at different depths.