Advanced Criteria and Techniques for Landslide Monitoring

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AMRA is developing two main tasks about landslide monitoring, which respectively concern advanced criteria (geoindicators) to be used within early warning systems of rainfall-induced flowslides (WP 4.3) and remote sensing techniques (WP 4.2).

Geoindicators

The interest for early warning takes its origin from the high rainfall-induced landslide hazard which affects extensive areas in Campania, Southern Italy, where debris flows can take place along steep slopes covered by shallow unsaturated deposits of loose granular pyroclastic soils. The great extent of zones susceptible to debris flow makes the adoption everywhere of structural works for slope stabilization practically impossible. So, the development of innovative procedures for timely landslide alerting is an emerging idea. This requires, as a first step, the understanding of the hydro-mechanical processes which lead to slope failure, and, as a second step, the study of the precursors and of the indicators of impending failure to be monitored and evaluated in real time.

Such a study is being carried out through physical modelling and monitoring of instrumented slopes. The physical model consists of a heavy instrumented flume, purposely designed and built to reproduce precipitation-induced slope failure in unsaturated soils, by imposing an artificial rainfall. Several sensors allow the observation of the soil behaviour, i.e.:
i) miniaturized tensiometers, to monitor matric suction; ii) minitransducers located at the bottom of the slope, to measure positive pore pressures; iii) laser sensors to record settlements of the soil surface; iv) video-cameras to investigate the displacement field prior and after slope failure.

The experiments show that slope failure in loose soils is announced by large volumetric strain and by the formation of large cracks in the source area. Also, if the slope angle is close to the friction angle of soil, failure occurs only when a condition of full saturation is reached. Thus, both soil deformation and water content changes can be used as indicators of impending failure. Starting from these considerations, a new experimental program is going on in order to test optical fibres and TDR sensors to be used in situ as geoindicators. Optical fibres are stimulated by two counterpropagating light-waves, whose interaction causes a power transfer which, in turn, depends on fibre temperature and strain. Although Time Domain Reflectometry technique for the measurement of the average soil moisture is well known, we are actually adopting an inverse procedure to retrieve the moisture profile along the entire probe. Such a technique seems promising since the thickness of the covers subjected to debris flows in source areas is generally quite thin, ranging between some decimetres and almost a few metres, and so the water content along the entire thickness of the soil can be estimated by a single probe.

We are testing both devices in the flume. The geometry of the slope and position of the adopted devices are illustrated in Figure 1: two strands of optical fibres, running the length of the slope, are buried in the soil. The two strands are separated by a fiber spoil of some tens of meters, placed outside the soil and not subjected to strain. The TDR is placed normal to the ground surface and can capture the entire profile of the water content within the layer.

TDR robes have been installed in an instrumented slope just aside the Cervinara landslide (1999) and in another slope (Monteforte Irpino) along the highway linking Naples and Avellino. The availability of rainfall data, which is monitored by a rain gauge and of suction, which is measured by a number of tensiometers will allow to assess the usefulness of the proposed approach in real cases.

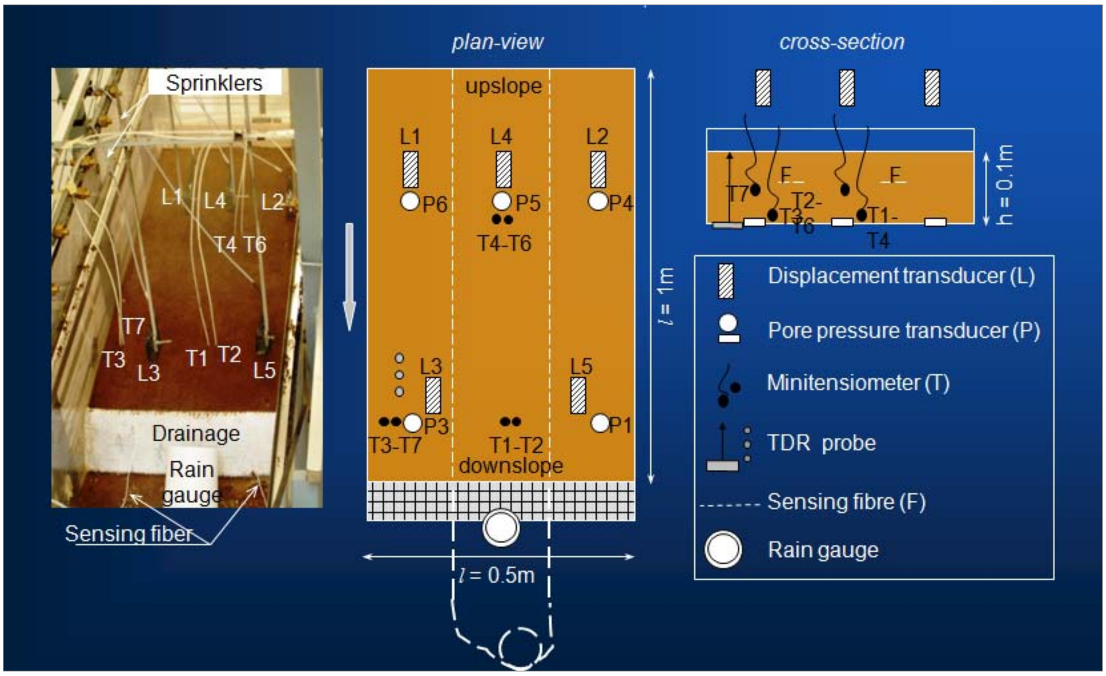

Fig. 1: Assessment of new devices for early warning of rainfall-induced flowslides.

Remote Sensing

The second part of the presentation in Vienna has dealt with remote sensing techniques for landslide monitoring. AMRA has first of all provided a contribution to the review of the so-called Advanced-DInSAR (A-DInSAR) techniques, i.e. the techniques that, allow monitoring of ground deformations by using multiple passes of the satellite SAR sensors. Such techniques are grouped in two classes: the Interferogram Stacking Techniques and the Persistent Scatterer Interferometry (PSI). The AMRA review activity has concerned the Interferogram Stacking Techniques, which have been originally designed for monitoring at a low resolution scale of scenes characterized by a distributed scattering. These techniques are complementary to the Persistent Scattering Interferometry techniques, which model the ground scattering and carry out only a highest scale analysis. Nonetheless, additional modules, such as the high resolution Small BAseline Subset (SBAS) and the Tomographic analysis, use the low resolution products for the calibration of the data and for the generation of DinSAR products at the highest resolution. An example of full resolution tomographic analysis is given in Figure 2a, which shows the radar points overlaid on the Google image in the area of Viale Giustiniano Imperatore in Rome: serious building damages were reported in the past and the deformation area associated with the red pixels is located on a recent alluvial deposit area due to the Tevere River. Figure 2b, on the other hand, shows an example of low resolution analysis performed on an area in Nevada of 60,000 km^2. Another contribution provided by AMRA in cooperation with the University of Salerno has regarded the analysis of already available DInSAR results relevant to the ERS-1 and ERS-2 satellite descending passes over the test site "Liri Garigliano Volturno Basin in Central Italy" (test site 33). In particular, we have investigated the issue of radar visibility of areas affected by landslides, which may be impaired by the presence of slopes. Typically, landslides are visible only on one of the pass classes: ascending (i.e. the radar line of sight toward east) and descending (i.e. the radar line of sight toward west). A-priori visibility maps allow to investigate, the visibility of the areas on the ground, thus providing useful indications for the choice of the dataset. Radar interferometry only allows measuring a scalar component of the displacement: i.e. the component of the displacement along the radar line of sight. We have also analyzed the possibility to integrate radar measurements and displacement models to allow improving the interpretation of DInSAR results (for instance evaluating the translational displacement).

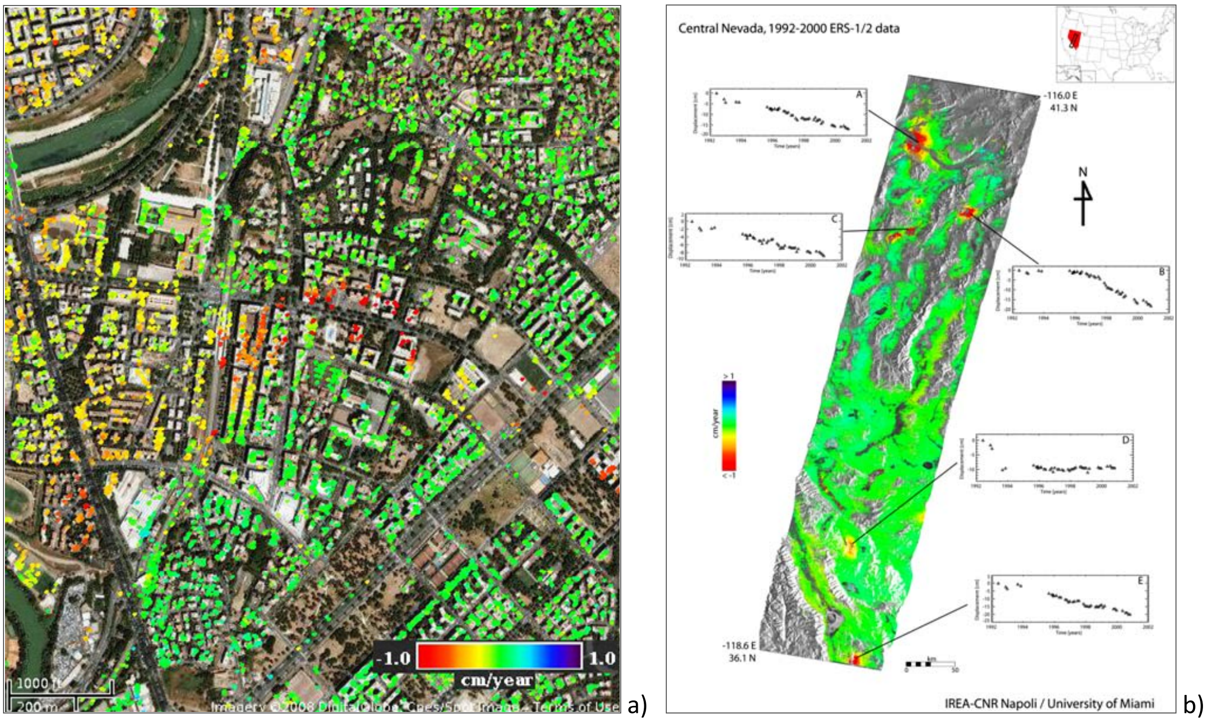

Fig. 2: Examples of tomographic analyses: a) full resolution; b) low resolution (IEEE Copyright).

References

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