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Detection of premonitory slow ground deformations on landslide-prone slopes through GPS and DInSAR techniques: a case study from Italy

J. Wasowski (1), M. Sorgente (1), M. Savio (2), Lollino G. (3), F. Godone (3), V. Del Gaudio (4), F. Bovenga (5), M. Baldo (3)

(1) CNR - IRPI, Bari - Italy; (2) Universidad Nacional de Catamarca - Argentina; (3) CNR - IRPI, Torino - Italy; (4) Dipartimento di Geologia e Geofisica, Università di Bari - Italy; Dipartimento di Fisica, Università di Bari - Italy

High precision surveying is required for the detection of very slow ground deformations that could represent premonitory signs of potential future slope failures. Although both GPS (Global Positioning Systems) and satellite-borne Differential Synthetic Aperture Radar Interferometry (DInSAR) can provide precise measurements of ground surface displacements, there are still very few examples of a joint use of GPS and DInSAR in landslide-prone areas. More comparative studies seem necessary to verify the capability of high precision GPS surveying to validate slope surface displacements measured with millimetric precision by DInSAR and to assess the practical applicability of these techniques for detecting pre-failure deformations. This work presents the outcomes of high precision GPS measurements employed to detect and monitor the instability of peri-urban slopes in a town located in the central Apennine mountains. The local slopes are characterised by the variable nature of the lithostratigraphy and groundwater conditions and the high temporal and spatial frequency of mass movements. In case of such complex, marginally stable peri-urban slopes, monitoring aimed at periodical detection of ground surface displacements and strains can be especially valuable for early warning purposes. A local GPS monitoring network was installed in 2002 just upslope the most landslide-prone terrain. The network consists of three reference (base) stations established in nearly flat, apparently stable ground areas and 13 measurement points. Most of the measurement points were strategically sited in the head and crown areas of recently active, potentially damaging landslides, i.e. those involving or located close to buildings, roads and other town's

infrastructures. Leica GPS System 500 equipment was used for surveying. Leica Ski-Pro Software as well as the Bernese GPS Software Version 4.2. were applied for post-processing, producing very similar results for the planimetric coordinates. The tests with an observation period of one hour indicate the measured formal error in a range of 3-5 mm in horizontal. The estimated precision (repeatability) of the measurements of baseline vectors between the reference stations is within 6 mm in horizontal and 15 mm in vertical; this estimate is derived from the results of 10 distinctive surveys, each with several hour observation time. The precision achieved in this study suggests that periodic GPS surveys will seldom be sufficient to truly (quantitatively) validate the very slow surface deformations measured by DInSAR, especially considering that the Line of Sight (LOS) geometry of the currently available radar platforms is most sensitive to vertical displacements, and that in the majority of landslides the horizontal components of motion exceed the vertical displacements. Both monitoring techniques, however, can usefully complement each other in that, unlike GPS, DInSAR offers a very high precision for the measurements of vertical displacements. In the case studied, the DInSAR approach revealed the general stability of the urban center, but no useful information was obtained for the most landslide-prone peri-urban slopes because of the relative scarcity of suitable radar targets there. The results gathered during six GPS surveys conducted in the period May 2002 - January 2005 show that the baseline vectors change mainly in the general direction of mass movements. Seven out of 13 measurement points indicated very slow (from 1.5 to over 4.4 cm/yr), but significant and consistently progressive displacements. Although in short term such low rate displacements can be acceptable, the three fastest moving points are located within an urbanised area just upslope two intermittently active landslides. Therefore, for preventive purposes it would be useful to continue periodic GPS controls at least in the slope situations that exhibit higher rates of deformations.

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