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Developing a Landslide Early Warning System based on satellite measurements

L. Guerriero (1), F. Bovenga (1), R. Nutricato (1), J. Wasowski (2), D. Casarano (2), P. Gostelow (2), V. Del Gaudio (3), P. Blonda (4), A. Refice (4),

(1) Dipartimento Iterateneo di Fisica, Università / Politecnico di Bari, Italy, (2) CNR-IRPI Sezione Bari, Italy, (3) Osservatorio Sismologico Università di Bari, Bari, Italy, (4) CNR-ISSIA Sezione Bari, Italy

(fabio.bovenga@ba.infn.it / Fax: 0039 0805443144 / Phone: 0039 0805442396)

This contribution presents some results of LEWIS (Landslide Early Warning Integrated System) project supported by the European Commission and concluded in 2005. The prime objective of the proposed research was to develop an approach which increases and promotes the value of comparatively low-cost, wide-area satellite data as an input to the assessment of hazard and risk from ground movements.

The key element in the LEWIS project is to avoid trying to infer absolute values of relevant geophysical parameters from Earth Observation (EO) data, but only their changes in time in the wider sense of “deviations from a known temporal evolution model”. Other periodic information can be obtained from existing ground networks, e.g. for rain and earthquakes. The detected changes have to be integrated into a Geographic Information System (GIS), together with other more static parameters, and used to infer potential slope stability changes and to produce early warning. The output product of the LEWIS project can be defined as an updateable slope instability susceptibility map, based on changes detected from moderate resolution EO data.The approach has been based on the well known principle that either an increase of shear stresses and/or the decrease of effective material shear strengths over a period of time are the primary cause of increasing susceptibilities to slope instability, thus contributing to first-time failures or reactivated movements on pre-existing slip surfaces.

The complementary expertise of the geologic and the Earth observation components of the project team allowed to define a geotechnical model suitable for the spatial/temporal resolution and for the precision of the EO change measurements. The geotechnical inference model firstly uses GIS topographic and geological ground data (a slope map derived from a Digital Elevation Model, a previous landslide map, a description of the lithological classification distinguishing between soil and rocks, and a brittleness index, reflecting the stress-strain behaviour of the engineering soils) to identify potential levels of susceptibility to deformation in slopes which are close to a factor of safety of 1.0, i.e. they are susceptible to mass movement. Secondly it integrates land use change maps derived by EO data to show levels of warning with respect to that deformation. The methodology used for the production of the land use change maps is based on advanced artificial intelligence techniques, i.e. neural networks classifiers and fuzzy logic and it follows three different approaches to change detection: a supervised approach, an unsupervised approach and a hybrid approach.

SAR Interferometry techniques based on Persistent Scatterers (PS) approach are used to give a warning signal through the detection of precursory movements, which may give rise to conditions leading to landslides, since the PS-detected slow ground deformations can indicate ongoing ground instability. After in situ validation the PS data indicative of movements at an average velocity equal or greater than 3 mm/year, can be added to the change-based model output in the warning map as a direct indicator of potential instability. The stable PS can also be taken into account and interpreted as signals that strongly indicate areas of ground stability.

The final result of the LEWIS project is a working prototype of a landslide early warning system, designed to cover regional areas. The prototype has been validated with encouraging results on two Italian test sites originally selected for the experiment. The verification of the approach on a third test site, in Greece, is still under way.

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