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Integrated landslide monitoring for early warning based on innovative technologies: evaluation of results from the SafeLand/TEMPEL network of test site in Europe

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Landslides are one of the major natural threats to human lives, settlements and infrastructure, causing enormous human suffering and property losses. The best way to restrain such high losses on property and lives is through effective land-use planning, based especially on a good knowledge of the landslide susceptibility, hazard and risk within specific areas as a part of mitigation. However, this ideal approach is, due to several natural, historical or political reasons in many places impossible. E.g., many human settlements and infrastructure lines had been built in landslide-prone areas or on dormant landslide bodies decades before the establishment of detailed hazard zone maps. In most cases it is not possible to resettle people living in such areas. Consequently it is the goal of stakeholders to guarantee a safe daily life of the people concerned. A good knowledge about structure, dynamics, triggers, history and possible magnitude of such high-risk landslides is an important task to be able to evaluate actual hazard and, eventually, to alert people before a catastrophic event in advance. This knowledge is obtainable only through a complex approach consisting of investigations by many different interdisciplinary methods and techniques, long-time continuous monitoring of deformation and triggering factors and by establishing early warning systems/centers. The most commonly used early warning parameters are pore water pressure and displacement. However recent research has shown that other parameters exist, which might give indications on impending triggering even a longer time before an actual displacement is measurable on the landslide surface. Since most of the European landslide events are intimately related to precipitation and to influence of underground water on slope stability (pore-water pressure, change of water flow regime, saturation), registering temporal changes of the geoelectric parameters seems to be a promising method for monitoring of landslides. Therefore research was started to evaluate temporal changes of geoelectrical properties of the subsurface as possible indicators of future failure of high risk landslides; such additional indicators would be beneficial to any effective early warning system. With geoelectric investigations it is possible to determine the distribution of the specific electrical resistivity of the subsurface, which mainly depends on porosity, water saturation, conductivity of pore fluid and clay content. Other geoelectric parameters, promising progress in landslide monitoring, could be derived from self potential (SP) and induced polarisation (IP) measurements. Since hardly any time series of permanent geoelectric, displacement and hydrological monitoring data coupled together exist for different types of landslides, several long-periodic monitoring experiments were started within the projects SafeLand (FP7) and TEMPEL (Austrian Science Found) at several landslides of different types. At the test sites of Gschlifgraben (A), Bagnaschino (I), Hausruck (A), Rosano (I) and Ancona (I) innovative permanent geoelectric monitoring (using the Geomon4D tool) and high resolution displacement monitoring using the DMS device (differential monitoring of stability, patents CSG S.r.l, Italy), high resolution automatic in place inclinometer columns, were applied together with other traditional parameter in frame of actual early warning projects. Additionally complex structural investigation (remote sensing, airborne and ground geophysics) were performed to investigate the underlying triggering processes. A preliminary comparative evaluation of the results coming from these test sites will be presented. The outcome clearly highlights the potential capabilities of geoelectrics as a pre-alarm parameter, which, in combination with DMS and precipitation monitoring, could result in an effective sensor platform for early warning systems for landslides.