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Multi-scale and global monitoring strategy for early-warning systems applied to ground failure hazards

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Ground failures related to underground cavity collapses and mass wasting result from the conjunction of multiple physical factors and interactions that lead eventually to the catastrophe.

However, in spite of the unpredictability of such events in time, the main factors involved at different scales and stages – both in time and space domains - are largely documented at least on a qualitative basis. Hence, they are geologic, geomorphic, geomechanical, hydrologic, environmental and human factors that may play some important roles. Quite often consequences and impact of the considered geohazard on public safety and vulnerable stakes are not always certain although domino effects are nowadays evaluated as far as possible.

Considering the empirical approach currently used in the risk assessment studies due to the inherent lack of accurate data, i.e. 1- the uncertainty of the mechanisms which prepare and trigger ground failures, 2- the uncertainty of the amplitude of the event 3- the uncertainty of induced effects, all these call clearly for a multi-parameter and global monitoring strategy.

Multi-parameter monitoring means that the setting-up of an early-warning device towards an identified ground failure hazard requires to monitor very heterogeneous and distant physical variables, ranging from water table level in an observation borehole at foothill to GPS monitoring uphill, passing by seismic ground shaking. State-of-the-art early warning systems must then be able to handle such a variety of measurements, related to both multi-frequency, transient and quasi-static, phenomena as well, and measured each of them at the right place. A multi-parameter approach leads to the definition and use of vigilance and alarm variables depending on the physical role of each of the measurement considered.

Global monitoring means monitoring of precursory mechanisms, ground failure itself as well as response of the stakes and potential aftermaths. All three of them provide the most coherent approach for both experts and decision makers. Stakes are all the more important to monitor as its partial or total alteration may be at the origin of a new induced risk.

It is clear that the design of multi-parameter and global monitoring systems calls for a specific clustered architecture of acquisition units including a « local server » featuring local network and links to central site capabilities.

The tracking of specific vigilance and alarm variables on each of the connected acquisition units has only a full sense when it is exploited automatically and immediately by the overall clustered system itself for triggering acquisition at the right time, adjusting smartly the measurement acquisition frequencies on all or selective part of the sensors as well as the transmission priorities of data towards a central site.

In order to meet the requirements of global and multi-parameter monitoring, INERIS designs and develops early-warning systems for optimally respond to the specific problems of geological hazards and large scale ground failures. These systems are based on two complementary and modular software and hardware platforms namely SYTGEO and SYTMIS.

The platform of SYTGEO tools is dedicated to active and quasi-static (period $>$ a few seconds) geotechnical measurements of stresses, strains, displacements, tilts, water levels, pressure, as well as meteorological and differential GPS measurements. Sensors are connected to nearby receivers for digitisation, ensuring high quality of data. Receivers are cabled and/or radio linked to one or several acquisition unit in charge of supervising, collecting and transmitting information and data.

Acquisition unit integrates an auto-adaptative strategy of data acquisition rate locked on the progression of the monitored phenomenon. Acquisition rate is automatically adapted in acceleration, or even in a continuous mode, so as to provide close tracking of the physics. The data transmission rate towards a central site is also adjusted automatically, thereby providing an early trigger of the warning or vigilance procedures. This overall scheme may also be triggered by transient input data coming from stress waves signals.

The SYTMIS platform is dedicated to passive monitoring of seismicity, microseismicity, acoustic events and pressure waves depending on the nature and scale of the relevant phenomena and type of sensors used. In the former case, interest is focused generally on the strong motion as a worsening or triggering factor. Nowadays local microseismic arrays are used for many applications related to underground risks and geostructural monitoring. This provides unique information on the progress of the instability phenomenon over time.

Considering the permanent bandwidth required for continuous high rate recording and digitisation, transient signals are directly connected to the acquisition unit. Once recorded waveforms are stored, partially processed and files are transmitted to a central site on a real-time or scheduled basis for further on-line processing.

Smart coupling of passive and active monitoring processes, through clustered and radio linked acquisition units, provide an architecture with great flexibility for field layout, with minimum compromise on the engineering design and clear cuts in installation costs, while the transmission of dataflow and alarms to a central site may be achieved by a unique high speed secured internet connection via the server acquisition unit, based on a mobile network if need be.

Facing the field situation of a geohazard to be monitored raises quite often difficult issues, ranging from the uncertainties and expectations of the expert responsible for following up the data flow versus time, and from the decision makers in terms of inherent economical constraints linked to the installation and the monitoring period. Nevertheless a strategy thought globally from the very early design and based on state-of-the-art technologies is clearly valuable, in a general societal environment where geohazards and scientific uncertainties have less and less social acceptance. Reciprocally, integration of new technological capabilities and performances has a direct structuring influence on the design and quality of the alarm device, upstream, as well as on the warning procedures managed downstream; the latter proving to be simpler for specialists and managers and therefore optimising the decision-making process when handling a crisis.