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Birth, growth and progresses through the last twelve years of a regional scale landslide warning system

Riccardo Fanti, Samuele Segoni, Ascanio Rosi, Daniela Lagomarsino, and Filippo Catani
Earth Sciences Department, University of Firenze, Italy

SIGMA is a regional landslide warning system that operates in the Emilia Romagna region (Italy). In this work, we depict its birth and the continuous development process, still ongoing, after over a decade of operational employ.
Traditionally, landslide rainfall thresholds are defined by the empirical correspondence between a rainfall database and a landslide database. However, in the early stages of the research, a complete catalogue of dated landslides was not available. Therefore, the prototypal version of SIGMA was based on rainfall thresholds defined by means of a statistical analysis performed over the rainfall time series.
SIGMA was purposely designed to take into account both shallow and deep seated landslides and it was based on the hypothesis that anomalous or extreme values of accumulated rainfall are responsible for landslide triggering. The statistical distribution of the rainfall series was analyzed, and multiples of the standard deviation (σ) were used as thresholds to discriminate between ordinary and extraordinary rainfall events. In the warning system, the measured and the forecasted rainfall are compared with these thresholds. Since the response of slope stability to rainfall may be complex, SIGMA is based on a decision algorithm aimed at identifying short but exceptionally intense rainfalls and mild but exceptionally prolonged rains: while the former are commonly associated with shallow landslides, the latter are mainly associated with deep-seated landslides. In the first case, the rainfall threshold is defined by high σ values and short durations (i.e. a few days); in the second case, σ values are lower but the decision algorithm checks long durations (i.e. some months). The exact definition of “high” and ”low” σ values and of “short” and “long” duration varied through time according as it was adjusted during the evolution of the model.
Indeed, since 2005, a constant work was carried out to gather and organize newly available data (rainfall recordings and landslides occurred) and to use them to define more robust relationships between rainfalls and landslide triggering, with the final aim to increase the forecasting effectiveness of the warning system.
The updated rainfall and landslide database were used to periodically perform a quantitative validation and to analyze the errors affecting the system forecasts. The errors characterization was used to implement a continuous process of updating and modification of SIGMA, that included:
- Main model upgrades (generalization from a pilot test site to the whole Emilia Romagna region; calibration against well documented landslide events to define specific σ levels for each territorial units; definition of different alert levels according to the number of expected
- Ordinary updates (periodically, the new landslide and rainfall data were used to re-calibrate the thresholds, taking into account a more robust sample).
- Model tuning (set up of the optimal version of the decisional algorithm, including different definitions of “long” and “short” periods; selection of the optimal reference rain gauge for each Territorial Unit; modification of the boundaries of some territorial
- Additional features (definition of a module that takes into account the effect of snow melt and snow accumulation; coupling with a landslide susceptibility model to improve the spatial accuracy of the model).
- Various performance tests (including the comparison with alternate versions of SIGMA or with thresholds based on rainfall intensity and duration).
This process has led to an evolution of the warning system and to a documented improvement of its forecasting effectiveness.
Landslide forecasting at regional scale is a very complex task, but as time passes by and with the systematic gathering of new substantial data and the continuous progresses of research, uncertainties can be progressively reduced and a warning system can be set that increases its performances and reliability with time.