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SIGMA: an operational warning system for the forecasting of landslide occurrence

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This work presents the results of a research co-funded by the Civil protection Agency of the Emilia Romagna Region, during which an operative regional scale warning system was developed for the management of the risk related to rainfall induced landslides (both shallow and deep seated). The model is named SIGMA (Sistema Integrato Gestione Monitoraggio Allerta, "Integrated service for the managing and monitoring of the alert").
The operative system for landslides early warning is currently based on the division of the regional territory into eight districts, called alert zones: each alert zone is divided into several territorial units (TU), defined on the basis of different physiographic and environmental features. For each TU a reference rain gauge is selected: its historical daily recordings were collected and used to build the time series of rainfall cumulates from 1 to 243 days.
The decisional algorithm at the core of the model is based on the comparison between rainfall recordings and statistically defined thresholds based on the total amount of rainfall. Assuming that anomalous or extreme values of rainfall are responsible for landslides triggering, in the proposed model the statistical distribution of the cumulative rainfall series is analyzed, and multiples of the standard deviation (σ) are used as thresholds to provide a level of criticality for each TU, using the four alert levels adopted in the civil protection procedure: "absent", "ordinary", "moderate" and "high". The thresholds were calibrated using a database of past geo-registered and dated landslides: an optimization algorithm identifies the σ curves that minimize the occurrence of the threshold overcoming in days for which landslides were not reported, without affecting the number of correctly detected landslides.
To consider different types of movement the method takes into account two different periods of cumulative rainfall: daily checks of one, two and three cumulative rainfall days (short period) are aimed at detecting shallow landslides; a series of daily checks over a longer time window (ranging from 4 to 243 days) is instead aimed at detecting deep seated landslides in low-permeability terrains.
For each reference rain-gauge a software combines rainfall recordings from the regional automated network with rainfall forecasts and compares the resulting cumulative rainfalls with the thresholds. In the territorial units where the latter are exceeded, the software provides the corresponding alert level. The results registered in the territorial units belonging to the same alert zone are then collected and combined to provide a criticality level for the whole alert zone, as requested by civil protection procedures. The method, as well as the results obtained, are discussed.