Geophysical Research Abstracts
Vol. 17, EGU2015-3399-1, 2015
EGU General Assembly 2015

Validation and evaluation of epistemic uncertainty in rainfall thresholds for regional scale landslide forecasting

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Prediction of rainfall-induced landslides can rely on empirical rainfall thresholds. These are obtained from the analysis of past rainfall events that have (or have not) resulted in slope failures. Accurate prediction requires reliable thresholds, which need to be validated before their use in operational landslide warning systems. Despite the clear relevance of validation, only a few studies have addressed the problem, and have proposed and tested robust validation procedures.

We propose a validation procedure that allows for the definition of optimal thresholds for early warning purposes. The validation is based on contingency table, skill scores, and receiver operating characteristic (ROC) analysis. To establish the optimal threshold, which maximizes the correct landslide predictions and minimizes the incorrect predictions, we propose an index that results from the linear combination of three weighted skill scores. Selection of the optimal threshold depends on the scope and the operational characteristics of the early warning system. The choice is made by selecting appropriately the weights, and by searching for the optimal (maximum) value of the index. We discuss weakness in the validation procedure caused by the inherent lack of information (epistemic uncertainty) on landslide occurrence typical of large study areas. When working at the regional scale, landslides may have occurred and may have not been reported. This results in biases and variations in the contingencies and the skill scores. We introduce two parameters to represent the unknown proportion of rainfall events (above and below the threshold) for which landslides occurred and went unreported. We show that even a very small underestimation in the number of landslides can result in a significant decrease in the performance of a threshold measured by the skill scores. We show that the variations in the skill scores are different for different uncertainty of events above or below the threshold. This has consequences in the ROC analysis.

We applied the proposed procedure to a catalogue of rainfall conditions that have resulted in landslides, and to a set of rainfall events that – presumably – have not resulted in landslides, in Sicily, in the period 2002-2012. First, we determined regional event duration–cumulated event (ED) rainfall thresholds for shallow landslide occurrence using 200 rainfall conditions that have resulted in 223 shallow landslides in Sicily in the period 2002-2011. Next, we validated the thresholds using 29 rainfall conditions that have triggered 42 shallow landslides in Sicily in 2012, and 1250 rainfall events that presumably have not resulted in landslides in the same year. We performed a back analysis simulating the use of the thresholds in a hypothetical landslide warning system operating in 2012.