Geophysical Research Abstracts
Vol. 18, EGU2016-13126, 2016
EGU General Assembly 2016
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Performance analysis of landslide early warning systems at regional scale: the EDuMaP method

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Landslide early warning systems (LEWSs) reduce landslide risk by disseminating timely and meaningful warnings when the level of risk is judged intolerably high. Two categories of LEWSs, can be defined on the basis of their scale of analysis: "local" systems and "regional" systems. LEWSs at regional scale (ReLEWSs) are used to assess the probability of occurrence of landslides over appropriately-defined homogeneous warning zones of relevant extension, typically through the prediction and monitoring of meteorological variables, in order to give generalized warnings to the public. Despite many studies on ReLEWSs, no standard requirements exist for assessing their performance. Empirical evaluations are often carried out by simply analysing the time frames during which significant high-consequence landslides occurred in the test area. Alternatively, the performance evaluation is based on 2x2 contingency tables computed for the joint frequency distribution of landslides and alerts, both considered as dichotomous variables. In all these cases, model performance is assessed neglecting some important aspects which are peculiar to ReLEWSs, among which: the possible occurrence of multiple landslides in the warning zone; the duration of the warnings in relation to the time of occurrence of the landslides; the level of the warning issued in relation to the landslide spatial density in the warning zone; the relative importance system managers attribute to different types of errors.
An original approach, called EDuMaP method, is proposed to assess the performance of landslide early warning models operating at regional scale. The method is composed by three main phases: Events analysis, Duration Matrix, Performance analysis. The events analysis phase focuses on the definition of landslide (LEs) and warning events (WEs), which are derived from available landslides and warnings databases according to their spatial and temporal characteristics by means of ten input parameters. The evaluation of time associated with the occurrence of landslide events (LE) in relation to the occurrence of warning events (WE) in their respective classes is a fundamental step to determine the duration matrix elements. On the other hand the classification of LEs and WEs establishes the structure of the duration matrix. Indeed, the number of rows and columns of the matrix is equal to the number of classes defined for the warning and landslide events, respectively. Thus the matrix is not expressed as a 2x2 contingency and LEs and WEs are not expressed as dichotomous variables. The final phase of the method is the evaluation of the duration matrix based on a set of performance criteria assigning a performance meaning to the element of the matrix. To this aim different criteria can be defined, for instance employing an alert classification scheme derived from 2x2 contingency tables or assigning a colour code to the elements of the matrix in relation to their grade of correctness. Finally, performance indicators can be derived from the performance criteria to quantify successes and errors of the early warning models. EDuMaP has been already applied to different real case studies, highlighting the adaptability of the method to analyse the performance of structurally different ReLEWSs.