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Integrated numerical modeling of a landslide early warning system in a context of adaptation to future climatic pressures

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Mountain regions are typically characterized by rugged terrain which is susceptible to different types of landslides during high-intensity precipitation. Landslides account for billions of dollars of damage and many casualties, and are expected to increase in frequency in the future due to a projected increase of precipitation intensity. Early warning systems (EWS) are thought to be a primary tool for related disaster risk reduction and climate change adaptation to extreme climatic events and hydro-meteorological hazards, including landslides.

An EWS for hazards such as landslides consist of different components, including environmental monitoring instruments (e.g. rainfall or flow sensors), physical or empirical process models to support decision-making (warnings, evacuation), data and voice communication, organization and logistics-related procedures, and population response. Considering this broad range, EWS are highly complex systems, and it is therefore difficult to understand the effect of the different components and changing conditions on the overall performance, ultimately being expressed as human lives saved or structural damage reduced.

In this contribution we present a further development of our approach to assess a landslide EWS in an integral way, both at the system and component level. We utilize a numerical model using 6 hour rainfall data as basic input. A threshold function based on a rainfall-intensity/duration relation was applied as a decision criterion for evacuation. Damage to infrastructure and human lives was defined as a linear function of landslide magnitude, with the magnitude modelled using a power function of landslide frequency. Correct evacuation was assessed with a 'true' reference rainfall dataset versus a dataset of artificially reduced quality imitating the observation system component. Performance of the EWS using these rainfall datasets was expressed in monetary terms (i.e. damage related to false and correct evacuation).

We applied this model to a landslide EWS in Colombia that is currently being implemented within a disaster prevention project. We evaluated the EWS against rainfall data with artificially introduced error and computed with multiple model runs the probabilistic damage functions depending on rainfall error. Then we modified the original precipitation pattern to reflect possible climatic changes e.g. change in annual precipitation as well as change in precipitation intensity with annual values remaining constant. We let the EWS model adapt for changed conditions to function optimally. Our results show that for the same errors in rainfall measurements the system's performance degrades with expected changing climatic conditions. The obtained results suggest that EWS cannot internally adapt to climate change and require exogenous adaptive measures to avoid increase in overall damage.

The model represents a first attempt to integrally simulate and evaluate EWS under future possible climatic pressures. Future work will concentrate on refining model components and spatially explicit climate scenarios.