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Modelling the Hydrological State for Debris-Flow Triggering and Magnitude in the Illgraben Catchment, Switzerland

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Hazard analysis and mitigation measure design require accurate and objective prediction of debris-flow triggering conditions and magnitudes. Since debris flows typically occur simultaneously with intense rainfall and/or snowmelt, it seems natural to identify conditions leading to debris-flow triggering and to predict the magnitude of debris flows in terms of hydrological parameters. For this purpose, we present an analysis using data from the Illgraben catchment in Switzerland and a simple hydrological model. The study gives insights on the hydrological controls on debris-flow triggering and magnitudes and their uncertainty.
The Illgraben debris-flow observation station, operated as from the year 2000, has successfully recorded 75 debris flows and debris floods, with volume and bulk density estimates available for most of these events since 2000 and 2004, respectively. The hydrological model used here is the module from the probabilistic sediment cascade model SedCas (Bennett et al. 2014). The hydrological model consists of a spatially lumped linear reservoir approach to simulate runoff as a function of soil-water storage in the catchment. The model accounts for all relevant hydrological processes, including precipitation, snow accumulation and melt, evapotranspiration and soil water storage. We relate observed debris flow magnitudes with the simulated hydrological conditions leading to their triggering.
The results show that the debris flow magnitudes can be estimated as a function of soil-water storage. Thereby, magnitude increases with soil-water storage antecedent to the debris-flow event. This can be explained with downstream enhanced entrainment along the flow path by increased pore-water pressure and a corresponding decrease in shear strength as the debris flow passes. However, it is difficult to define a critical discharge or soil water storage for debris-flow triggering. We conclude that there are three possible reasons for this, which most likely interact: 1) geomorphological conditions (i.e. sediment availability) limit debris-flow magnitude; 2) the daily temporal resolution of the hydrological model does not account for triggering due to short duration heavy rainfall events and the lumped spatial representation discounts the actual sources of debris flows; and 3) stochasticity in the triggering process. The results will be further investigated and incorporated into the SedCas model to improve prediction of debris-flow activity.