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Evaluation of a debris-flow entrainment model on field cases from the Swiss Alps

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Debris-flow erosion is an important process for shaping the landscape and highly relevant in terms of hazard due to the potential of substantially increasing the flow magnitude. Here we describe the development and testing of a model for the erosion of sediment deposits by entrainment. The model is based on a generalization of field data from the Illgraben torrent channel in Switzerland, where the slope of the channel on the fan varies between 8% and 10%. The entrainment model predicts the maximum depth of erosion as a function of basal shear stress (Schürch et al., 2011), and limits the rate of erosion to be less than the maximum erosion rate observed at the Illgraben by Berger et al. (2010, 2011). The entrainment model is a module implemented in the RAMMS debris-flow runout model which solves the 2D shallow water equations of motion for granular flows and includes the Voellmy friction relation (Christen et al., 2012).
The intention of the model is to provide a tool to researchers and practitioners to estimate and investigate the influence of debris-flow erosion on the runout of debris flows, at least until new physically-based models are available.

After calibration of the friction coefficients without considering entrainment, the model was systematically tested at two field sites where both the sequence of debris flows is known and where differential terrain elevation models have been used to identify the spatial pattern of erosion. Tests at the field site Spreitgraben (Canton Berne), where the channel slope on the fan is approximately 30%, indicate that the new model is better at predicting the flow pattern in comparison with model results without entrainment. Additionally, when sediment erosion is included in model, the shape of the debris-flow wave (flow depth as a function of time) has a generally steep debris-flow front, which is typical of field observations of debris flows. The model as also evaluated at the field site Meretschibach catchment (Canton Valais) where the channel slope varies between 40% and 60% providing a test of the performance of the model on very steep slopes and with much smaller initial sediment volumes.