Submitted Abstract

ID IMC22-FSAbstr- 607

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Country	Switzerland
Region	Western Europe
Title	An Engineering Approach To Modelling Sediment Cascade Problems In Alpine Settings.
Keywords	Rock Avalanches, Debris Flows, Landslides, Sediment Cascades, Entrainment
Type	List Of Focus Session
Focus Session ID	12

Abstract

Sediment cascade problems are characterized by a general lack of knowledge of the initial and boundary conditions. Additionally, the timing of past events can only rarely be constrained, and future events cannot be predicted with certainty. While sophisticated 3D multi-phase slope stability and mass-movement runout models may include accurate descriptions of the dominant processes in each part of the sediment cascade, such models are computationally expensive and consequently only a few simulations can be performed in the time available for engineering analyses. This limits the ability to accurately predict runout, especially when considering multiple scenarios describing the initial and boundary conditions. E.g. a difference of a factor of two in the initial volume of a rock avalanche may dramatically influence the runout of the landslide and formation of subsequent debris flows. Considering various plausible volume-, friction-, ice- and water-content scenarios may necessitate many 10's of simulations to constrain the maximum plausible runout distance of a complex sediment cascade event such as at Piz Cengalo in Switzerland in 2017 or Chamoli in India in 2021.

Post event calibration of an historical rock avalanche is relatively straight forward. In general, one assumes that the initial mass instantaneously fails and disintegrates into a flowing landslide, and then the friction is typically calibrated to best match observed runout patterns. Prediction prior to an event is a much more challenging task, especially considering that the initial volume and mode of failure (e.g. one coherent landslide, or a series of retrogressive failures) cannot be accurately predicted.

The additional complexity of coupling several single-process models, or using single models with internal process transitions (e.g. the transformation of a landslide to a debris flow), without detailed knowledge of initial and boundary conditions, further reduces the ability to provide meaningful predictions within a reasonable amount of time. Therefore, we advocate the use of computationally inexpensive 2D depth-averaged flow models for runout prediction including entrainment of sediment, water, ice, and snow along the flow path, and separate models for predicting subsequent down-slope effects such as debris flows.

In this contribution we describe our efforts to develop a modelling framework, whereby estimates of sediment availability along the flow path are coupled with a simple hydrological model to estimate the water content of the deposits. These models now include rock, ice, snow and water phases, while including other relevant processes such as phase-changes (ice-water) and the formation of an air-blast.