Towards the predictive simulation of complex high-mountain landslide cascades

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Complex cascades of landslide processes in changing high-mountain areas have the potential to result in disasters with major loss of life and disruption of critical infrastructures. Simulation tools have been developed to anticipate and, consequently, more effectively manage, landslide hazards and risks. However, the detailed prediction of future events remains a major challenge particularly for complex cascading events. In the previous years, we have successfully back-calculated a set of well-documented historic landslide cascades with the mass flow simulation tool r.avaflow, deriving sets of optimized parameters. In the present contribution, we use the findings from these back-calculations to propose two approaches for predictive simulations with an updated version of r.avaflow, based on the multi-phase mass flow model by Pudasaini and Mergili (2019):

(i) Using the minima and maxima of the parameter sets summarized from the back-calculations to simulate areas of certain impact and areas of possible impact, and ranges of possible travel times and kinetic energies. The limitation of this method is that parameters often depend on the process magnitude and have to be spatially differentiated for zones of similar topography and process type, meaning that the process type has to be prescribed.

(ii) Deducing from the guiding parameter set a function that relates the key model parameters (particularly, friction parameters) to a suitable dynamic flow parameter (we suggest the kinetic energy). This approach has the advantage that the definition of zones becomes obsolete. However, much more research is necessary to constrain the proposed function.

We apply both approaches to the well-documented 2002 Kolka-Karmadon event in the Russian Caucasus, where an initial fall of ice and rock entrained almost an entire glacier, triggering a high-energy ice-rock avalanche followed by a distal mud flow. Both of the simulations (i) and (ii) yield empirically mostly adequate results in terms of impact areas, volumes, hydrographs, and flow velocities, leading to the preliminary conclusion that they represent a major step forward in our ability to predict high-mountain process chains. However, some aspects are not fully reproduced by (i), whereas others are not fully reproduced by (ii), calling for further research.
