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The mass movement routing tool r.randomwalk and its functionalities for parameter sensitivity analysis and optimization

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r.randomwalk is a GIS-based, multi-functional conceptual tool for mass movement routing. Starting from one to many release points or release areas, mass points are routed down through the digital elevation model until a defined break criterion is reached. Break criteria are defined by the user and may consist in an angle of reach or a related parameter (empirical-statistical relationships), in the drop of the flow velocity to zero (two-parameter friction model), or in the exceedance of a maximum runup height. Multiple break criteria may be combined. A constrained random walk approach is applied for the routing procedure, where the slope and the perpetuation of the flow direction determine the probability of the flow to move in a certain direction. r.randomwalk is implemented as a raster module of the GRASS GIS software and, as such, is open source. It can be obtained from http://www.mergili.at/randomwalk.html.

Besides other innovative functionalities, r.randomwalk serves with built-in functionalities for the derivation of an impact indicator index (III) map with values in the range 0–1. III is derived from multiple model runs with different combinations of input parameters varied in a random or controlled way. It represents the fraction of model runs predicting an impact at a given pixel and is evaluated against the observed impact area through an ROC Plot. The related tool r.ranger facilitates the automated generation and evaluation of many III maps from a variety of sets of parameter combinations.

We employ r.randomwalk and r.ranger for parameter optimization and sensitivity analysis. Thereby we do not focus on parameter values, but – accounting for the uncertainty inherent in all parameters – on parameter ranges. In this sense, we demonstrate two strategies for parameter sensitivity analysis and optimization. We avoid to (i) use one-at-a-time parameter testing which would fail to account for interdependencies of the parameters, and (ii) to explore all possible parameter combinations, which would be inefficient in terms of the computational time when considering more than two parameters. Instead, we present and discuss:

(1) A stepwise strategy for parameter testing, starting with optimizing one parameter and then, with the optimized range of this parameter, testing the next one and so on. Two or more cycles through the whole set of parameters may be necessary to arrive at the final, optimized combination of parameter ranges.

(2) A nested strategy, starting with testing the entire space of parameter combinations at a rough resolution. Then, the parameter sub-space associated with the best model performance is analyzed at a higher resolution in order to better constrain the optimized combination of parameter ranges. Narrowing the parameter space and refining the resolution is repeated until the model performance associated with the optimized parameter sub-space remains constant or decreases.

We compare these strategies with two rock avalanche events: the Acheron Rock Avalanche in New Zealand and the Black Rapids Rock Avalanche in Alaska. Thereby, we focus on the parameters governing the lateral spreading of the flow, and the basal friction and the mass-to-drag ratio needed for the two-parameter friction model. Repeating the optimization procedure for a larger number of test cases, we aim at deriving guiding parameter ranges for forward calculations of various types of mass movement processes.

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