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Modelling forest effects on snow avalanche runout with the Flow-Py simulation tool

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Forests cover large parts of mountain areas. It is therefore necessary to include their effects in simulations at the regional scale to understand the key role forests have for risk mitigation. Process-based physical models can be used for such simulations, but they often require larger computational resources than statistical models. Flow-Py is a customizable, open-source simulation tool to predict the runout and intensity of gravitational mass flows (GMF). Flow-Py is based on data-driven empirical modeling ideas with automated path identification to solve the routing and stopping of GMFs in three-dimensional terrain, requiring fewer parameters than physical GMF runout models. Here we present the custom-built forest plug-in to the Flow-Py simulation tool which accounts for forest effects in the transit and runout zones of snow avalanches.

Flow-Py employs the well-known runout angle (α) concept to determine the stopping of a GMF, and routing algorithm consisting of a terrain contribution and persistence contribution. The interaction between forest and avalanches, which can reduce their runout and decrease their intensity can be broken down into two main processes, 1) adding friction and 2) reducing flowing mass or the detrainment of snow. The forest plug-in has the capability to mimic these physical interactions by increasing the runout angle and adjusting the routing flux in forested areas. We present the framework of the forest plug-in for a test case and the results of a sensitivity study on parameters controlling the forest-avalanche interaction.

The forest plug-in requires the spatial extent of the forest and an estimate of the kinetic energy of the avalanche to compute the forest's effect on the avalanche movement. Additional information on the structure of the forest (e.g., forest type, stem density, canopy cover, basal area) can be used to amplify or dampen these effects. The forest information is summarized in the forest structure index (FSI), which indicates how developed a forest is with regards to its optimal protective effect against snow avalanches and ranges between 0 (no protection) and 1 (optimal protection), considering, e.g., dominant forest type, elevation band, or the forest development stage.

Forests located in the starting zones of avalanches have long been used as an efficient mitigation measure to reduce avalanche risk. However, forests located in the transit and runout zones of avalanches also have mitigating properties, but the degree of protection is difficult to quantify without simulation tools and their integrated models. Including forest-avalanche interactions in regional-scale simulations with Flow-Py and its forest plug-in allows to estimate the degree to which forest protects human activity and infrastructure against potential avalanches. That is, by combining simulation results with and without forest it is possible to estimate the forest impact, i.e., how much the forest reduces the magnitude (runout and intensity) of the avalanche. Such regional overviews can be calculated fast with large-scale input data, which is important to, e.g., quantify changes in the protective effect of a forest area caused by disturbance agents such as wind, bark beetles or fire.