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Modeling the propagation of volcanic debris avalanches by a Smoothed Particle Hydrodynamics method

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Hazard from collapses of volcanic edifices threatens million of people which currently live on top of volcanic deposits or around volcanoes prone to fail. Nevertheless, no much effort has been dedicated for the evaluation of the hazard posed by volcanic debris avalanches (e.g. emergency plans, hazard zoning maps).
This work focuses at evaluating the exceptional mobility of volcanic debris avalanches for hazard analyses purposes by providing a set of calibrated cases. We model the propagation of eight debris avalanche selected among the best known historical events originated from sector collapses of volcanic edifices. The events have large volumes (ranging from 0.01-0.02 km3 to 25 km3) and are well preserved so that their main features are recognizable from satellite images. The events developed in a variety of settings and condition and they vary with respect to their morphological constrains, materials, styles of failure.
The modeling has been performed using a Lagragian numerical method adapted from Smoothed Particle Hydrodynamics to solve the depth averaged quasi-3D equation for motion (McDougall and Hungr 2004). This code has been designed and satisfactorily used to simulate rock and debris avalanches in non-volcanic settings (McDougall and Hungr, 2004). Its use is here extended to model volcanic debris avalanches which may differ from non-volcanic ones by dimensions, water content and by possible thermodynamic effects or degassing caused by active volcanic processes.
The resolution of the topographic data is generally low for remote areas like the ones considered in this study, while the pre event topographies are more often not available. The effect of the poor topographic resolution on the final results has been evaluated by replicating the modeling on satellite-derived topographical grids with varying cell size (from 22 m to 90 m). The event reconstructions and the back analyses are based on the observations available from the literature. We test the performance of the three chosen rheologies (Frictional, Voellmy, and plastic) and we define, for each rheology, a range of values for the parameters which best replicate the propagation of the volcanic debris avalanches.
Irrespective of the variety of conditions in which the events occurred, the best fitting parameters span in a narrow interval, and are significantly lower than those typical of non-volcanic rock and debris avalanches. As an example, the bulk basal friction angles (the sole parameter required in the frictional rheology) range within 3° and 7.5° whereas typical values for non-volcanic debris avalanches vary from 11° to 31°. The consistency of the back-analyzed parameters is encouraging for a possible use of the model in the perspective of hazard mapping. These parameters could be useful to predict the possible evolution of future collapses.