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Abstract

Alpine mass movements can generate process cascades involving different materials including rock, ice, snow, and water. Numerical modelling is an essential tool for the quantification of natural hazards, but state-of-the-art operational models reach their limits when facing unprecedented or complex events. Here, we advance our predictive capabilities for process cascades on the basis of a three-dimensional numerical model, coupling fundamental conservation laws to finite strain elastoplasticity. Through its hybrid Eulerian-Lagrangian character, our approach naturally reproduces fractures and collisions, erosion/deposition phenomena, and multi-phase interactions, which finally grant very accurate simulations of complex dynamics. Four benchmark simulations demonstrate the physical detail of the model and its applicability to real-world full-scale events, including various materials and ranging through four orders of magnitude in volume. In the future, our model can support risk-management strategies through predictions of the impact of potentially catastrophic cascading mass movements at vulnerable sites.