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Landslide boost from entrainment of erodible material along the slope

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Landslides, debris flows, pyroclastic flows and avalanches are natural hazards that threaten life and property in mountainous, volcanic, coastal and seismically-active areas. The granular mass tends to accelerate as gravity pulls it down the slope and will decelerate on more gentle slopes, where frictional forces that dissipate energy can overcome the driving forces. The entrainment of underlying sediments or debris into the gravitational granular flows is suspected to be critical to their dynamics, but direct measurement of material entrainment in natural flows is very difficult. Nevertheless, qualitative and quantitative field observations suggest that material entrainment can either increase or decrease flow velocity and deposit extent, depending on the geological setting and the type of gravitational flow.

We present laboratory experiments of granular column collapse over an inclined plane covered by an erodible bed, designed to mimic erosion processes of natural flows traveling over deposits built up by earlier events. The controlling parameters are the inclination of the plane, the aspect ratio of the granular column released and the thickness of the erodible layer. The avalanche excavates the erodible layer immediately at the flow front, behind which waves traveling downstream help removing grains from the erodible bed are observed. We show that erosion processes increases the flow mobility (i. e. runout) by up to 25% over slopes with inclination close to the repose angle of the grains. Erosion efficiency is shown to strongly depend on the slope and on the nature of the erodible bed (i. e. degree of compaction): erosion effects are smaller as the compaction of the erodible granular bed increases. The excavation depth first increases and stabilizes to a critical value, and finally decreases when increasing the thickness of the erodible bed. We demonstrate that the increase of mass of the flowing grains caused by entrainment of the erodible layer is not enough to explain the observed increase in velocity and runout of the granular mass. Finally, numerical simulations using a 2D hydrodynamic model and a 3D visco-plastic model are performed to obtain insight into the physical processes at work during entrainment processes.