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Fundamental changes of granular flows dynamics, deposition and erosion processes at high slope angles: insights from laboratory experiments.

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Geophysical granular flows commonly interact with their substrate in various ways depending on the mechanical properties of the underlying material. Granular substrates, resulting from deposition of earlier flows or various geological events, are often eroded by avalanches [see *Hungr and Evans*, 2004 for review]. The entrainment of underlying debris by the flow is suspected to affect flow dynamics because qualitative and quantitative field observations suggest that it can increase the flow velocity and deposit extent, depending on the geological setting and flow type [*Sovilla et al.*, 2006; *Iverson et al.*, 2011]. Direct measurement of material entrainment in nature, however, is very difficult. We conducted laboratory experiments on granular column collapse over an inclined channel with and without an erodible bed of granular material. The controlling parameters were the channel slope angle, the granular column volume and its aspect ratio (i.e. height over length), the inclination of the column with respect to the channel base, the channel width, and the thickness and compaction of the erodible bed. For slope angles below a critical value θ_c, between 10° and 16°, the runout distance r_f is proportional to the initial column height h_0 and is unaffected by the presence of an erodible bed. On steeper slopes, the flow dynamics change fundamentally since a last phase of slow propagation develops at the end of the flow front deceleration, and prolongates significantly the flow duration. This phase has similar characteristics that steady, uniform flows. The slow propagation phase lasts longer for increasing slope angle, column volume, column inclination with respect to the slope, and channel width, and for decreasing column aspect ratio. It is however independent of the maximum front velocity and, on an erodible bed, of the maximum depth of excavation within the bed. Both on rigid and erodible beds, the increase of the slow propagation phase duration has a crucial effect on the granular flows dynamics and deposition. (i) Over a rigid bed, as the slow propagation phase lasts longer, the normalized runout distance r_f/h_0 is greater for a given slope angle and the front of the flow deposit becomes steeper. (ii) Over an erodible bed, increasing the duration of the slow phase causes the bed excavation to lasts longer and leads to the increase of the runout distance compared with the case on the rigid bed being greater; this is even more significant as the bed is less compact.