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A debris-flow with changing mass in clay-shales: behaviour and runout distance.

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There are very few studies which attempt to quantify the erosion and deposition processes by debris-flows in the channel paths, although these processes can be responsible of high differences in sediment volume between the source area and the deposition area, and significantly change their behaviour and travel distance. Clay-shales watersheds of Southeast France are particularly prone areas for such phenomena because hillslopes can provide a large quantity of poorly-sorted and highly erodible solid materials to the torrent. For instance, erosion rates of around 15 to 20 $m^3.m^{-1}$ have been estimated from detailled geomorphological surveys.

The objective of this work is to simulate runout distance and material distribution along the channel with a physically-based debris-flow runout model incorporating changing mass. The dynamic model is two-dimensional and consider an equivalent fluid whose bulk properties approximate the behaviour of a one-phase prototype. The net driving force, consisting, of the tangential component of weight, and the tangential internal pressure, are calculated with the simplified Janbu equilibrium model; this stability model satisfies force equilibrium on each slice and moment equilibrium on the whole failure surface. The basal flow resistance force depends on the rheology of the flow. In a first stage of model development, a simplified 2-parameters Bingham plastic rheology is used and a velocity profile which increases linearly with flow depth is assumed. The solution is explicit and occurs in time steps; the solution is referenced to X-Z coordinates and uses a fixed mesh. An eroded scoured volume determined with a semi-empirical approach can be added for each slice of the flow prototype at each time step. This volume can be determined by two methods, assuming a constant or a variable scour rate for a given torrent section. The first method assumes a constant scour rate for homogeneous geological and geomorphological sections whose value depends on the (relative) ranking of material erodibility. The second method assumes that the scoured volume depends essentially on a kind of integrated mean shear stress of the debris-flow mixture which passed through section of the torrent, and is controlled by the slope gradient, and the volume and density of the mixture volume which enters this section.

The model is applied on a large event ($> 100{,}000$ m^3) that occurred on August, 2003 on the 4-km length Faucon stream. Simulations are in accordance with the geomorphological observations (distribution and height of material, travel distance) and the rheological characteristics determined from laboratory tests. However, flow velocity is underestimated by the model. The scoured volume determined by the first method provides the best results. Without scouring, a scenario analysis indicates that an initial volume of at least 12,000 to 20,000 m^3 is necessary for the mixture to reach the alluvial fan. With scouring, an initial release of no more than 5,000 m^3 is sufficient for the mixture to reach the alluvial fan. Once validated, the model can be applied to assess debris-flow hazard on the alluvial fans.