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DEBRA: A multi-rheological 2D steep shallow water finite volume scheme for debris flow propagation in mountain areas

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In steep mountain areas, rapid mass movements such as avalanches and debris flows are surface processes which are characterized by large masses of granular material flowing at high speed. These processes may pose a serious threat whenever their path crosses populated areas, or damage key infrastructures. Numerical methods describing the motion of granular material coupled with remote sensing are the only option to assess run-off distance, velocity and depositional height, ultimately used to construct hazard maps. State of the art numerical modelling include three-dimensional and multiphase description of the phenomena. Despite the technical advancement provided by these implementations, which tend towards a complete model, in which both solid and liquid phases are considered, complexity, computational burdens and calibrating parameters scale accordingly. However, due to the intrinsic unknowns connected to debris flows (e.g. rheology, availability of sediments, liquid discharge), in the context of hazard mapping using a monophasic assumption regarding the physics of the flow is still a viable option because of the relatively low model complexity and computations times, allowing the user to perform multiple simulations to account for uncertainties. In the literature there are various numerical codes able to describe monophasic granular flow on complex topography both commercial (e.g. RAMMS, FLO-2D), and open source (e.g. HEC-RAS Mud and Debris flow), with different rheologic assumptions. Most models solve the classical Shallow Water Equations (SWE) which may not be valid in steep mountain bathymetry. Furthermore defining the flow depth orthogonally to the bottom may lead to practical difficulties in some situations, only solvable by introducing laborious pre- and/or post- processing calculations which may be complex on irregular topography. In this contribution we present some advances on a shock-capturing finite volume numerical scheme able to solve the recently introduced monophasic 2D Steep Slope Shallow Water Equations (SSSWE) on an unstructured grid using a set of different rheological laws (Manning, Voellmy and O'Brien). The use of an unstructured grid allows the user to capture in a simplified way the interaction between the flow and the buildings or channel beds naturally present in the computational domain regardless of the mesh size used. Furthermore, we present a novel analytical solution of a dam break test case on a sloping channel in presence of the O'Brien rheology, useful to benchmark existing numerical models. The numerical model implemented is called DEBRA (Debris-flow Evolution and Behaviour for Risk Assessment) and we assess its performance against other widely used commercial software for debris flow simulation.