Geophysical Research Abstracts
Vol. 16, EGU2014-915-2, 2014
EGU General Assembly 2014
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Numerical simulation of the debris flow dynamics with an upwind scheme and specific friction treatment

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Debris flows, snow and rock avalanches, mud and earth flows are often modeled by means of a particular realization of the so called shallow water equations (SWE). Indeed, a number of simulation models have been already developed [1], [2], [3], [4], [5], [6], [7]. Debris flow equations differ from shallow water equations in two main aspects. These are (a) strong bed gradient and (b) rheology friction terms that differ from the traditional SWE. A systematic analysis of the numerical solution of the hyperbolic system of equations rising from the shallow water equations with different rheological laws has not been done. Despite great efforts have been done to deal with friction expressions common in hydraulics (such as Manning friction), landslide rheologies are characterized by more complicated expressions that may deal to unphysical solutions if not treated carefully.

In this work, a software that solves the time evolution of sliding masses over complex bed configurations is presented. The set of non- linear equations is treated by means of a first order upwind explicit scheme, and the friction contribution to the dynamics is treated with a suited numerical scheme [8]. In addition, the software incorporates various rheological models to accommodate for different flow types, such as the Voellmy frictional model [9] for rock and debris avalanches, or the Herschley-Bulkley model for debris and mud flows.

The aim of this contribution is to release this code as a free, open source tool for the simulation of mass movements, and to encourage the scientific community to make use of it. The code uses as input data the friction coefficients and two input files: the topography of the bed and the initial (pre-failure) position of the sliding mass. In addition, another file with the final (post-event) position of the sliding mass, if desired, can be introduced to be compared with the simulation obtained result. If the deposited mass is given, an error estimation is computed by means of the Nash-Shutcliffe statistic [10]. This error estimation can be used to calibrate the input friction coefficients, providing an efficient tool for risk analysis in many regions of the world and specially in areas with steep topographic gradients such as mountain ranges, heavily incised river networks, coastal cliffs, etc.

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