A two-layer shallow water framework accounting for granular-phase dilatation: results and experimental comparison with geomorphic dam-break waves.

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ABSTRACT

We present a new framework of governing equations aimed at simulating fast geomorphic shallow flows. The model builds up on previous works by Capart (2000) and Fraccarollo et al. (2003). It relies on a similar two-layer shallow-water description of the flow, in which sediment transport occurs in an active layer composed of a homogeneous mixture of water and moving grains (sheet flow), separated by sharp interfaces from an overlying water layer and underlying motionless bed. Uniform profiles of velocities and solid concentrations are assumed within each homogeneous phase. Geomorphic exchanges (erosional or depositional) result from the upward or downward movement of the morphodynamic bed interface.

As opposed to previous formulations, solid concentrations in the static bed and moving transport layer are no longer assumed equal: grain entrainment for example requires a vertical expansion of the granular bed, the deficit in pore volume being supplied by additional water transferred from the upper pure water layer. This induces both mass and momentum exchanges between the two moving layers, which are accounted for explicitly in the governing equations. This new hypothesis is grounded on experimental observations of geomorphic dam-break waves and uniform debris flows, and has several implications on the flow behaviour. In particular, the postulated flow structure is believed to better cope with the sustained erosive behaviour of fast geomorphic flows, erosion being now associated with an increase of the flow momentum within the transport layer, due to the transfer of water from the faster-moving water layer.

The new set of equations is solved using a Strang-splitting approach: the hyperbolic part of the equations is dealt with using an approximate state Riemann solver following the approach of Harten, Lax & Van Leer, along with the lateralisered treatment of the topographical source terms proposed by Capart et al (2004). Frictional and geomorphic source operators are treated separately, and integrated analytically using an implicit backward Euler scheme.

Simulation results are faced with experimental data of the IMPACT benchmark simulating the propagation of a dam-break wave over a movable bed made of artificial PVC pellets (Spinewine & Zech, 2003). Advantages and drawbacks of the proposed approach are outlined, as they come out of the comparison with the experiments.
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FIGURES

The following figures superimpose the numerical interfaces onto the digital images of the flow at selected times $t = 0.2 \, s, \, 0.4 \, s, \, 0.6 \, s, \, 1.0 \, s$, respectively.