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Coupling Depth-Averaged and 3D models for debris flow: a multi-domain strategy

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Debris flows are landslide phenomena which occur worldwide, posing a major threat to mountain settlements. They consist of flowing fine and coarse sediment saturated with water, which propagate mainly in channelized paths. Because of their high velocity and unpredictability, the evacuation of local populations is often impossible. Losses of human lives and economical damages can be avoided if a correct risk mitigation procedure is adopted. Hence, mitigation structures, such as filter barriers or flexible barriers are often installed in high-risk areas. The primary goal of these structures is to reduce the flow energy and to retain the coarsest boulders. Their design process, which is still frequently based only on empirical or simplified models, would greatly benefit from the support of a reliable numerical model.

In this framework, continuum-based Depth-Averaged Models (DAMs) have been the dominant numerical tool since the 90s. DAMs can simulate events propagating over a wide area while keeping the computational time low, even on complex topographies (Pirulli, 2010). Nevertheless, the averaging process applied to velocity and pressure causes a loss of information, which is critical when the flow impact against structures is evaluated. A full 3D model would allow for a more accurate resolution of fluid-structure interaction (Leonardi et al., 2016). However, debris flows may propagate up to kilometres, and a complete 3D analysis would therefore require exceedingly long computational times.

To bypass the shortcomings mentioned above, this work aims to couple DAMs to a 3D model based on the Lattice Boltzmann Method (LBM). Thus, the domain is split into two parts. First, DAMs describes the flow evolution from its initialization to the transport phase. In this portion of the domain, no structures are present. When the flow approaches a structure, DAMs is coupled to a 3D model. To verify the coupling procedure accuracy, the model is benchmarked on the laboratory tests conducted by Moriguchi et al. (2009). These laboratory tests targeted the flow of dry sand on a steep chute, evaluating the flow impact on a barrier. Preliminary results suggest that the coupled model reproduces the laboratory results reasonably well.

Keywords: debris flow, coupled numerical modelling, depth-averaged method, 3D Lattice-Boltzmann Method

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