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A numerical approach for simulating two-dimensional dense-snow avalanches in global coordinate systems

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Snow avalanche models are commonly based on a continuum fluid scheme, on the assumption of shallow flow in the direction normal to the bed, on a depth-averaged description of the flow quantities and on different assumptions concerning the velocity profile, the friction law, and the pressure in the flow direction (see Bartelt et al, 1999, Barbolini et al., 2000, for an overview). The coordinate reference system is commonly local, i.e., for each point of the domain, one axis is normal to the bed while the other two axes lay in a tangent plane. When the bed is vertical and the flow is not aligned with the steepest direction (e.g., in case of a side wall), the flow depth is no longer defined considering the normal direction and the model based on the local coordinate system is no longer valid. In near-vertical conditions, numerical problems can be expected.

Another critical point, for numerical models based on finite volume schemes and Godunov fluxes, is the accurate treatment of the source term in case of no-motion conditions (persistence, starting and stopping of the flow) due to the presence of velocity-independent, Coulomb-type terms in the bed shear stress.

In this work, we provide a numerical approach for a Voellmy-fluid based model, able to overcome the limits depicted above, to accurately simulate analytical solutions and to give reliable solutions in other cases (Zugliani & Rosatti, 2021). Firstly, differently from the other literature models, the chosen coordinate reference system is global (an axis opposite the gravity vector and the other two orthogonal axes lay in the horizontal plane) and therefore, the relevant mass and momentum equations have been derived accordingly. Secondly, these equations have been discretized by using a finite volume method on a Cartesian square grid where the Godunov fluxes has been evaluated by mean of a modified DOT scheme (Zugliani & Rosatti, 2016) while source terms in conditions of motion have been discretized by using an implicit operator-splitting technique. Finally, a specific algorithm has been derived to deal with the source term to determine the no-motion conditions. Several test cases assess the capabilities of the proposed approach.

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