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Modelling two-phase debris flows down general channels and their numerical simulation

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This paper is an extension of the single-phase cohesionless dry granular avalanche model equations over generally curved and twisted channels proposed by Pudasaini & Hutter (2003) to a two-phase fluid-solid mixture of debris material. The idea of combining two separate mass and momentum balance equations into simplified single mass and momentum equations is primarily based on the work of Iverson (1997). The model equations of this paper are rigorously derived which simultaneously and explicitly include the effects of the curvature and torsion of the topography into the dynamics of the debris flow down arbitrarily curved and twisted channels of variable channel width. The equations are put into a standard conservative form of partial differential equations from which one can easily infer the importance and influence of the pore-fluid-pressure distribution into the dynamics of the debris flow. The solid-phase is modelled by applying a Coulomb dry friction law whereas the fluid phase is assumed to be an incompressible Newtonian fluid. Input parameters of the model equations are the internal and bed friction angles of the solid particles, the viscosity and volume fraction of the fluid, the total mixture density and the pore pressure distribution of the fluid at the bed. Given the bed topography and initial geometry and the initial velocity profile of the debris mixture, the model equations are able to describe the dynamics of the debris-flow-depth profile and bed parallel depth-averaged velocity profiles from the initial position to the final deposit as the debris flow sets into motion over a curved and twisted channel of general type. Simulation results present the combined effects of curvature, torsion and pore fluid pressure on the dynamics of the flow over a general basal topography. These simulation results reveal the physics of the debris flows over such non-trivial topography which could not be achieved in this form with previous model equations.