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Analysis of curvature effects for frictional rheologies in thin-layer depth-averaged flow propagation models

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Topography has a prominent role in controlling the dynamics of landslides. Taking into account accurately topography effects is thus of prior importance when performing numerical simulations of gravity-driven flows, with strong implications for hazard assessment. Most propagation models use the thin-layer depth-averaged approximation leading to Saint-Venant-like systems, with various basal rheologies.

We particularly focus on frictional rheologies which have been proved to reproduce accurately dry granular flows, that can model rock avalanches or dry debris flows. These rheologies include curvature terms, in particular due to the complex expression of the pressure at the base of the flow. We investigate the importance of these curvature effects on flow dynamics in the SHALTOP numerical model that has already reproduced successfully experimental granular flows and real landslides. For that purpose we generate 1D (topography given by z=b(x)) and 2D (z=b(x,y)) simple synthetic tests reproducing channeling and changes in flow direction, or interactions with protective dams.

Three situations are considered: (1) when the curvature is simply ignored, (2) when the curvature is simplified and taken as a combination of the curvatures in the x and y directions, and (3) when the full curvature tensor is taken into account. We analyze the influence of each situation on the runout, the thickness of the deposits and the velocity and momentum of the flow, and identify situations where the model hypotheses are nor longer verified. Eventually, SHALTOP is compared to VOLCFLOW, another widely used numerical model, to assess the influence of curvature effects in respect of inherent uncertainties in numerical methods.

Our analysis could enable a more robust quantification of the error made when assessing hazards related to gravity-driven flows on complex topographies and/or interacting with structures.