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### Basal friction in granular flows down smooth inclines

Geophysical mass movements driven by gravity, such as rock avalanches and pyroclastic currents involve complex physical and mechanic processes encompassing multiphysical and multiphase interactions. Consequently, their prediction -including long-distance propagation— and modeling remain significant challenges for multiple scientific communities. Owing to the large spatial scales involved, these geophysical flows are typically described by depth-averaged continuum models, often relying on friction-based rheologies to account for basal dissipation. While depth-averaged models can predict runout distances and flow velocities, the accuracy of these models relies on the calibration of the basal friction coefficient,  $\mu$ , which empirically encompasses the complex interplay of multiphysics and multiphase local dissipation mechanisms. A first attempt to model such complex flows consists in simplifying the system by considering only a solid granular phase, neglecting additional processes. In this simplified framework, the basal friction coefficient  $\mu$  depends primarily on grain–grain interactions, bed contacts, and near-wall-dynamics.

On smooth bottoms, significant basal sliding occurs. In these regimes, the basal friction primarily depends on a single dimensionless velocity, expressed as a Froude number. In the present work, we employ DEM simulations to investigate granular flows over a smooth incline in a geometrical configuration resembling a laboratory-scale experimental facility. Unlike typical numerical setups that rely on streamwise periodicity to enforce steady-uniform regimes, our configuration retains the full streamwise extent of the flow by incorporating an inlet silo discharge and an outlet chute. This complete resolution of the flow along the incline provides a robust basis for developing a depth-averaged formulation specifically adapted for the application of an inverse method to extract the effective basal friction law  $\mu(Fr)$ . To this end, we formulate a compressible framework to derive the effective bottom friction law. This framework also allows us to assess the extent to which the inverse approach can serve as a robust tool for flow configurations where internal stresses are difficult to determine. Using this approach, we conduct an extensive parametric study to analyze the physical origin and influence of contact properties—such as particle-bottom and particle-particle frictions—on the effective friction law  $\mu(Fr)$ .