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# Depth averaging two phase flow equations: combining hydraulic and granular flow extremes for hazard mapping.

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Ground-hugging particle-laden flows constitute some of the most dangerous natural phenomena on Earth. Such currents, in the form of snow avalanches, pyroclastic flows, debris flows, lahars, and landslides, are among the most destructive processes in nature. Humans tend to settle in areas near rich soils, volcanoes, or watercourses, all of which could be strongly affected by these dangerous flows.

In order to improve risk preparedness and site management in the affected zones, an appropriate knowledge of these natural hazardous phenomena is required. Their evolution in time, flow dynamics and run out distance are key aspects that help in the planning for hazardous events, development of hazardous regions and design of management policy to prepare in advance of potential natural disasters.

This paper describes a depth-averaged model for two phase flows that is currently in develop at the University at Buffalo. It will be fully implemented within the TITAN2D framework that presently simulates dry geophysical mass flows over natural-scale terrains. The initial TITAN2D code was developed to simulate granular flow. But because the introduction of an interstitial fluid strongly modifies the dynamics of the flow, a new, more general, two-phase model was developed to account for a broad range in volume fraction of solids. The proposed mathematical model depth-integrates the Navier-Stokes equations for each phase, solid and fluid. The solid phase is modeled assuming a Coulomb constitutive behavior (at the theoretical limit of pure solids), whereas the fluid phase conforms to a typical hydraulic approach (at the limit of pure fluid). The linkage for compositions between the pure end-member phases is accommodated by the inclusion of a phenomenological-based drag coefficient. The model is capable of simulating particle volumetric fractions as dilute as 0.001 and as concentrated as 0.55.