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A Dilatant, Two-Phase Debris Flow Model for Hazard Mitigation

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To implement an accurate numerical tool to simulate debris flow hazard is a longstanding goal of natural hazard research and engineering. In Switzerland the application of numerical debris flow models has, however, been hampered by many practical and theoretical difficulties. One practical problem is to define realistic initial conditions for hazard scenarios that involve both the rocky (granular solid) and muddy (fluid) material. Still another practical problem is to model debris flow growth by entrainment [1]. These problems are compounded by theoretical uncertainties regarding the rheological behavior of multi-phase flows. Recent analysis of debris flow measurements at the Swiss Illgraben test-site [2] (shear and normal stresses, debris flow height) show that the shear force, and therefore the entire debris flow behavior, is largely influenced by the debris flow composition, i.e. the amount of solid particle and muddy fluid at any specific location within the debris flow body (front, tail, etc.). The debris flow composition is, in turn, determined by the initial and entrainment conditions for a specific event. As a consequence, we have concluded that the very first step to construct a robust numerical model is to accurately predict the space and time evolution of the solid/fluid flow composition for any set of initial and boundary conditions. To this aim, we have developed a two-phase dilatant debris flow model [3, 4, 5] that is based on the idea that the dispersion of solid material in fluid phase can change over time. The model is thus able to predict different flow compositions (rocky fronts, watery tails), using shallow-water type mass, momentum and energy conservation equations. This helps to predict when the solid phase deposits, and when muddy fluid washes and channel outbreaks in the runout zone can occur. The parameters controlling the evolution of debris flow density and saturation have been derived by direct comparison to the full-scale measurements performed at the Illgraben test site.

References