Dynamics of Three-dimensional, Two-phase Landslides and Debris Flows

Kattel, P.[1,3], Kafle, J.[1], Khattri, K. B.[1], Pokhrel, P. R.[1], Gurung, D. B.[1], Pudasaini, S. P.[2]

[1]*School of Science, Kathmandu University, Dhulikhel, Kavre, GPO Box 6260, Kathmandu, Nepal.*
[2]*Department of Geodynamics and Geophysics, Steinmann Institute, University of Bonn, Meckenheimer Allee 176, D-53115 Bonn, Germany.*
[3]*Department of Mathematics, Tri-Chandra Campus, Tribhuvan University, Kathmandu, Nepal.*

[1] Correspondence to: Parameshwari Kattel ,
School of Science, Kathmandu University, Dhulikhel, Kavre,
GPO Box 6260, Kathmandu, Nepal
Tel: +977-11-661-399;
E-mail: pkattel@student.ku.edu.np

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1 Introduction

Landslides, debris flows and debris avalanches are large mass movements, and extremely destructive natural hazards that often occur as the motion of the mixture of soil, rock and fluid down mountain slopes (Hungr, 1995; Iverson, 1997; Iverson and Denlinger, 2001; Pudasaini and Hutter, 2003, 2007; Pitman and Le, 2005; Pudasaini et al., 2005; Takahashi, 2007; Pudasaini and Miller, 2013). Their occurrence is largely unpredictable. Therefore, the study of their dynamics is important for mountainous countries. So, reliable methods are needed to accurately predict the flow evolution, run-out distances, inundation areas, deposition behavior, impact forces, and the overall dynamics of the flows from inception to its standstill. This is required for the prevention measures and mitigation strategies in geo-hazard-prone areas.

2 Modeling landslides and debris flows

We consider the general two-phase mass flow model presented by Pudasaini (2012) which is a comprehensive theory that accounts for interactions between the solid and the fluid. The model, which includes buoyancy, also includes three new and important dominant physical aspects of enhanced non-Newtonian viscous stress, virtual mass force, and generalized drag (Pudasaini and Miller, 2012a,b). Model equations reveal strong coupling between solid and fluid momentum transfer, both through interfacial momentum transfer and the enhanced viscous stresses. The model presented unifies the three pioneering theories in geophysical mass flows, the dry granular avalanche model of Savage and Hutter (1989), the debris-flow model of Iverson (1997), and Iverson and Denlinger (2001), and the two-fluid debris-flow model of Pitman and Le (2005), and result in a new, generalized two-phase debris-flow model.

Based on Pudasaini (2012), here, we present new simulation results for three-dimensional, two-phase solid-fluid mixture flows down a slope. Simulations include the detailed analysis of flow inception, acceleration, transition to the run out zone, final deposition processes and their morphologies. The simulation provides, as out-put, the time and spatial evolution of the solid and fluid components, solid and fluid volume fractions, geometrical evolution of the debris mixture as a whole, and the solid and fluid velocities in the flow directions. A two-dimensional and real two-phase flow simulation is presented in Fig. 1. High-resolution, shock-capturing Total Variation Diminishing Non-Oscillatory Central (TVD-NOC) scheme is implemented to solve the model equations Numerically (Pudasaini, 2011).

3 Concluding remarks

Depending on the amount of the fluid in the initial and moving mass, phase interactions, and the overall dynamics of the mixture, the considered real two-phase mass flow model and the simulation strategies can directly be applied to a wide range of geophysical mass flows, including dry granular flows, snow and rock avalanches in the Himalayas, and the flow of powders and grains in the pharmaceutical industries, as well as the debris flows and flash floods, including glacial lake outburst floods (GLOF), in mountain valleys and terrain regions.

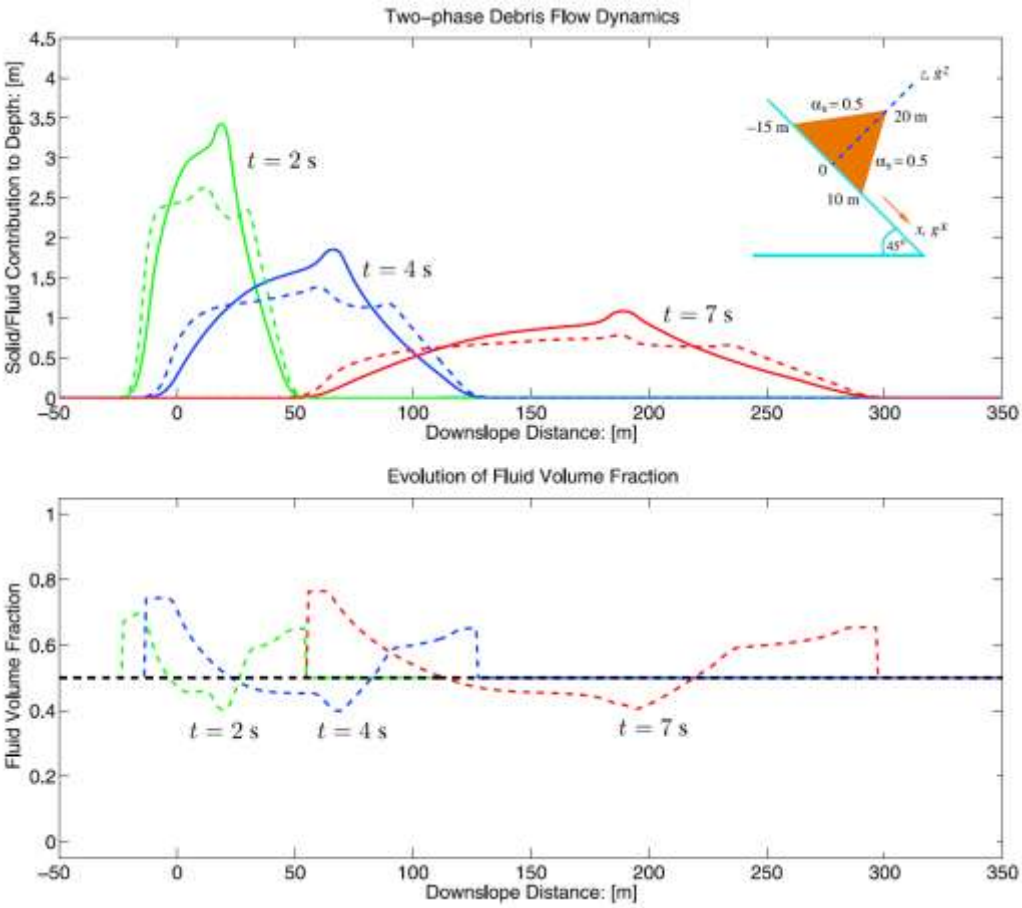

Figure 1: Spatial and temporal evolution of a two-phase debris flow as the mixture moves down an inclined channel as shown in the inset for t = 0. Initially, the upper and lower triangles are homogeneously and uniformly filled (50% solid, 50% fluid). (top) The evolution of the solid and the fluid phases, represented by the solid and the dashed lines, respectively. After debris collapse, the fluid rapidly moves in the front- and slowly in the back-ward directions leading to bulging of the fluid in both sides of the debris. It is observed that the front and tail are dominated by the fluid component. (bottom) The non-linear evolution of fluid volume fraction during the debris motion (Pudasaini, 2012).

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