



## A two-phase debris flow model with turbulence

Jeevan Kafle (1,2), Benjamin J. Dewals (3), and Shiva P. Pudasaini (4)

(1) School of Science, Department of Natural Sciences, Kathmandu University, Dhulikhel, Kavre, Nepal (jkafle@student.ku.edu.np), (2) Central Department of Mathematics, Tribhuvan University, Kirtipur, Kathmandu, Nepal, (3) Department ArGEnCo, HECE - Hydraulics in Environmental and Civil Engineering, University of Liege, (4) Institute of Geosciences and Meteorology, Geophysics Section, University of Bonn, Germany

Turbulence is an important mechanical aspect that substantially influences the dynamics of the complex mass flows. Following Pudasaini and Kafle (2019), here, we extend the general two-phase debris flow model (Pudasaini, 2012), as a mixture of solid particles and viscous fluid, by including the turbulence associated with the fluid-phase. The emergence of the additional shear stress terms further dissipates the fluid energy stabilizing the fluid component in the mixture, and thus, the mixture as a whole. This helps in numerical simulation as the fluid component is a source of numerical instability. Based on the Boussineq approximation, we obtain different turbulent stresses. Following Dewals et al. (2008) and Erpicum et al. (2009), the turbulent eddy/kinematic viscosity is modelled in two different ways with RANS. First, we use a simple algebraic turbulent closure. For this, we assume that turbulence is bed dominated which includes the flow depth and the shear velocity. This is reasonable for a shallow flow consideration. Second, a  $\kappa - \varepsilon$  turbulence model is used. Furthermore, for computational efficiency, both the two-phase turbulent models are reduced from full three-dimensional models to depth-averaged two-dimensional models. Resulting models are compared, also with the constant algebraic turbulent closure. Basic analytical and numerical results are presented to highlight the importance and application potential of the turbulence in two-phase mixture flows.

### References:

- Dewals, B. J., Kantoush, S. A., Erpicum, S., Piroton, M., Schleiss, A. J. (2008): Experimental and numerical analysis of flow instabilities in rectangular shallow basins. *Environmental Fluid Mechanics*, 8, 31-54.
- Erpicum, S., Meile, T., Dewals, B. J., Piroton, M., Schleiss, A. J. (2009): 2D numerical flow modeling in a macro-rough channel. *International Journal for Numerical Methods in Fluids*, 61, 1227-1246.
- Pudasaini, S. P. (2012): A general two-phase debris flow model. *J. Geophys. Res.* 117, F03010, doi: 10.1029/2011JF002186.
- Pudasaini, S. P., Kafle, J. (2019): Two-phase debris flow model with turbulence (In Preparation).