Geophysical Research Abstracts
Vol. 19, EGU2017-5030-1, 2017
EGU General Assembly 2017

Mechanical coupling between two innovative theories on erosion, transportation and phase-separation: Solving some long-standing problems in mass flows

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Debris flows are gravity driven mixture flows of soil, sand, rock and water. The solid particles and viscous fluid governs the rheological properties, and their coupling significantly influences the dynamics. For example, debris flows can dramatically increase their volume and destructive potential, and become exceptionally mobile by entraining bed material. The mixture composition can evolve to strikingly change the spatial distribution of particles and fluid, and thus frictional and viscous resistance. So, erosion-deposition and phase-separation between solid and fluid, which strongly depend on material composition, play a critical role in debris flow dynamics. Proper understanding of these complex physical processes is very important in accurate description of impact forces, inundation areas, landscape evolution and developing reliable mitigation plans. Predicting the underlying processes of erosion, phase-separation and deposition in debris flow are long-standing challenges. However, due to lack of data and suitable models, there exists no runout prediction method that includes observed processes of erosion of dry and saturated beds, entrainment and diffusion of eroded material, grain sorting, phase-separation, levee/lobe formation and evolution of deposition patterns.

Based on innovative mechanical models for erosion-deposition (Pudasaini and Fischer, 2016a) and phase-separation (Pudasaini and Fischer, 2016b) that explicitly consider changes in local flow compositions, and their basic/potential validations, we present a novel, unified, efficient and fully coupled solution method to these true multi-phase, three-dimensional mass flow problems. As debris flows are better described by a three-phase mixture that include viscous fluid, and fine and coarse grains as compared to often used single-phase models, we propose model extensions that consists of three-phases including yield strength. Thus, we present an advanced mass flow simulation model aiming to accurately predict debris flow dynamics, phase-separation, erosion, deposition and runout. As such, the model will substantially help debris-flow hazard mitigation and reduce damage and fatalities worldwide. In order to facilitate such applications, the new model has been implemented with the advanced open-source GIS mass flow simulation tool r.avaflow. We demonstrate this implementation for selected generic case studies.

References:

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Pudasaini, S. P., Fischer, J.-T. (2016b): A mechanical model for phase-separation in debris flow. arXiv:1610.03649.