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Simulating complex erosion-deposition and phase-separation patterns with novel two-phase mechanical models

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Mass flows, including landslides, debris flows and floods are gravity driven multi-phase 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. In these flows, erosion and phase-separation fundamentally control the motion, run-out and deposition morphology. However, predicting erosion and phase-separation processes are long-standing challenges.

On the one hand, mass flows become exceptionally mobile by entraining bed material composed of sediment and fluid. Associated with increased volume, such flows can dramatically increase their destructive power. As erosion-deposition processes directly alter the flow rheology and driving forces, these result in immediate changes in the flow bed and the flow dynamics. Recently, erosion induced mobility has been explained explicitly by deriving mechanically consistent closures for erosion rates (Pudasaini and Fischer, 2016a). On the other hand, the mixture composition can evolve to strikingly change the spatial distribution of particles and fluid, and thus frictional and viscous resistance. So, phase-separation between solid and fluid, which strongly depend on material composition, play a critical role in multi-phase mass flow dynamics. Pudasaini and Fischer (2016b) presented an innovative mechanical model for phase-separation that explicitly considers changes in local flow compositions. Proper understanding of these complex physical processes is very important in accurate description of impact forces, landscape evolution, inundation areas and developing reliable mitigation plans.

Based on these innovative erosion and phase-separation models, we present solutions for multi-phase, three-dimensional mass flow problems, aiming to accurately predict debris flow dynamics that incorporates erosion, mixing, phase-separation, deposition and runout. We apply the models to subaerial/submarine environments, incorporating obstacles, and present first-ever simulation results. This helps in understanding the complex morphological patterns induced by erosion, mixing and phase-separation mechanisms, and emerged orders and systems in fundamentally different environments. This offers unique application potential in constructing reliable and advanced mechanics-based engineering solutions to hazardous hydro-geomorphological problems.

References:

Pudasaini, S. P., Fischer, J.-T. (2016a): A mechanical erosion model for two-phase mass flows. arXiv:1610.01806.

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