



A mechanical erosion model for two-phase mass flows: Tackling a long standing dilemma of mass mobility

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Landslides and debris flows can dramatically increase their volume and destructive potential, and become exceptionally mobile by entraining bed sediment and fluid. Additionally changes in flow bed by erosion-deposition mechanisms, and thus changes in the driving force components, play a critical role in debris flow dynamics. Usually erosion related geophysical mass flows are more mobile than without erosion. However, this fact has never been explained mechanically explicitly and unambiguously. In literature, it is mentioned that erosion results in shorter travel distance due to the energy lost in erosion, but it has also been argued that, e.g., due to the added mass, the debris travels longer distance. The dilemma of erosion and flow mobility however is, that no clear explanation and derivation exists to mechanically explicitly describe the state of mobility. To cope with these challenges a two-phase variably saturated erodible basal morphology is introduced and allows for the evolution of erosion-deposition-depths, incorporating the inherent physical process including momentum and rheological changes of the flowing mixture. By rigorous derivation, we show that appropriate incorporation of the mass and momentum productions or losses in conservative model formulation is essential for the physically correct and mathematically consistent description of erosion-entrainment-deposition processes. We show that mechanically deposition is the reversed process of erosion. We derive mechanically consistent closures for coefficients emerging in the erosion rate models. We prove that effectively reduced friction in erosion is equivalent to the momentum production. With this, we solve the long standing dilemma of mass mobility, and show that erosion enhances the mass flow mobility. The model appropriately captures the emergence and propagation of complex frontal surge dynamics associated with the frontal ambient-drag with erosion. Thus, the novel enhanced real two-phase model reveals some major aspects of the mechanics associated with erosion, entrainment and deposition. The new erosion model has been implemented with the advanced open-source GIS mass flow simulation tool r.avafflow. We demonstrate this implementation for selected generic case studies.

References:

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