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Physical Model and numerical modeling of earth-surface flows on erodible beds

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Abstract:
The bed sediment erosion and depositional processes along the channel play a significant role in geo-hazards like debris flows, landslides and dam failures. Large quantities of theoretical, experimental and field researches have shown that the final debris flow volume could possibly be several-fold beyond its initial volume as it incorporates material from the basal beds. A number of catastrophic events imply the damage is still generally underestimated, especially in the area influenced by strong earthquake such as Wenchuan 5.12 earthquake in 2008.
An increasing number of researchers have been dedicated to using depth-integrated Na-vier-Stokes equations to determine the runout distance and final deposition volume of land-slides or debris flows over erodible beds. Nevertheless, it has been found out that the role of mass and momentum exchange at flow-bed boundaries in conservation equations was im-properly exhibited in some literatures, as reviewed by Iverson and Ouyang (2014). In addition, it is also illustrated that erosion or deposition rates at the interface between layers must satisfy three jump conditions which are similar to Rankine-Hugoniot conditions in gas dynamics. Here, several basal entrainment models satisfying the momentum jump conditions are proposed. Coupled mass and momentum equations integrated with sediment transport and morphological evolution are presented. A time and space second-order MacCormack-TVD finite difference method, which does not require the knowledge of the characteristic speeds of the system, is programmed to solve the coupled equations. A series of numerical simulations compared with theoretical solution and laboratory experiments were carried out to verify the accuracy and its robustness. Numerical comparisons with USGS flume experiment and Hongchun gully debris flow in Wenchuan earthquake-induced area are well carried out. It is exhibited the momentum exchange term between the flows and the basal materials has a sig-nificant influences on the dynamic characteristics and the entrainment effects are essential to reveal the dynamic process of debris flows in earthquake-induced area.

Keywords: Entrainment rate; Erodible beds; MacCormack-TVD; Depth-integrated conserva-tion equations; Debris flow