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Erosion on irregular slope surface: A full N-S equation based numerical study

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ABSTRACT

Soil erosion by overland flow on hillslopes is one of the most crucial fundamental sediment yield processes. Generally, Saint-Venant equation based overland flow model is widely used to model this special flow, and in turn, the sheet erosion. However, it becomes more and more clear that the overland flow, which generally involves irregular micro landform, could behave different characteristics from river flow in which classical depth-averaged model suits well. The key issue is that the characteristic length of the irregular micro landform is considerable large comparing with the overland flow depth, which leads to non-uniform velocity profile in the depth direction. Thus, this paper employed full Navier-Stokes equation to study the overland flow on partially inundated irregular micro-relief and discuss the self-enhanced sheet erosion processes.

To understand the self-enhanced sheet erosion processes, we first generate irregular micro-relief (0.4 m × 0.2 m) using Monte Carlo method basing on statistics data obtained from 3D scanner. Next, an automatic mesh generation script is utilized to generate valid CFD meshes (2 mm spatial resolution and minimum 0.05 mm in height direction with dynamic adaption technique). On this mesh, the flow is solved with a CFD code using VOF method and SIMPLE scheme on the "Yuan" super computer of CAS. Finally, we extract the surface shear stress and flow structure from simulation results. Potential erosion intensity is estimated with empirical equation of shear stress. As the sheet erosion induced landform change is much slower than flow solving time steps, we assume that the surface morphology change could be decoupled from flow solving. Thus, by designing different micro-relief to reflect the influence of morphology change, the self-enhanced sheet erosion processes could be discussed. In the simulation, the adaption refine technology is employed in the VOF calculation to reduce possible shear stress errors around the interface between water surface and landform for partially inundated cases. And the *low-Re k-ε* model is chosen to simulate the viscosity of the overland flow to balance the accuracy and compute efficient.

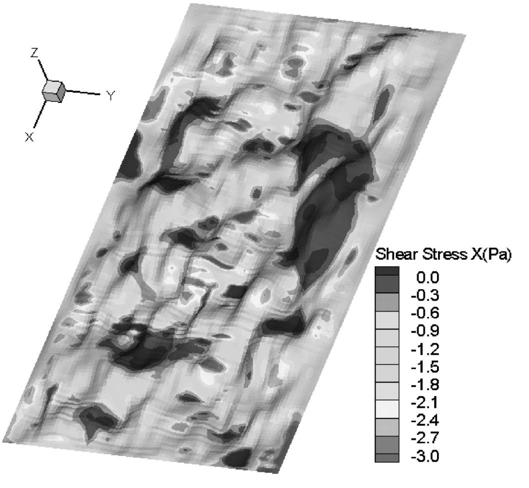

Figure 1. Typical shear stress distribution on an irregular hillslope surface (note that the blue area is not inundated).

It is note that the inundated situation is the critical factor determining the sheet erosion development, which has also been discussed by Dunkerley (2004) and Emilio et al. (2012). When the slope is mild, the inundate area would not change a lot when flow discharge increases, and the sheet erosion distribution is relatively wide on the surface. While for the steep cases, the mean shear stress is strong and the sheet erosion is localized around the lower zones near obstacles. The erosion process in the latter situation is developed more rapidly and might lead to rill erosion.

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