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Some issues and challenges in landslide hazard modeling.

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Mass movements are dynamic systems that are complex in time and space and closely linked to both inherited and current preparatory and triggering controls. It is not yet possible to assess in all cases conditions for failure, reactivation and rapid surges and successfully simulate their transient and multi-dimensional behavior. We will present some issues related to the modeling of landslide processes and identify some pressing challenges for the development of our modeling capabilities for hazard assessment in the forthcoming years.

Worldwide landslides are most frequently triggered by rainfall. There are many types of hydrological triggering mechanisms, dependent on the state of the hydrological system, which defines the thresholds for first-time failure and landslide reactivation. Consequently, a relevant hazard analysis requires that the hydrological system is studied diligently and that the transient nature of the unsaturated and saturated zone is reflected. The influence of the vegetation on water losses by evapotranspiration must play a major role in future investigations.

Another challenge is to quantify the influence of preferential flows on soil stability, especially because the architecture of the fissures and the flow processes in the fissures are difficult to detect. We need to analyze the hydraulic behavior of water in fissures and the interaction with the soil matrix, and to upscale these concepts to the slope scale.

An essential part of any landslide hazard risk assessment is to model post-failure be-

havior to reproduce accurately the deceleration and acceleration of landslide bodies and in particularly, to forecast of the potential transformation towards catastrophic, extremely rapid surges. The parameterization of hydrological and geomechanical factors by field and laboratory tests is not always sufficient to describe the post-failure movement patterns of these landslides. It is therefore a challenge to unravel the complex interactive processes within these landslides which controls the moving pattern.

Several methods have been developed to analyze the travel distance, material spreading and velocities of rapid mass movements like mud- and debris-flows (avalanches) and rock falls, ranging from empirical (black-box) methods to physically-based approaches. Empirical based models may reveal large scatter and they are not able to provide an estimate of the flow velocities, which is important to evaluate the vulnerability of infrastructures and buildings and their occupants. Physically-based models, depends on the rheological characteristics of the material, which may be highly variable, or likely to change during the flow itself. The processes involved in the motion of fast gravitational flows are very complex. Direct measurements of key variables such as pore-pressure and viscosity are impossible in full-scale events. Rheological properties (yield stress, viscosity) determined from laboratory small-sale samples may not be representative at the slope scale.

The forecast of material spreading of these flows on low graded alluvial fans require accurate DTMs and the stochastic changes in topography during depositional process complicates the modeling of the spreading pattern. Finally, it should be noted that relevant estimates of run-out distance are associated to relevant estimates of initial volumes of failed material. The variety of processes involved in the triggering of these volumes makes the estimate of these initial volumes rather difficult. Another challenge is to improve the modeling of the scouring of in-situ bed material during the flow event in the run out track, which is also of paramount importance.