

## **Triggering of Rapid Mass Movements in Steep Terrains:**

### **Mechanisms and Risks**

#### **Summary**

The goal of the conference was to assemble experts working on different types of mass movements and hillslope processes to identify unifying concepts and underlying processes for these natural hazards in mountainous regions. The workshop benefited from uniform high quality presentations including many presented by young scientists, and we were particularly impressed by dialogue to identify analogies among different types of mass release events. An additional value of the conference was the organization of a 'practitioner's day' with experts on natural hazards in Switzerland joining the workshop to discuss findings of ongoing research.

#### **Motivation of conference**

Prediction of rapid mass movements, such as shallow landslides, debris flows and snow avalanches remains an unsolved task. These spontaneous mass movements differ greatly in size and impact without clear relationship between precipitation rate, geometrical aspects and initial condition within the slope. While limited predictability can be explained partially by the heterogeneity of soil and snow properties, we have also to state that our knowledge about details of material failure and triggering mechanisms is limited. Notwithstanding the differences between the three types of mass movements (snow avalanches, debris flows and landslides), research on mass movements is similar and can be classified as follows:

- Characterization of slope heterogeneity and quantifying water flow and material deformation affecting stability of snow and soil
- Adapting alternative model concepts of material failure and triggering, and relate them to precursor events and frequency magnitude relationships
- Establishing new thresholds for transition of destabilized mass to hazardous mass movement

#### **Scientific program**

It was the goal of this workshop to look for unifying concepts and methods for quantifying landslides, debris flows and snow avalanches with particular emphasis on triggering mechanisms. To discuss these unifying concepts we organized six sessions not according to the type of released mass but based on the underlying mechanisms and properties.

In a first session - 'Triggering at various scales' - the application of new triggering concepts were presented. In general, not the slow deformation of elements but their abrupt failure at a small scale that may culminate in 'avalanches' of failures at larger scales were discussed. Session two - 'Deep and shallow water flow as a key for mass release triggering' - emphasized the role of spatio-temporal distribution of water in soils and snow on release of landslides and wet snow avalanches. Formation of wet patterns may control if a local perturbation dilutes or will propagate across the system. Mechanical deformation and failure was addressed in session three - 'Material failure'. This session was split into three blocks focusing on role of hydrogeomorphic properties on landslide triggering, on

deformation of material and role of vegetation on stability and triggering. In addition to 'back-analysis' of natural mass release events, lab and field experiments can be carried out to have better control on parameters relevant for triggering. Hence, in the fourth session - 'From lab experiments to full-scale field experiments' - results of such lab and field experiments were presented. In session five - 'On characterization and predictability of rapid mass movements' - strategies to predict zones prone to mass release and to measure precursor events were analyzed. Finally, the last session - 'Dynamics of released mass' - focused on the dynamics of moving masses to predict not only the volumes but also the impact and run-out distances.

### **Main results**

The conference revealed that we can simplify and unify mass release events as perturbation of a weak spot (for snow avalanches denoted as 'sweet spot') within the slope initiating a chain reaction that may culminate into hazardous mass release. The main tasks we have to solve based on the findings of the conference are (i) to characterize slopes to understand where weak spots may occur, (ii) to formulate new mechanisms of 'chain reactions' and (iii) to develop sensors and mathematical tools to analyze precursor events that may indicate occurrence and position of local failures acting as trigger of mass release.

### **Acknowledgments**

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