Crossing thresholds – Analysis of hazardous tipping points in alpine watersheds

Geomorphic processes are a paradigm of systems controlled by thresholds. Shifts in system behaviour occur when certain thresholds have been crossed which may result in increasing magnitude or frequency of natural hazards. Thresholds may be increased by engineering measures, or considerably lowered by expansion of settlements and lifelines into endangered areas while climate change can cause long-term shifts in the basic disposition for natural hazards and in the frequency of threshold exceedance. However, in the relation between precipitation, runoff and sediment transport, non-linearities and complex second-order threshold behavior have to be considered. Severe extreme events can lead to mobilisation of formerly decoupled sediment stores and to shifts in system response. Thus, the crossing of thresholds can be connected with climate change, but also with vegetation changes (e.g. anthropogenic deforestation) or inherent cyclic behaviour of the geomorphic system.

The questions to be addressed by the planned PhD thesis are as follows:

1. *What do we learn from event records worldwide for threshold conceptions?* The hypothesis is that geomorphological extreme events are caused by the exceedance of external and intrinsic threshold, of which complex intrinsic thresholds haven't received enough attention. We aim at a literature review on catastrophic events in torrential systems worldwide, with special emphasis on analysing the respective threshold conditions (climatic, anthropogenic or system-internal). The results will be analysed according to existing theories of equilibrium, sensitivity, complexity and panarchy in geomorphic systems. The outcome could be a review paper on thresholds in geomorphology and the reasons for non-linear system response.
2. *Which thresholds apply for hazardous torrential events in Styria?* The hypothesis is that precipitation is the most important trigger of flash floods in Styria, however strongly modified by vegetation and sediment availability. We aim to analyse flash flood hazards in Styria within the last decades to assess if the same thresholds apply for different catchments or at different points in time. We want to reduce uncertainties in between the upper precipitation threshold (from which on a catastrophic event surely occurs) and a lower threshold under which there is no system reaction, as most hazardous events occur in the uncertainty range in between. Spatial accuracy will be improved using downscaled INCA precipitation data. Case studies will deal with the other influences, particularly the role of vegetation and of system-internal cyclicity.
3. *Will the magnitude or frequency of flash floods increase due to climate change?* From available inventories, we will assess if and where the frequency of torrential hazards has already changed. The further development under climate change scenarios will be estimated drawing from the results of questions 1 and 2 and from scenarios of future precipitation extremes. The pivotal question is, if climate change will result in the crossing of tipping points from which on a non-linear increase in frequency or magnitude is to be expected.
4. *Will the possible increase of natural hazards affect critical thresholds of environmental, social and economic systems?* This question can only be answered in the context of the entire doctorate programme CC-Cope. Apart from the outlined workflow, ample free space for developing own ideas and interdisciplinary exchange will be provided. Important cooperation is foreseen with other members of the DK who will supply scenarios of future precipitation, economic aspects, system science approaches and normative theory.