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Crossing thresholds: Analysis of hazardous tipping points in alpine catchments

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Steep mountain channels or torrents in small alpine catchments are characterized by high geomorphic activity with sediment dynamics being inherently nonlinear and threshold-mediated. Localized, high intensity rainstorms can drive torrential systems past a tipping point resulting in a sudden onset of hazardous events like (flash-) flooding, heavy bedload transport or debris flows. Such responses exhibit an abrupt switch in the fluvial system's mode (e.g. transport / supply limited). Changes in functional connectivity may persist beyond the tipping point. Torrential hazards cause costly damage in the densely populated Alpine Region. Thus, there is a rising interest in potential effects of climate change on torrential sediment dynamics. Understanding critical conditions close to tipping points is important to reduce uncertainty in predicting sediment fluxes. In this study we aim at (i) establishing threshold precipitation characteristics for the Eastern Alps of Austria. Precipitation is hypothesized to be the main forcing factor of torrential events. (ii) How do thresholds vary in space and time? (iii) The effect of external triggers is strongly mediated by the internal disposition of catchments to respond. Which internal conditions are critical for susceptibility? (iv) Is there a change in magnitude or frequency in the recent past and what can be expected for the future?

The 71 km2 catchment of the river Schöttlbach in the East Alpine Region of Styria (Austria) is monitored since a heavy precipitation event resulted in a catastrophic flood in July 2011. Sediment mobilization from slopes as well as within-channel storage and bedload transport are regularly measured using photogrammetric methods and sediment impact sensors. Thus, detailed knowledge exists on magnitude and spatial propagation of sediment waves through the catchment. The associated hydro-meteorological (pre-) conditions can be inferred from a dense station network. Changing bedload transport rates and yield can thus be related to critical precipitation and internal dynamics (sediment availability, cut-and-fill cycles). Then, general relationships beyond site-specific, singular characteristics are conceptualized for broader applications. For this purpose, a Styria-wide torrential event database covering several decades is analyzed. For each event, critical precipitation characteristics are inferred from high resolution INCA data of the Austrian weather service. Factors possibly controlling the internal susceptibility of catchments are evaluated in a regional GIS approach (morphometry, geology, stream network, proxies for sediment availability). Similarity measures are then used to group catchments into sensitivity classes of different proximity to tipping points. The distribution of catchments sensitive towards heavier and more frequent precipitation will change with applied climate scenarios. Results will give valuable advice for the design of protection measures in mountain torrents.