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Controls on hillslope stability in a mountain river catchment

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Sediment transport in fluvial systems accounts for a large fraction of natural hazard damage costs in mountainous regions and is an important factor for risk mitigation, engineering and ecology. Although sediment transport in high-gradient channels gathered research interest over the last decades, sediment dynamics in steep streams are generally not well understood. For instance, the sourcing of the sediment and when and how it is actually mobilized is largely undescribed. In the Erlenbach, a mountain torrent in the Swiss Prealps, we study the mechanistic relations between in-channel hydrology, channel morphology, external climatic controls and the surrounding sediment sources to identify relevant process domains for sediment input and their characteristic scales.

Here, we analyze the motion of a slow-moving landslide complex that was permanently monitored by time-lapse cameras over a period of 70 days at a 30 minutes interval. In addition, data sets for stream discharge, air temperature and precipitation rates are available. Apparent changes in the channel morphology, e.g. the destruction of channel-spanning bed forms, were manually determined from the time-lapse images and were treated as event marks in the time series.

We identify five relevant types of sediment displacement processes emerging during the hillslope motion: concentrated mud flows, deep seated hillslope failure, catastrophic cavity failure, hillslope bank erosion and individual grain loss. Generally, sediment displacement occurs on a large range of temporal and spatial scales and sediment dynamics in steep streams not only depend on large floods with long recurrence intervals. We find that each type of displacement acts in a specific temporal and spatial domain with their characteristic scales. Different external climatic forcing (e.g. high-intensity vs. long-lasting precipitation events) promote different displacement processes. Stream morphology and the presence of boulders have a large effect on sediment input through deep seated failures and cavity failures while they have only minor impact on the other process types. In addition to large floods, which are generally recognized to produce huge amounts of sediment, we identify two relevant climatic regimes that play an important role for the sediment dynamics: a) long-lasting but low-intensity rainfall that explicitly trigger specific sediment displacement processes on the hillslopes and b) smaller discharge events with recurrence intervals of approximately one year that mobilize sediments from the hillslope's toes along the channel.