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Short and long term sediment dynamics in an alpine headwater catchment

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Mechanisms increasing recent debris flow dynamics are intensively dicussed and often related to global warming and associated permafrost degradation. However, present-day events have been rarely set in relation to the overall Postglacial and Holocene activtiy by comparing their magnitudes with cumulative landform volumes. Moreover, recent events remain often poorly constrained lacking reliable time-series. The establishment of meaningful frequency-magnitude-relations with respect to the long-term context of actitivy are therefore highly needed to better evaluate and assess the state of present day geomorphic activity.
To address this issue we focus on contemporary and postglacial sediment dynamics within a small-scale denudation-accumulation system in the Austrian Alps using a multi-temporal sediment budget approach.
The long-term perspective of averaged Holocene debris flow activity is based on the analysis of the sedimentary architecture and the reconstruction of the infill history of a closed, former lake basin in the Hohe Tauern region (Gradenmoos Basin, 4.5 km^2). For this, we applied a number of field, lab and modelling techniques involving drill core anyalsis, geophysical prospection and terrestrial laserscanning (TLS). Early-Holocene radiocarbon ages of our lowest sediment core samples indicate that postglacial sedimentation started after Younger Dryas deglaciation c. 11 ka BP after the related glacier almost entirely emptied the basin. After deglaciation, lake formation maximised trap efficiency for the following 7.5 ka as proved by stratigraphic and palynologic information. This did even not change after the lake was filled around 3.5 ka ago due to the low transport capacity of the trunk stream. The basin fill was quantified via a GIS-based approach (bedrock interpolation, 3D cut-and-fill modelling) combining drill core, geophysical and TLS data. Sediment storage volumes sum up to c. 20 Mm^3 corresponding to long-term rates of postglacial sediment yield between 214 and 855 m^3/a for three cirques supplying sediment to the basin.
Monitoring of short-term sediment dynamics is restricted to the most active cirque subsystem (855 m^3/a) feeding a massive coalescing debris cone mainly through debris flows. Here, we quantify present-day sediment supply through TLS-monitoring (time series 2009-2018), different routines of geomorphic change detection (cloud-to-cloud, mesh-to-mesh, as well as raster based), and roughness-based error modelling. In the 9-year study period sediment input was dominated by three huge debris flow events supplying a total volume of c. 81,400 m^3, what corresponds to an annual average input of c. 9,000 m^3/a to the cone (accompanied by further c. 20,600 m^3 redeposition).
We discuss drivers of this tenfold increased debris flow dynamics in the past decade with respect to recent permafrost warming/degradation, triggering rainfall thresholds, and the role of perennial snow patches as important links in mountain sediment cascades. Finally, we evaluate the transferability of these findings in the light of the current debate on more frequent extreme events in Alpine environments.