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Analysis of sediment yield and delivery using historical digital elevation models

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Multitemporal Digital Elevation Models (DEMs) can be used to analyse spatial patterns of erosion and deposition in order to infer and quantify the activity of different geomorphic processes. The photogrammetric analysis of recent and historical imagery, together with present-day surveys using terrestrial and airborne LiDAR or drone-based photogrammetric DEMs, has greatly enhanced opportunities to perform such investigations on a longer temporal scale.
We use the example of proglacial areas to highlight these opportunities. In these areas, geomorphic changes following recent glacier retreat have been occurring for a period that can be covered by historical aerial imagery. In the absence of historical quantitative information, investigations of soil, vegetation and also geomorphological (landform) evolution traditionally employed an ergodic approach (space-for-time-substitution): Present-day conditions and dynamics observed at different locations are related to the distance of these locations from the present-day glacier, taking the distance as a substitute for the time since deglaciation. Such an approach relies on a number of assumptions, for example neglecting path-dependence and contingent factors. Multitemporal, historical DEMs (with a sufficient density with respect to the temporal extent of the investigation period) make it possible to observe and quantify morphodynamics on the same areas (e.g., sections of a lateral moraine) for subsequent periods of time. This makes it possible to understand local landform evolution better than by comparative analysis of morphodynamics on different areas for the same period of time.
This work presents preliminary results of the SEHAG research unit that sets out to understand the SEnsitivity of High Alpine Geosystems to climate change since the end of the Little Ice Age (c. 1850 AD) in three central Alpine catchments. This project relies on measured and modelled (downscaled reanalysis data) time series of meteorological and hydrological data, and on the photogrammetric analysis of historical aerial and terrestrial photos. By means of an example case study of recently deglaciated steep lateral moraines, we demonstrate two applications of recent and historical DEMs with respect to sediment yield and delivery:
(1) Spatially distributed sediment delivery ratios (SDR): We employ a recently published approach to estimating spatially distributed SDR from DEMs of difference (DoD) that represents a data-based (rather than purely model-based) assessment of functional sediment connectivity. This opens the opportunity to investigate the explanatory or predictive capacity of topography-related factors and connectivity indices. For example, we show how the average slope of the contributing area relates to SDR.
(2) Scaling of SY: Previous work has found a strong correlation of SY measured in sediment traps (or using accumulated DoD) with the size of the corresponding sediment contributing area (SCA) that can be delineated on a DEM using a set of rules. Multiple historical DEMs offer the opportunity not only to compare time slices with respect to morphodynamics and sediment yield, but also to estimate the parameters of the respective SCA-SY relationships as they change through time. In our case study, SY has increased significantly, with only minor differences in the slope of the SCA-SY relationship.