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Network analysis of sediment cascades derived from digital geomorphological maps – a comparative study of three catchments in the Austrian and Swiss Alps

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Sediment fluxes in alpine environments are strongly conditioned by sediment storage, resulting in non-linear feedbacks between sediment input and output. Recently, geomorphological mapping in alpine regions has focused on the static distribution of sediment storage units, neglecting the dynamic links of geomorphic processes units along the sediment pathways. Here we present an approach i) to analyse the sediment connectivity of a catchment based on coupling relationships of neighbouring storage units, and ii) to re-evaluate existing geomorphological maps in terms of the network structure.

The approach is applied in three catchments in the European Alps, which were mapped in previous geomorphological studies: i) the Gradenbach catchment (Upper Tauern, Carinthia, Austria), ii) the (upper) Kaunertal (Ötztal Mountains, Tyrolia, Austria) and the Val Müschauns (Engadine, Switzerland). While the morphology of all study areas is predominantly controlled by former glaciations, only the two Austrian areas feature recent glaciers. The available geomorphic maps consist of non-overlapping polygons representing geomorphic process units of erosion, sediment transport and deposition. Mapping was conducted in the field, and supported by digital orthophotos and derivatives of LiDAR-based digital elevation models (slope, curvature, aspect, shaded relief, etc.). Based on the observation of diagnostic features, the geomorphic coupling state of every pair of adjacent landforms, i.e. the existence of sediment transfer across their common boundary, was assessed and mapped.

Taking the landforms as nodes, and the inferred coupling relationships as edges, a graph model of the sediment transfer system is established. Graph theory offers a versatile toolbox for the analysis of the spatial structure of sediment cascades in different ways: Nodes are analysed for the number of incoming and outgoing edges, and classified as sediment source, sink, or link. Depending on the spatial and functional configuration of the respective catchment, groups of connected landforms that are decoupled from the remaining catchment can be identified (as “connected components”). The importance of edges is assessed using graph-theoretical measures such as the betweenness centrality. Sequences of edges (paths) leading to storage landforms, the channel network, or the catchment outlet are addressed as sediment cascades; the distribution of path lengths, for example, is one of several features characterising the whole graph.

The work presented here is designed to assess the potential of network representations of geomorphic systems for the comparative analysis of sediment connectivity among catchments, and among subareas at different spatial scales. Furthermore, it represents a novel application of geomorphological maps.