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Analysing sediment pathways from rockfaces to a glacier forefield – a contribution to proglacial sediment budgets

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This study applies a simulation model and graph theory to the analysis of (potential) rockfall trajectories in the Kaunertal valley/Austria. It is part of the interdisciplinary joint project PROSA (High-resolution measurements of morphodynamics in rapidly changing proglacial systems of the Alps) dealing with sediment fluxes and budgets of the proglacial area of the Gepatschferner glacier in reaction to the ongoing rapid deglaciation of the past decades; the proglacial area is defined here as the area within the boundaries of the Little Ice Age lateral and terminal moraines.

Proglacial sediment budgets have mostly been established using data on suspended and bedload sediment yield in the proglacial stream(s), frequently disregarding the contribution of nonglacial processes. However, large quantities of sediments stored in moraine, talus and similar landforms are expected to be available to (re-)mobilisation by non-glacial processes as a consequence of deglaciation. The PROSA project will address these research needs by quantifying surface changes and sediment fluxes (including those caused by slope wash, rill erosion, debris flows and rockfall) by field measurements and terrestrial LiDAR on the local scale; models like the one presented here will be used to upscale the results to the catchment scale.

This study deals with the contribution of rockfall to the proglacial sediment budget; it is mainly focused on the identification of potential source areas, the simulation of potential trajectories of rockfall and the analysis of connectivity by assessing those trajectories which may deliver sediment to the proglacial area. Source areas are delineated using a simple threshold of slope gradient on a digital elevation model (DEM). A stochastic model (random walks) is used to establish potential trajectories; along each trajectory, the development of particle velocity is simulated using a one-parameter friction model, including free fall and impact on the ground. In order to construct a graph model of rockfall sediment flux, each trajectory is represented as a graph edge from a source node to a depositional node; the latter can be a sink node (if deposition occurs on a storage landform), but may also represent a linkage, e.g. if deposition occurs on the glacier or directly within the proglacial area where sediments are reworked by other geomorphic processes. The source and target nodes of the graph (and hence the trajectories) are classified according to a simplified geomorphological map. In the absence of direct rockfall measurements in the study area (which will be available from net collectors and multitemporal LiDAR surveys at a later stage of the research project), we couple rockfall rates calculated from rockwall retreat rates documented in the literature to the graph edges for a preliminary quantification of deposition rates within or outside of the proglacial area.