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

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Introduction

Glacier recession and its causes have lead, and will continue to lead, to changes in permafrost distribution, river runoff, soil development, vegetation and the activity of geomorphic processes, with all of these components generally interacting. The formation of paraglacial sediment storage landforms from the erosion or re-mobilisation of glacigenic sediments (e.g. moraines), and the successive reworking of the latter, are being witnessed at great intensity in the forefields of alpine glaciers, within the area that has become ice-free since the end of the LIA, which we refer to as the proglacial area. Knight & Harrison (2009) argue that paraglacial processes reworking stores of unconsolidated sediment will, under conditions of present and future climate change, be ranked among the most relevant processes of sediment and landscape dynamics in low and mid latitudes. While simple processes have been the subject of several case studies, field studies of proglacial areas including multiple processes, their rates and interactions are rare (Wardburn 1990, O’Farrell et al. 2009).

The issue of sediment connectivity is very important for establishing sediment budgets, and for assessing the potential impact of hypothesised future sediment availability and increased morphodynamics on sediment yield and processes in the fluvial system downstream of the proglacial area. We present a graph theoretical approach towards regionalising sediment transfer by rockfall processes, including the connectivity of rockfall trajectories from bedrock sources to proglacial system.

Study Area

**Model Approach**

The PROS A joint project (High-resolution measurements of morphodynamics in rapidly changing PROglacial Systems of the Alps: 2011-2015) aims at establishing the proglacial sediment budget with respect to different geomorphic processes. It will employ high-resolution surveying methods to quantify surface changes and sediment fluxes, including terrestrial and aerial LiDAR. Hillslope-scale results will be upscaled using geomorphological maps and modelling approaches. Sediment output will be gauged at the outlet of the proglacial system and at a delta within the Knaus moraine which can be EDMEDAR surveyed when the lake level is lowered in a controlled manner.

**4 First results**

**Rockfall sources**

A simple approach is used to delineate rockfall trajectories from a DEM. All cells steeper than a threshold (40°) are selected.

**Rockfall deposition**

**Graph-based analysis of rockfall trajectories and connectivity to the proglacial area**

**Model Results**

**Rockfall simulation model**

Starting from source cells, rockfall trajectories are simulated using a stochastic approach (Wichmann & Becht, 2006). Repeated random walk simulations allow rockfall trajectories to diverge from their source cell. The procedure is controlled by three parameters:

1. *slope threshold* (no divergence above threshold)
2. *divergence exponent* (controls tendency to diverge from direction of steepest descent)
3. *persistence factor* (increases transition probability for previous direction)

Rockfall velocity is modelled using a numerical one-particle motor friction model with the following properties:

* slip threshold for modelling free fall
* Energy loss upon impact after free fall (75%)
* Gliding friction (between 0.6 and 0.7)
* Simulated particle stops when velocity reaches 0.

Additionally, an edgelist is stored which contains the unique ID of start and stop cells, and properties of the respective trajectory.

The edgelist is used to generate a graph model of sediment trajectories.

**5 The next steps**

* Attaching transport rates (measured, from literature, uniform vs spatially distributed) to modelled trajectories
* Refining preliminary map for a more differentiated picture of rockfall connectivity
* Including other processes in graph analysis
* Analysis of sediment cascades

These preliminary results show that most rockfall transport (93.5%) occurs outside of the proglacial area. i.e. the corresponding trajectories do not reach the proglacial area. This is obviously due to the buffering effect of lateral moraines and the spatial distribution of rockfall processes acting as rockfall sources. Only 4.7% of all rockfall trajectories reach the proglacial area (from outside or from within it).