



Towards Reconstructing Debris Supply to Reproduce the Historic Changes in Debris Extent at a Swiss Glacier

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Debris-covered glaciers play an important role in alpine hydrology and surface debris substantially alters glacier processes and evolution. Yet the processes governing the transport and distribution of debris remain poorly understood, and thus poorly included in models of glacier evolution. To address this gap, we are developing a numerical model of debris transport within the framework of the Instructed Glacier Model (IGM), leveraging a newly implemented Lagrangian particle tracking module to simulate the movement of debris across the glacier.

This study focuses on the Oberaletsch Glacier in Switzerland, where we explore different seeding strategies for the debris particles, which involve defining how and where debris particles are introduced into the model to simulate their transport and distribution. These strategies aim to reproduce the spatial and temporal evolution of debris coverage, starting from a debris-free glacier geometry at the end of the Little Ice Age. This negligible-debris known geometry allows us to spin up the model without debris for our initial condition. To reach this pseudo-steady-state, we calibrate the mass-balance model with historic measurements at the nearby Grosseraletschgletscher. We then focus on the debris seeding: by adjusting the debris seeding locations and rates to reproduce the historic changes in debris extent, we assess the influence of initial particle placement and quantity on the debris distribution.

Preliminary results highlight the sensitivity of debris coverage to changes in the seeding strategies. Our simulations also reveal that certain characteristics of the glacier-surface debris coverage—the location and extent of medial moraines—are linked to glacier morphology and arise from the interaction between ice flow dynamics and the structure of the glacier bed, which collectively dictate where debris is transported and deposited on the glacier surface, irrespective of debris seeding strategy.

This study highlights the potential of integrating Lagrangian particle tracking into glacier models as a robust tool for advancing our understanding of debris-covered glaciers. This approach also provides new insights into the coupling of glacier dynamics and debris transport processes, and

offers a framework to understand and characterize the debris inputs to these systems. It is the first step towards developing fully operational models for predictions of glacier evolution in debris-covered glacier systems under changing climatic conditions.