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Numerically simulated ice dynamics and erosion patterns under specific climate scenarios

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Numerical modeling already demonstrated to be a powerful tool for investigating the role of surface processes, including glaciation, in landscape evolution. Ice model developments from 1-D simulations (Oerlemans, 1984; MacGregor et al., 2000) to more recent 2-/3D models (e.g. Egholm et al., 2011) allow investigating glacier dynamics and landscape erosion over various timescales by also incorporating the effects of rugged topography and feedbacks between erosion by glacial sliding and the extent of glaciation.

Precipitation and temperature are primary controls on glacier mass balance, driving basal sliding and erosion in response to changes in both ice thickness and extent. However, still little is known on how erosion patterns behave under temporally- and spatially-varying combinations of these two climatic parameters. Since ice basal sliding and fluctuations of water-pressure peak around the equilibrium-line altitude (ELA) (MacGregor et al., 2000; Herman et al., 2011), erosion would be expected to follow similar patterns due to their relationship with abrasion and quarrying. However, modeled glaciers with similar geographical extents may present significant differences in either ice thickness and/or ELA, depending on the simulated climate scenarios (i.e. combinations of precipitation/temperature). This will in turn affect ice dynamics and thus erosion patterns, especially differences between the accumulation and ablation areas.

In this study we aim to numerically explore how both ice dynamics and erosion patterns are influenced by specific climatic scenarios (i.e. precipitation and temperature conditions). Towards this, we used the Integrate Second Order Shallow Ice Approximation - iSOSIA (Egholm et al., 2011) model, which uses a positive degree-day (PDD) model for mass balance and a depth-integrated computation for ice flux with irregular Voronoi cell grids, allowing local mesh adjustments in selected topographic areas. In addition, this model is capable to couple ice, water and sediments which permits to explore erosion feedbacks onto ice dynamics.

Using a synthetic Alpine landscape, we performed a set of simulations with mass balance scenarios preserving similar ELAs and ice extents between runs. From these simulations, we generated glacial erosion patterns (e.g. steady-state erosion, total erosion integrated over a glacial cycle), testing different erosion laws (abrasion, quarrying) as well as the role of subglacial water

and sediment entrainment. From the different scenarios, we also investigated how ice dynamics (i.e. ice flux and thickness) and erosion rates vary spatially and differ between the accumulation/ablation areas. Our ultimate goal is to understand how glacial erosion patterns, combined with classic paleo-glacial reconstructions and paleo-ELA estimates, can be used as proxies for paleoclimate reconstruction.

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