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Modelling alpine glacier dynamics over geological timescales: sensitivity of paleo-ice extent reconstructions to surface mass-balance

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Several different surface-process models have been developed in the last decades to explore the dynamics of glacial erosion and its impact on mountain landscapes. These models are key to understand the net effect of Quaternary glaciations on alpine topography but their predictions are strongly dependent on the glacier dynamics included in the models. While recent model improvements have been devoted to more realistic treatment of ice deformation, subglacial hydrology, or sediment production and transport, the simulation of the surface mass-balance remains fairly simplistic in most models of glacier dynamics on geological timescales. In contrast to glaciological models, which include detailed meteorological data in glacier mass-balance simulations (daily- to monthly-variability in both temperature and precipitation, glacier exposure, wind effects...), surface-process models only consider yearly-averaged temperature data (which is often the only available climatic dataset) as a proxy for calculating glacier surface mass-balance.

Here, we present glacial simulations in the Mont-Blanc massif and the Swiss Valais area (Western European Alps). We first model the present-day glacier extent within the Mont-Blanc massif and highlight the sensitivity of model predictions to the surface mass-balance calibration (spatial variability in precipitation, altitudinal gradients in snow accumulation / ablation). Our results show that estimating the ELA (Equilibrium Line Altitude) from temperature records may be problematic, and suggest that calibrating surface mass-balance directly against ELA values leads to more realistic glacier extents. However, this approach still remains overly simplistic (e.g., no snow-redistribution by wind or slope processes, no orographic model for spatial variability in precipitation).

We subsequently use paleo-ELA estimates from glacier reconstructions to model the extent of past glaciers. Our simulations show a good agreement between predicted ice-extents and moraine- or trimline-based reconstructions. However, paleo-ELAs are mostly available only for the post-LGM glacial history (i.e. for the last $\sim$20 ka) and do not directly reflect the entire glacial/interglacial cycle (i.e. the last $\sim$100 ka). This lack of data might be even more problematic for modelling glacial dynamics over the full Pleistocene epoch, as only few remaining markers of glacier extents or climate variability are available for pre-LGM times.