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On Glacier Surface Mass Balance at the Last Glacial Maximum

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Geomorphological evidence shows that during the last glacial period glaciers reached far into the foreland of the Alps. How frequent such advances took place, how long the glaciers remained in advanced position and how fast they advanced or retreated, however, is difficult to reconstruct from geomorphology. Models of glacier flow are increasingly used to assess ice dynamics during the last glacial period. Driving such models relies on a series of estimates, including ice rheology, the forcing climate and glacier mass balance. Thereby, the latter strongly depends on climate and the equations used to describe their connection.

Here, we focus on reconstructing surface melt of the Rhine glacier ($\sim$16,000 km^2) at the last glacial maximum (LGM). Given large uncertainties in our knowledge of the LGM climate, we base our estimates on (i) analogies from Arctic present-day climate and mass balance and on (ii) theoretical considerations. Thereby we investigate which are the key climatic characteristics that need to be specified to simulate LGM glacier melt. We find that changes in the amplitude of annual air temperature substantially influence simulated ablation-area mass balance gradients db/dz, and thus glacier-wide mass balance. While this influence has been shown in earlier research, it has not yet been considered in reconstructions of glacier mass balance during the last glacial.

Paleoclimatic evidence from Central Europe suggests that during the LGM annual amplitude of air temperature was larger than today. We show that computing LGM glacier mass balance while assuming no change in amplitude compared to present-day climate can result in an overestimation of db/dz ($\sim$0.4 m w.e. (100 m)$^{-1}$ yr^{-1} vs. $\sim$0.55 m w.e. (100 m)$^{-1}$ yr^{-1}). It remains to be explored how these differing db/dz could influence simulated glacier dynamics during the last glacial.