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# High resolution climate information over Europe during glacial times using a dynamical downscaling approach

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To understand the processes that govern the climate response and feedbacks, modelling paleoclimate states offers a unique possibility to have insights into the mechanisms that convert a modified forcing into climate changes. In spite of the benefit of using global climate models (GCMs) for reproducing other climate states, their spatial resolution insufficiently represents regional and local climates, especially over complex topography. In this study, we bridge this scale gap by using a dynamical downscaling with the regional climate model Weather Forecast Research Model version 3.8.1. that is driven by the fully coupled Community Climate System Model version 4. Focussing on the Alpine region, we obtain climate information at 2 km resolution at present-day (perpetual 1990 AD conditions), the Last Glacial Maximum (LGM, 21 kya) and Marine Isotope Stage 4 (MIS4, 65 kya). The benefit of the dynamical downscaling approach is illustrated by analysing the PD and LGM simulations with the proxy evidences. The orbital forcing response is assessed by the comparing MIS4 to LGM simulations. Since the height of the Laurentide and Scandinavian ice sheets may still have some uncertainties, we carry out two additional dynamically downscaled simulations where the thickness of the ice-sheets is modified to 66% and 125% of the LGM level.

Focusing on temperature and precipitation, we observe that the dynamical downscaling approach improves the representation of the Alpine climate agreeing the proxy evidences better than the GCM, especially during colder months. Furthermore, the MIS4 orbital forcing shows an increase of temperature over the Alpine region, in particular at low levels and during colder months. In addition, the precipitation is slightly increased over low-altitude areas, but strongly over the mountains, in particular in the western Alps during colder months. This increase of precipitation is the result of an increment of water content due to the temperature rise. The outcome of using different ice-sheet thicknesses shows that temperature remains almost unchanged but the precipitation patterns is modified showing differences over southwestern and northeastern Alps, especially during colder months. This change in the precipitation pattern is explained by the modification of the atmospheric dynamics over the North Atlantic and Europe, in particular by the orientation and the shift of the larger-scale wind patterns, i.e., wind stream and storm tracks.

In conclusion, we demonstrate that the regional dynamical downscaling is a valuable method for representing paleoclimates at a finer scale. Moreover, a different orbital forcing mostly impacts on temperature, especially during colder months. Whereas a modified thickness of the Laurentide

and Scandinavian ice-sheets mainly impacts on precipitation pattern, in particular the southwestern and northeastern regions during colder months.