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Winter and summer climate in Eurasia during abrupt glacial climate changes: modelled variability much larger than indicated by biotic proxies

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The last glacial climate of Greenland was punctuated by frequent phases of abrupt warming, so-called Dansgaard-Oeschger (DO) events. DO events were probably caused by a recovery of the Atlantic meridional overturning circulation (AMOC) from a weak or shutdown stadial state to a relatively strong interstadial state. Previous modelling experiments have shown that increased northward heat transport in the North Atlantic Ocean leads to rapid atmospheric warming in this region, especially during winter. The modelling results have also indicated that on the European continent, the strongest warming occurs during spring as snow cover melts earlier in the year. Summer temperatures, on the other hand, are less affected. However, these model results could not be confirmed by independent proxy data, since abrupt warming is not present in most continental palaeoclimate reconstructions, let alone the seasonal variability of this signal. Moreover, it is not clear whether terrestrial biotic proxies register long-term summer climate in an unbiased manner. If not, they might fail to show strongest climatic change along a DO onset.

We therefore use climate model experiments performed with the LOVECLIM 3D earth system model to investigate if summer temperatures rise less than winter / spring temperatures over Eurasia during rapid warming. In addition, we present seasonality parameters that bypass some discrepancies between modelled and reconstructed

abrupt climate change. To this end, we simulated an AMOC shutdown and subsequent resumption in a glacial background climate. In this freshwater hosing experiment, we used transient DO 14 onset forcing for greenhouse gas and dust concentrations and orbital changes, as well as a constant Marine Isotope Stage 3 ice sheet configuration and a glacial land-sea mask. In our model, the seasonal temperature cycle differed between the cold phase and the following warm phase over many parts of Europe. In the cold phase, very cold and long winters contrasted with peak summer temperatures approaching those of the warm phase over Northwest Europe. The main reasons for these cold winters are increased surface albedo due to southward sea ice expansion and winter snow cover. The differences between seasonal cycles of both phases decreased south- and eastward into northern Asia. Over these regions, winter snow cover was (nearly) absent, or lasted into spring in both phases.

To study the changes in seasonality over a DO onset in detail, we have defined three parameter sets that characterize winter and summer duration in different ways. These parameter sets pinpoint some possible reasons for discrepancies between modelled and reconstructed variability of seasonality. If vigorous warming along a DO onset had occurred over Eurasia, the nature of the seasonality variability may have prevented (allowed) certain biota from thriving in a palaeo-environment where they would (not) have been expected. In this view, seemingly conflicting information from biotic proxies can be re-interpreted. This may lead to more accurate reconstructions, containing climate information on its average state and variability.