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Influence of the Scandinavian Ice Sheet on Spatiotemporal Patterns of European Hydroclimate During the Younger Dryas from Decadally-Resolved Lacustrine Biomarker Records

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The Younger Dryas (YD) cold period, thought to result from a combination of processes including freshwater forcing and a slowdown of the Atlantic Meridional Overturning Circulation (AMOC), provides an opportunity for understanding regional variability in the response to abrupt climate changes. Many existing archives are, however, not sufficiently well dated or of high enough resolution for direct comparisons at decadal-scales across the European continent. We measured biomarker hydrogen isotopic composition (δD), a proxy for precipitation δD on four high-resolution lacustrine sediment profiles spanning a 900km W-E European transect (Meerfelder Maar, western Germany; Hämelsee, northern-central Germany; Rehwiese, eastern Germany; Trzechowskie, central Poland). These sediments are annually laminated and contain common tephra layers, permitting direct comparisons and allowing the identification of spatiotemporal leads and lags in the response of the hydrological cycle to YD cooling on decadal timescales.

We observed decreasing biomarker δD values at the YD onset at all sites, likely reflecting NE Atlantic and European cooling. This took place about 100 yrs later than the δ18O decrease in the Greenland ice core and was a few decades earlier in eastern Europe than western Europe. This is inconsistent with the expected eastward propagation of cooling into Europe from the NE Atlantic but suggests that cool air masses advanced southwards from the Scandinavian Ice Sheet (SIS) into eastern Europe, due to either an increase in strength of the high pressure system over the SIS and/or the reorganization of atmospheric circulation over Europe. In addition, the magnitude of the isotopic change at the YD onset was smaller in eastern Europe (10‰ than in western Europe (20‰. We suggest this was due to the dominance of convective precipitation during summer in eastern Europe and more advective oceanic winter-spring precipitation in western Europe during the YD. Comparison with recent high resolution climate model data confirms that strong seasonal and regional differences during the YD were caused by the modulation of atmospheric flow by the SIS.

During the second half of the YD, we find pronounced multi-decadal δD variability in western Europe, likely reflecting longitudinal westerly wind shifts driven by sea-ice variability in the NE Atlantic. This variability was subdued in eastern Europe, likely due to blocking by the SIS and thus more continental climate conditions in eastern Europe. We also find spring-summer aridity, estimated from terrestrial and aquatic biomarkers, increasing at the YD onset - a few decades later than the cooling and slightly stronger in western Europe than eastern Europe. This suggests that atmospheric blocking over SIS was stronger during the YD cutting off eastern Europe from moist westerly flow from the Atlantic. Overall, our results highlight differences in the response of hydroclimate to abrupt changes across relatively small spatial scales and emphasise the importance of the SIS for regional atmospheric circulation and hence climate evolution in Europe. Our comparison with recent climate modeling data confirms that regional climate drivers and the SIS strongly influence the spatiotemporal patterns of changes in heat and moisture in response to the strong AMOC-slowdown during the YD.