REGIONAL MULTIDECADAL LEADS AND LAGS DURING LATE GLACIAL ABRUPT CLIMATE CHANGE OVER EUROPE

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Introduction

Future projections of European hydroclimate change under global change scenarios remain uncertain (1), despite the potential importance for targeted adaptation and mitigation policies. This is due to a lack of understanding of drivers of regional changes in the hydrological cycle and associated mechanisms. Improved understanding of past abrupt changes can thus help to identify mechanisms as well as particularly vulnerable regions in European hydroclimate. However, most existing continental paleohydrological records are not of sufficiently high resolution and/or sufficiently well dated for the assessment of leads and lags on decadal to centennial timescales, hampering a direct comparison of abrupt events across the European continent as well as with the Greenland ice cores. In addition, traditional hydrological proxies are mostly indirect recorders of hydrology (such as vegetation reconstructions from pollen) and do not solely reflect hydrological changes. Moreover, on the timescales of abrupt climate change (i.e. several decades) vegetation may respond to changes in temperature and hydrology differently and with delay. Employing direct hydrological proxies, which can record different components of the hydrological cycle (moisture source vs. plant evapotranspiration), such as aquatic and terrestrial lipid biomarker stable isotope values on highly resolved records, can provide new insights into the spatiotemporal sequence of events during abrupt climatic change.

Results

To better understand mechanisms and feedbacks of hydrological changes during the last major abrupt climate change from Greenland Interstadial 1 (GI-1) or the Allerød warm period to Greenland Stadial 1 (GS-1), corresponding to the Younger Dryas (YD) cold period, we applied biomarker based paleohydrological proxies (i.e. compound-specific hydrogen isotope ratios of terrestrial and aquatic biomarkers) to four well dated annually laminated lacustrine sediment profiles along a 900km W-E transect from western Germany to eastern Poland including (1) Meerfelder Maar, western Germany [MFM]; (2) Hämelsee, northern-central Germany (HÄM); (3) Rehwiese, eastern Germany [RW]; (4) Trzechowskie, central Poland [TRZ]).
We compare biomarker hydrogen isotope records (δD values) from terrestrial and aquatic sources from these sites to the Greenland ice cores. In addition to annually laminated sediments, these sediment records comprise common tephras, permitting precise synchronization of each site without tuning, and

allowing the identification of leads and lags in the response of the hydrological cycle to cooling and warming on decadal timescales.
We observed a decrease in aquatic (nC$_{23}$ alkane) and terrestrial (nC$_{29}$ alkane) biomarker δD values, likely reflecting cooling and/or a changing moisture source, 90 to 200 years later than the onset of cooling onset of Greenland Stadial 1 (GS-1) in the NGRIP ice core at 12,846 years BP in the western European sites, with a progressive lag of several decades in the more easterly sites. Furthermore, by comparing the response of terrestrial and aquatic biomarker δD values we can separate temperature and/or moisture source changes from aridification, since leaf wax n-alkane δD values are affected by plant transpiration and aquatic sourced compounds are not. We observed that the onset of aridification at all four sites along the E-W gradient occurred simultaneously and coincident with the biostratigraphically-defined onset of the YD at 12,679, yet 170 to 100 years later than the initial isotopic decrease in most sites. This highlights that major ecosystem changes at the onset of the YD were primarily forced by the onset of arid conditions due to the influx of dry polar air into central and eastern Europe, when the polar front was pushed southward by the expanding winter sea ice cover in the North Atlantic (3).

According to our new results the increase in biomarker δD values at the termination of the YD in continental central and eastern Europe, likely reflecting warming and changing moisture sources, predates the termination of GS-1 in the Greenland ice cores by almost a century. This observation provides further evidence of an atmospheric driver, i.e. the northward retreat of the polar front due to decrease in North Atlantic winter sea ice cover and the establishment of modern atmospheric conditions with a dominating westerly wind field over central Europe.
The magnitude of biomarker δD and aridification changes at the YD onset and termination is greater in western Europe than eastern Europe suggesting a decreasing impact of changes further eastward. In addition, changes seem more gradual in eastern Europe, likely related to the increasing distance from the source of climate forcing, i.e. the North Atlantic Ocean.

Conclusions

Our results suggest that hydrological changes at the onset of the YD were not uniform, but were strongest and most abrupt in western Europe, where a substantial increase in aridity occurred over just 80 years, resulting in widespread environmental changes (2, 3). These differences in magnitude and the distinct temporal succession are likely related to changing atmospheric conditions, i.e. the N-S movement of the westerly wind belt forced by sea ice changes in the North Atlantic. The lower magnitudes of change at the more eastern sites can be related to the influence of the Fennoscandian ice sheets and/or the Siberian High, which may have been extended further west at this time. Further evidence for an atmospheric driver of the regional differences in the response to an abrupt forcing is provided by the earlier response of lipid biomarker δD values at the YD termination in lacustrine sediments of central European lakes compared the response seen in the Greenland iceore isotope record. In summary, our spatiotemporal reconstruction of hydrological changes at the onset and the termination of GS-1 permits the testing of mechanisms with climate models to better understand the drivers of the sequence of events during abrupt climatic changes.

References

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