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First steps towards a Paleo-Lake Model Intercomparison Project (PLMIP): Lake simulations under extreme late-glacial conditions

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The late-glacial (15.000 to 11.000 years before present) climate over the Euro-Atlantic region is dominated by rapid shifts between warm (interstadial) and cold (stadial) climate states in response to strong changes in the Atlantic Meridional Overturning Circulation (AMOC) and sea-ice extent. Many paleolimnological climate proxies (e.g. chironomids) suggest large changes in European summer temperatures. However, some of these changes appear to be inconsistent with terrestrial summer climate proxies and climate model simulations. The latter suggests that rather the winter-spring seasons undergo extreme changes which may explain the divergence between limnological and terrestrial proxies. This raises important questions about the stationarity of the used transfer functions to infer ambient air temperatures from aquatic species under fundamentally different climatic conditions.
To investigate the impact of extreme atmospheric changes (temperature, cloudiness, solar insolation and humidity) on lakes – and hence on the potential non-stationarity of temperature reconstructions, we present here a first comparison of paleo-lake simulations performed with the freshwater lake model FLake (0-D bulk model) and PROBE-lake (1D-model) for different warm and cold climates during the late-glacial. Using the model output from different late-glacial climate simulations as forcing for our lake models, we investigate how extreme changes in atmospheric drivers and extreme seasonality affect lake temperatures and ice-free seasons depending on geographic location and lake depth.
For the comparison of stadial vs. interstadial climate states, we find that shallow lakes (3-5 m) still reach warm summer conditions during cold states but need up to one month longer to warm up and compensate for late ice melting. In contrast, deeper lakes remain very cold during stadials and hence decouple from summer air temperatures. In case of intermediately deep lakes, summer temperatures during cold states strongly depend on the presence or absence of stratification. As a result, lake temperatures and hence paleolimnological proxies may reflect very different water temperatures than the actual air temperatures depending on lake depth and changes in seasonality.
The comparison of two lake models shows notable differences in some cases. It is hence crucial to perform multi-model comparisons in the context of paleo studies. We, therefore, invite the lake modelling community to join our PLMIP efforts. This is a good opportunity to test different lake models under extreme climate conditions and to increase our understanding of paleolimnological climate proxies.