Project: 965
Title: Our way to Europe - Palaeoclimate and Palaeoenvironmental reconstructions
Report for period 01.01.2021-31.07.2021

During the year 2021, several research questions have been addressed by using computing time in the granted project. Several publications (accepted, in review) benefit from resources in project bb0965; additional publications are currently in preparation. Collaborations with people from MPI and AWI as well as external partners (University of Cologne, University Koblenz, IPSL (France)) are ongoing concerning different aspects of regional paleoclimate simulations.

a) Malaco temperature reconstructions and numerical simulation of environmental conditions in the southeastern Carpathian Basin during the Last Glacial Maximum

Glacial climate conditions in the southeastern Carpathian Basin (Vojvodina, Serbia) were analyzed based on the reconstruction of malacological palaeotemperatures and results from a high-resolution regional climate simulation. Land snail assemblages from eight loess profiles are used to reconstruct July temperatures during the Last Glacial Maximum (LGM). The malacological reconstructed temperatures are in good agreement with the simulated LGM July temperatures by the Weather Research and Forecast model. Both methods indicate increasing temperatures from the northwestern towards the southeastern parts of the study area. LGM aridity indices calculated based on the regional climate model data suggest more arid conditions in the southeastern parts compared with more humid conditions in the northwestern parts. However, for present-day conditions, the moisture gradient is reversed, exhibiting more humid (arid) conditions in the southeast (northwest). An explanation for the reversed LGM aridity pattern is provided by an analysis of the prevailing wind directions over the South Banat district (Serbia). The prevailing moist northwesterly winds during summer are not able to compensate for the annual lack of moisture induced by the dry winds from the southeast that are more frequent during the LGM for the other seasons.

Ludwig, P., Gavrilov, M.B., Radaković, M.G. and Marković, S.B. (2021), Malaco temperature reconstructions and numerical simulation of environmental conditions in the southeastern Carpathian Basin during the Last Glacial Maximum. J. Quaternary Sci. https://doi.org/10.1002/jqs.3318

b) A new perspective of permafrost boundaries in France during the Last Glacial Maximum

During the Last Glacial Maximum (LGM), a very cold and dry period around 26.5 to 19 thousand years ago, permafrost was widespread across Europe. We evaluated the potential of regional climate model simulations to reconstruct the permafrost distribution in western Europe during the LGM. In addition, criteria for possible thermal contraction cracking of the ground are applied to climate model data for the first time. These criteria serve as a precondition for the development of ice and sand wedges, which are a common proxy for past permafrost. In the LGM simulations, both permafrost and ground cracking distributions are better in agreement with proxy data when easterly winds are more frequent which lead to a colder climate in Europe (Figure 1). Whereas the permafrost extent and ground cracking regions in the global climate model simulation deviate from proxy evidence despite the easterlies, they are in good agreement in the regional counterpart. Furthermore, the model data provide evidence that thermal contraction cracking occurred in Europe during the LGM also south of the probable permafrost border. This enables the reconsideration of the significance of ice wedge pseudomorphs and sand wedge casts to understand past climate variations.

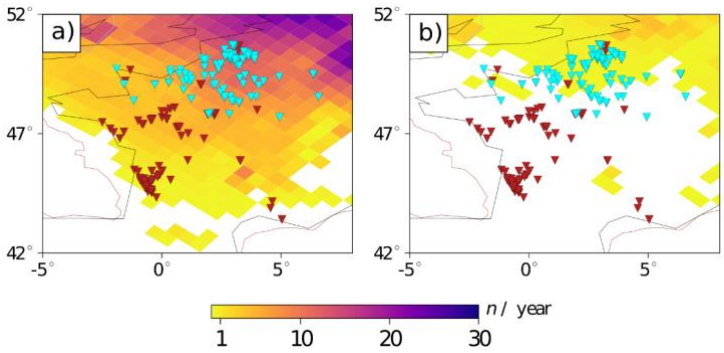

Figure 1: Heat maps of the mean number of days per year when the conditions for thermal contraction cracking are fulfilled for each grid box (model resolution of 50 km) in the regional AWI driven simulation with prevailing westerly winds (a) and MPI driven simulation with more frequent easterlies (b). Ice wedge pseudomorphs and sand wedges are highlighted with cyan and red triangles, respectively, only when located in France. Black line: LGM coastline, gray line: LGM ice sheet

Albers, K. H., Ludwig, P., Bertran, P., Antoine, P., Shi, X., Lohmann, G., and Pinto, J. G. (2021): A new perspective of permafrost boundaries in France during the Last Glacial Maximum, Clim. Past Discuss., https://doi.org/10.5194/cp-2021-60, (in review).

c) Greenland ice core record of last glacial dust sources and atmospheric circulation.

During the last glaciation, abrupt and large-scale climate changes have occurred repeatedly. Such events, where dramatic warming occurs over decades, are well represented in both Greenland ice core mineral dust and temperature records, suggesting a causal link. However, the feedbacks between atmospheric dust and climate change during these Dansgaard–Oeshger events are poorly known and the processes driving changes in atmospheric dust emission and transport remain elusive. Constraining dust provenance is key to resolving these gaps. In this study, a multi-technique analysis of Greenland dust provenance using multiple novel and established, source diagnostic isotopic tracers as well as dust trajectory modelling is performed. The existing dominant model for the provenance of Greenland dust as sourced from combined East Asian dust and Pacific volcanism is not supported. Rather, mineralogical and isotopic analyses from last glacial Greenland dust reveal three possible scenarios; direct dust sourcing from the Taklamakan Desert in western China, direct sourcing from European montane or ice marginal sources, or a mix of dust originating from Europe and North Africa. Furthermore, dust trajectory modelling demonstrates the plausibility of European or mixed European/North African sources for the first time.

G. Újvári, U. Klötzli, T. Stevens, A. Svensson, P. Ludwig, T. Vennemann, S. Gier, M. Horschinegg, L. Palcsu, D. Hippler, J. Kovács, C. Di Biagio, P. Formenti (2021): Greenland ice core record of last glacial dust sources and atmospheric circulation, PNAS, (in review).

d) Hydro-climate and cyclone characteristics in the LGM using regional climate model simulations over the Levant.

Proxy based hydro-climatic reconstructions over the Eastern Mediterranean suggest enhanced water availability during the Last Glacial Maximum (LGM) compared to present day conditions. To date, the governing hypothesis is that additional water availability may be directly linked to increased Cyprus Low frequency and intensity over the region. Since this paradigm has not been tested in a modelling framework, we used results from a regional weather type classification algorithm and regional climate simulations in this study. For the LGM, our simulations suggest that both evaporation and precipitation were actually lower compared to pre-industrial conditions. Additional water availability during the LGM can thus most likely be explained by relative changes in evaporation and precipitation. Particularly,

lower evaporation during LGM summer may have sustained the year-round wetter conditions in the Levant. In addition, significant changes in Cyprus Low characteristics are found in the LGM. Our findings are in line with a plethora of proxy-based reconstructions. Finally, the analyzed models suggest two different pathways regarding the changes in the occurrence of Cyprus Lows during the LGM compared to pre-industrial times. However, a significant increase in Cyprus Low frequency during LGM winter is shown to be more likely (+22%). This study places projected hydro-climatic drying of the Levant in a much longer time perspective. As such, it improves our understanding of the physical processes influencing the hydrological cycle in this vulnerable region situated on the border between sub-tropical and mid-latitude climatic zones.

P. Ludwig, and A. Hochamnn (2021): Hydro-climate and cyclone characteristics in the LGM using regional climate model simulations over the Levant, Environ. Res. Letters, (in review).