Project: 965 Title: Our way to Europe - Palaeoclimate and Palaeoenvironmental reconstructions Report for period 01.01.2018-31.12.2018

During the year 2019, different research questions have been addressed by using computing time in the granted project. This leads to 3 submitted publications that benefit from resources in project bb0965, which are currently under review and 2 more publications currently in preparation. Additionally, collaborations with people from the PALMOD-project (MPI, AWI) and external partners (University Erlangen, IPSL (France)) are ongoing concerning different aspects of regional paleoclimate simulations with high resolution.

a) Linkage between Dust Cycle and Loess of the Last Glacial Maximum in Europe

This article establishes a linkage between the mineral dust cycle and loess deposits during the Last Glacial Maximum (LGM) in Europe. We simulate the LGM dust cycle at high resolution using a **regional climate-dust model** (WRF-CHEM) at DKRZ and benefit from granted computing time in project bb0965. The model-simulated dust deposition rates are found to be comparable with the mass accumulation rates of the loess deposits determined from more than 70 sites. In contrast to the present-day prevailing westerlies, winds from northeast, east and southeast (36%) and cyclonic regimes (22%) were found to prevail over central Europe during the LGM. This supports the hypothesis that the recurring east sector winds associated with a high-pressure system over the Eurasian ice sheet (EIS) dominated the dust transport from the EIS margins in eastern and central Europe. The agreement between the climate model simulations and the mass accumulation rates of the loess deposits cycle hypothesis for Europe



Figure: Conceptual model explaining the linkage between the European dust cycle during the Last Glacial Maximum and the loess deposits. The main dust deposition areas (filled), emission areas (hatched) and pressure patterns (H/L: high/low pressure) are highlighted. The center of the region for the Circulation Weather Type analysis is denoted with CWT. (a) Northeasters, easterlies and southeasters (the east sector winds; transparent arrows with black perimeter) caused by the semi-permanent high-pressure over the Eurasian ice sheet (white) prevailed 36% of the time over central Europe. (b) The cyclonic weather type regimes which prevailed 22% of the time over central Europe (from Schaffernicht et al. 2019).

Schaffernicht, E. J., Ludwig, P., and Shao, Y.: Linkage between Dust Cycle and Loess of the Last Glacial Maximum in Europe, Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2019-693, in review, 2019.

b) Solar insolation as a potential long-term pacemaker for demographic developments in Europe between 43 and 15 ka ago

The sun's energy available at a certain time and place is one of the main factors influencing plant growth. The amount of plant biomass in turn, largely determines the amount of animal biomass in a landscape. The latter is the most important source of energy for European Upper Palaeolithic hunter-gatherers. Here, we aim to assess the potential influence of changes in solar insolation on palaeodemographic development in Western and Central Europe between 43 and 15 ka ago. To this end, we present estimates on the number, density and spatial distribution of hunter-gatherers for five consecutive Upper Paleolithic periods in Europe. Based on **regional climate model data** (WRF model; kindly created by granted computing time in project bb0965) for the Last Glacial Maximum and solar insolation data, we calculate (1) differences in the amount of MJm-2, (2) start, end, and length of the growing season, as well as (3) summed temperatures during the entire duration and during the first 30 days of the growing season.

A Maier, P Ludwig, A Zimmermann, I Schmidt: The sunny side of the Ice Age: Solar insolation as a potential long-term pacemaker for demographic developments in Europe between 43 and 15 ka ago. PaleoAnthropology (in review)

c) Human Existence Potential during the Last Glacial Maximum

Archaeological records indicate that many regions in Europe were unoccupied by hunter-gatherers during the Last Glacial Maximum (LGM). It is assumed that the limitation of potential habitats was due to the harsh climatic conditions and glacial extent. To better understand human occupation of Europe during the LGM, Human Existence Potential (HEP) is presented, which expresses the suitability for hunter-gatherers to inhabit a region under given environmental conditions. We estimate the HEP based on archaeological site locations and reconstructed **regional climate model data** (WRF-model; kindly obtained by granted computing time in project bb0965). Using HEP, important anthropological and archaeological questions can be studied. A clear difference in environmental adaptation is found between the populations in western and eastern Europe, and a significant climate barrier prevented the propagation of the Solutrean to eastern Europe.



Figure: Human Existence Potential (HEP) derived by logistic regression with bioclimatic variables and archaeological sites of the western population (west of 10_E). Grey dots: archaeological sites assigned to the LGM and incorporated in the model.

K Klein, C Wegener, I Schmidt, M Rostami, P Ludwig, S Ulbrich, GC Weniger, Y Shao: Human Existence Potential in Europe during the Last Glacial Maximum. Quaternary International (in review)

d) Regional Paleoclimate Simulations for mid-holocene conditions over Europe

During the "Workshop on the comparison of paleoclimate data and simulations over time periods up to the last glacial cycle" in April 2018 in Hamburg, several activities have been initiated. New **regional climate simulations** have been conducted on mistral at DKRZ based on new realizations with the MPI-ESM-P (collaboration with J. Jungclaus). The new simulations clearly show the northern European warming and Mediterranean cooling as suggested partly by proxy data. The simulations are currently analyzed in detail and a publication is planned after full evaluation.

P Ludwig, S Wagner, O Bothe, E Zorita, J Pinto, J Jungclaus et al: (The stationarity of) natural modes of Holocene climate variability over the North Atlantic-European sector – Reconciling proxy reconstructions with ESM and RCM simulations (in preparation)

e) Characteristics of Extra-tropical Cyclones over the North Atlantic and Western Europe during the Last Glacial Maximum

Extra-tropical cyclones are dominant feature of the mid-latitudes, as their passage is associated with strong winds, precipitation, and temperature changes. The statistics and characteristics of (extreme) extra-tropical cyclones over the North Atlantic realm exhibit some fundamental differences between present day and glacial climate conditions. Here, the *statistics* are analysed based on results of a tracking algorithm applied to global climate simulations for pre-industrial (PI) and glacial (last glacial maximum, LGM) conditions. During the LGM, the number and strength of detected cyclones was higher compared to PI. Increased cyclone track density is detected close to the Laurentide ice sheet and over central Europe and stronger cyclones are observed between Newfoundland and the British Isles. To determine changes in cyclone *characteristics*, we have simulated the TOP 30 storms with higher resolution (WRF-model; 50 km and 10 km grid spacing) over the eastern north Atlantic with a regional climate model.

J Pinto, P Ludwig: Characteristics of Extra-tropical Cyclones over the North Atlantic and Western Europe during the Last Glacial Maximum (in preparation)