Project: 965
Title: Our way to Europe - Palaeoclimate and Palaeoenvironmental reconstructions
Report for period 01.01.2020-31.12.2020

During the year 2020, different research questions have been addressed by using computing time in the granted project. This led to 3 publications that benefit from resources in project bb0965; additional publications are currently in preparation. Collaborations with people from the PALMOD-project (MPI, AWI) and external partners (University of Cologne, University Koblenz, IPSL (France)) are ongoing concerning different aspects of regional paleoclimate simulations with high resolution.

a) 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 high resolution **(**50 km and 10 km grid spacing) over the eastern north Atlantic with the regional climate model WRF.

Pinto, J. G.; Ludwig, P. (2020): Extratropical cyclones over the North Atlantic and Western Europe during the Last Glacial Maximum and implications for proxy interpretation. Climate of the past, 16, 611–626. doi:10.5194/cp-16-611-2020

b) A review of past changes in extratropical cyclones in the northern hemisphere and what can be learned for the future.

Extratropical cyclones, a major phenomenon of the mid-latitude atmospheric dynamics, show strong variability over a range of time scales. Future projections hint at an increase of cyclonic intensity and the associated precipitation, an important fact to be considered when developing future risk assessments. In this review presents a first overview of studies which (a) puts the current variability and projected future climate changes of extratropical cyclone characteristics in a long-term perspective, (b) shows connections to natural external forcing, and (c) deepens the understanding of cyclone intensification processes for past climate periods. The current state of knowledge for two periods in the past—the last millennium and the Last Glacial Maximum (LGM, 21,000 years ago) is summarized and results from regional climate modelling at DKRZ were included (Figure 1). The review demonstrates how a paleoclimatic view can foster an extended process understanding and be instrumental to better understand future changes in extratropical cyclones and associated characteristics.

Raible, C. C.; Pinto, J. G.; Ludwig, P.; Messmer, M. (2020): A review of past changes in extratropical cyclones in the northern hemisphere and what can be learned for the future. Wiley interdisciplinary reviews / Climate change. doi:10.1002/wcc.680

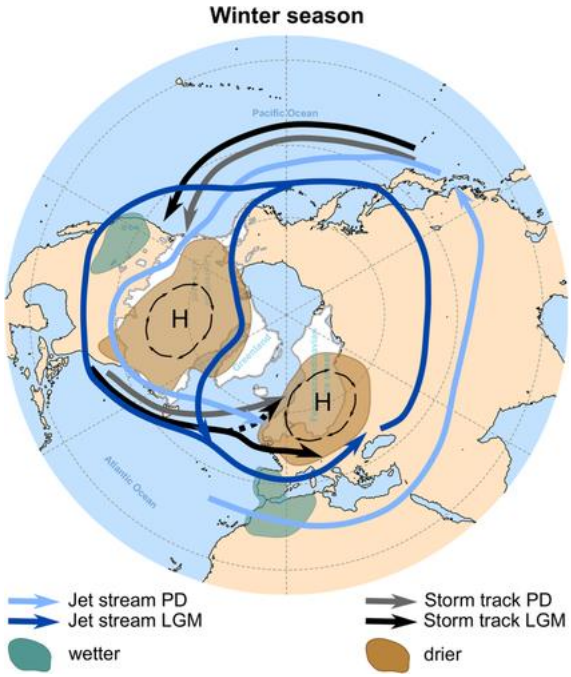

Figure 1: Schematic of the storm tracks, atmospheric circulation relevant for extratropical cyclones, and hydrological implications of extratropical cyclones comparing present day (PD) with the Last Glacial Maximum (LGM) based on model evidence. The compilation is based on several modeling studies using different models. We only include features where models agree on. The dashed arrow between Iceland and Scandinavia is only based on limited model evidence. Note that we focus on the winter, where extratropical cyclones are mostly pronounced, and, thus, most of the studies focus on.

c) Simulated regional dust cycle in the Carpathian Basin and the Adriatic Sea region during the Last Glacial Maximum.

The climate and environmental conditions in the Carpathian Basin and the adjacent northern Italy/Adriatic region during the Last Glacial Maximum (LGM) were investigated based on regional climate simulations. The high-resolution model output (grid spacing of ~8.5 km) is in good agreement with available proxy data, showing much colder (particularly during winter) and drier conditions during the LGM over the model domain. The simulated aeolian dust cycle shows highest dust emissions simulated to the east of the Alpine ice sheet and in the Kvarner Bay region. In the northern Carpathian Basin, dust deposition plumes indicate prevailing northerly (NW, N and NE) winds (Figure 2). Strong Bora winds flowing down the slopes of the Dinaric Alps appear to play a major role in the local to regional dust cycle in the northern Adriatic region. A closer look at climate and environmental conditions at key areas reveals that high mean wind speeds and low precipitation rates correlate well with the high dust emissions during winter and spring. In contrast, lower wind speeds, increasing precipitation and the greening of vegetation prevent high dust emissions during summer and autumn. An additional analysis of the occurrence frequency of cyclonic circulation patterns in the Adriatic shelf region reveals that individual passing cyclones played an important role in the transport of dust particles from the alluvial Po plain towards the eastern Adriatic loess stacks.

Ludwig, P., Gavrilov, M.B., Markovic, S.B., Ujvari, G., Lehmkuhl, F. (2020) Simulated regional dust cycle in the Carpathian Basin and the Adriatic Sea region during the Last Glacial Maximum, Quaternary International, https://doi.org/10.1016/j.quaint.2020.09.048

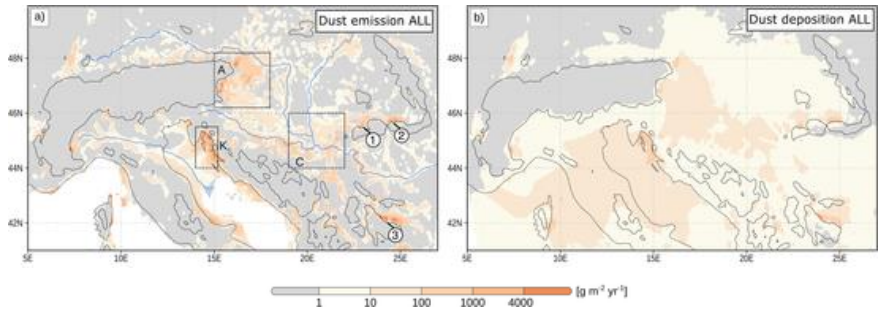

Figure 2. Model based (a) annual mean dust emission, (b) annual mean total dust deposition. Stippled line denotes topography higher 1000m.