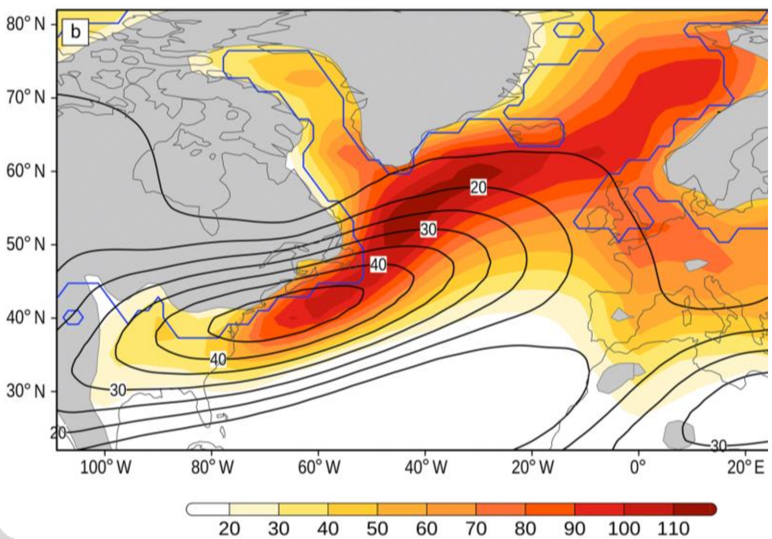
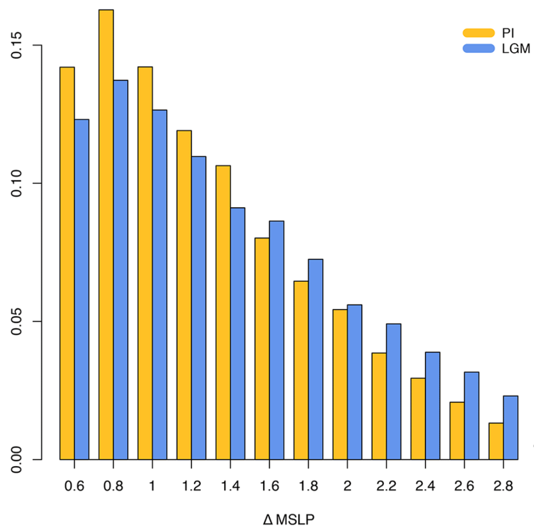
Extratropical cyclone characteristics over the North Atlantic and western Europe during the Last Glacial Maximum

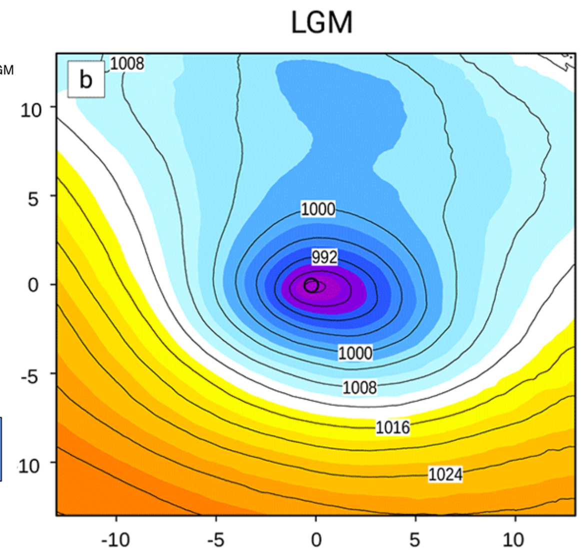
Joaquim G. Pinto and Patrick Ludwig

joaquim.pinto@kit.edu; patrick.ludwig@kit.edu

Institut für Meteorologie und Klimaforschung – Department Troposphärenforschung







Abstract

Extratropical cyclones are a dominant feature of the mid-latitudes, as their passage is associated with strong winds, precipitation, and temperature changes. The statistics and characteristics of extratropical cyclones over the North Atlantic region exhibit some fundamental differences between Pre-Industrial (PI) and Last Glacial Maximum (LGM) climate conditions. Here, the statistics are analysed based on results of a tracking algorithm applied to global PI and LGM climate simulations. During the LGM, both the number and the intensity of detected cyclones was higher compared to PI. In particular, increased cyclone track activity is detected close to the Laurentide ice sheet and over central Europe. To determine changes in cyclone characteristics, the top 30 extreme storm events for PI and LGM have been simulated with a regional climate model and high resolution (12.5 km grid spacing) over the eastern North Atlantic and Western Europe. Results show that LGM extreme cyclones were characterised by weaker precipitation, enhanced frontal temperature gradients, and stronger wind speeds than PI analogues. These results are in line with the view of a colder and drier Europe, characterised by little vegetation and affected by frequent dust storms, leading to reallocation and build-up of thick loess deposits in Europe.

The results have been recently published

Karlsruher Institut für Technologie

Clim. Past, 16, 611–626, 2020
https://doi.org/10.5194/cp-16-611-2020

Climate of the Past
Open Access
EGU

Extratropical cyclones over the North Atlantic and western Europe during the Last Glacial Maximum and implications for proxy interpretation

Joaquim G. Pinto[1,★] **and Patrick Ludwig**[1,★]

[1]Institute of Meteorology and Climate Research, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany
★These authors contributed equally to this work.

Correspondence: Joaquim G. Pinto (joaquim.pinto@kit.edu)

Received: 19 November 2019 – Discussion started: 2 December 2019
Revised: 20 February 2020 – Accepted: 1 March 2020 – Published: 1 April 2020

Abstract. Extratropical cyclones are a dominant feature of the midlatitudes, as their passage is associated with strong winds, precipitation and temperature changes. The statistics and characteristics of extratropical cyclones over the North Atlantic region exhibit some fundamental differences between pre-industrial (PI) and Last Glacial Maximum (LGM) climate conditions. Here, the statistics are analysed based on results of a tracking algorithm applied to global PI and LGM climate simulations. During the LGM, both the number and the intensity of detected cyclones were higher compared to PI. In particular, increased cyclone track activity is detected close to the Laurentide ice sheet and over central Europe. To determine changes in cyclone characteristics, the top 30 extreme storm events for PI and LGM have been simulated with a regional climate model and high resolution (12.5 km grid spacing) over the eastern North Atlantic and western Europe. Results show that LGM extreme cyclones were characterised by weaker precipitation, enhanced frontal temperature gradients and stronger wind speeds than PI analogues. These results are in line with the view of a colder and drier Europe, characterised by little vegetation and affected by frequent dust storms, leading to reallocation and build-up of thick loess deposits in Europe.

1 Introduction

The day-to-day weather conditions in the midlatitudes are strongly affected by the passage of extratropical cyclones, which are typically associated with precipitation, strong winds and changes in temperature and cloudiness. Cyclones also play a major role in the water cycle and the redistribution of momentum and energy in the climate system (Hoskins and Valdez, 1990; Chang et al., 2002). The assessment of cyclone activity, notably to analyse their paths, characteristics and impacts, is thus key to determine the day-to-day weather conditions, the regional mean climate and its variability on multiple timescales. In fact, there is a wide range of literature analysing case studies of extreme cyclones (e.g. Wernli et al., 2002; Ludwig et al., 2015), the mean cyclone activity in the midlatitudes in the recent past (e.g. Hoskins and Hodges, 2002; Ulbrich et al., 2009) and possible changes under future climate conditions (e.g. Bengtsson et al., 2009; Ulbrich et al., 2009). On the other hand, studies analysing the structural characteristics of extratropical storms from a climatological perspective are less frequent (e.g. Catto et al., 2010; Rudeva and Gulev, 2011; Dacre et al., 2012; Hewson and Neu, 2015; Sinclair et al., 2020). While some general concepts are available on how warmer climate conditions will affect the intensity and structure of cyclones, there are still several open questions, particularly regarding how dominant the increased latent heating may become compared to other physical processes like low-level and upper-level baroclinicity (see Catto et al., 2019; their Fig. 2).

The availability of studies addressing the characteristics of cyclone activity outside of the period extending from the mid-19th century to the end of the 21st century decreases sharply. Raible et al. (2018) analysed variations of cyclone statistics in a very long simulation with a fully coupled Earth system model from 850 to 2100 CE. While they identified

Published by Copernicus Publications on behalf of the European Geosciences Union.

Pinto JG, Ludwig P (2020) Extratropical cyclones over the North Atlantic and western Europe during the Last Glacial Maximum and implications for proxy interpretation. Clim. Past, 16, 611–626, doi:10.5194/cp-16-611-2020

https://www.clim-past.net/16/611/2020/

Key Figures

Karlsruher Institut für Technologie

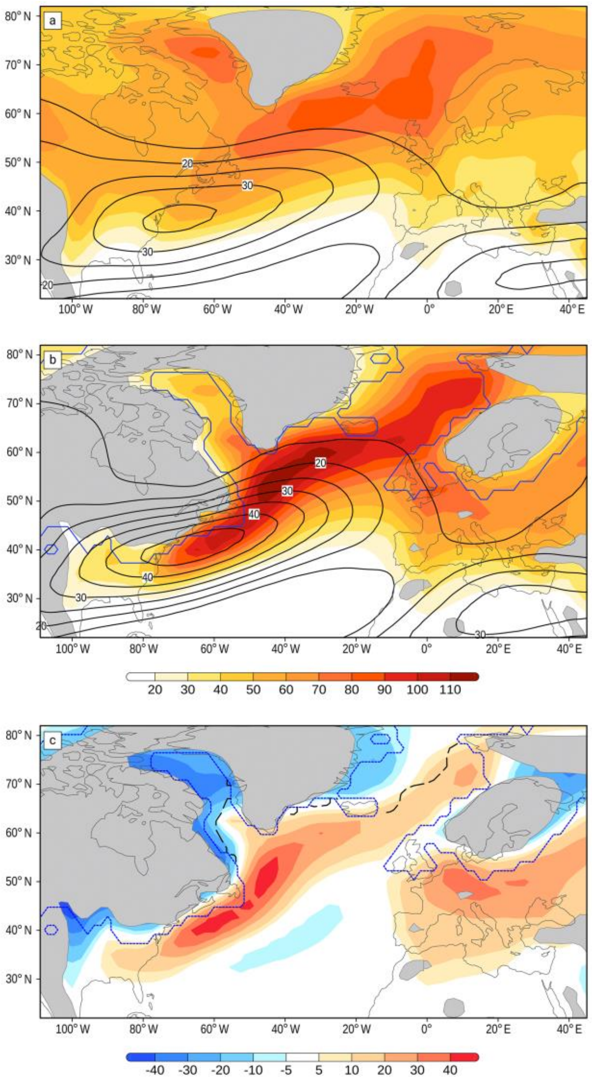


Figure 1 (left): Cyclone track density (cyclone days per extended winter per (deg. lat.)^2) (coloured) and 300 hPa wind speed (m s^{-1}) (contours) based on MPI-ESM-P data for **(a)** PI, **(b)** LGM and **(c)** difference between LGM and PI. Areas with topography higher than 1000 m are shaded grey; ice sheet margins **(b, c)** are denoted by the thin stippled line; dashed black line in panel **(c)** denotes the margin of 40 % annual sea ice cover.

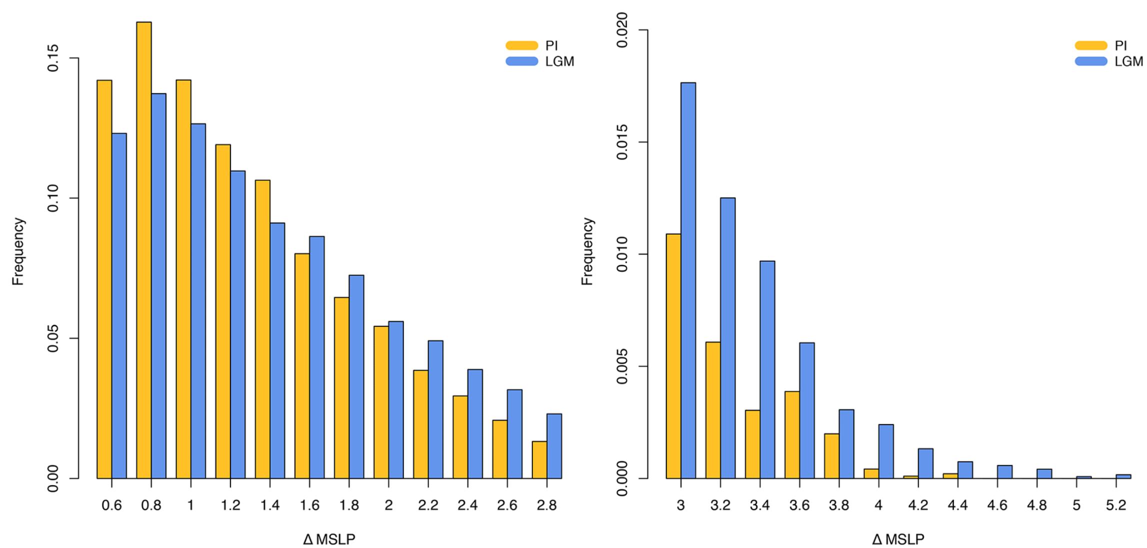


Figure 2: Histogram of cyclone intensity (Laplacian (Δ) MSLP) over the North Atlantic (35–70◦ N, 70◦ W–0). For intense cyclones (ΔP≥3), the y axis is adjusted (right panel).

Key Figures

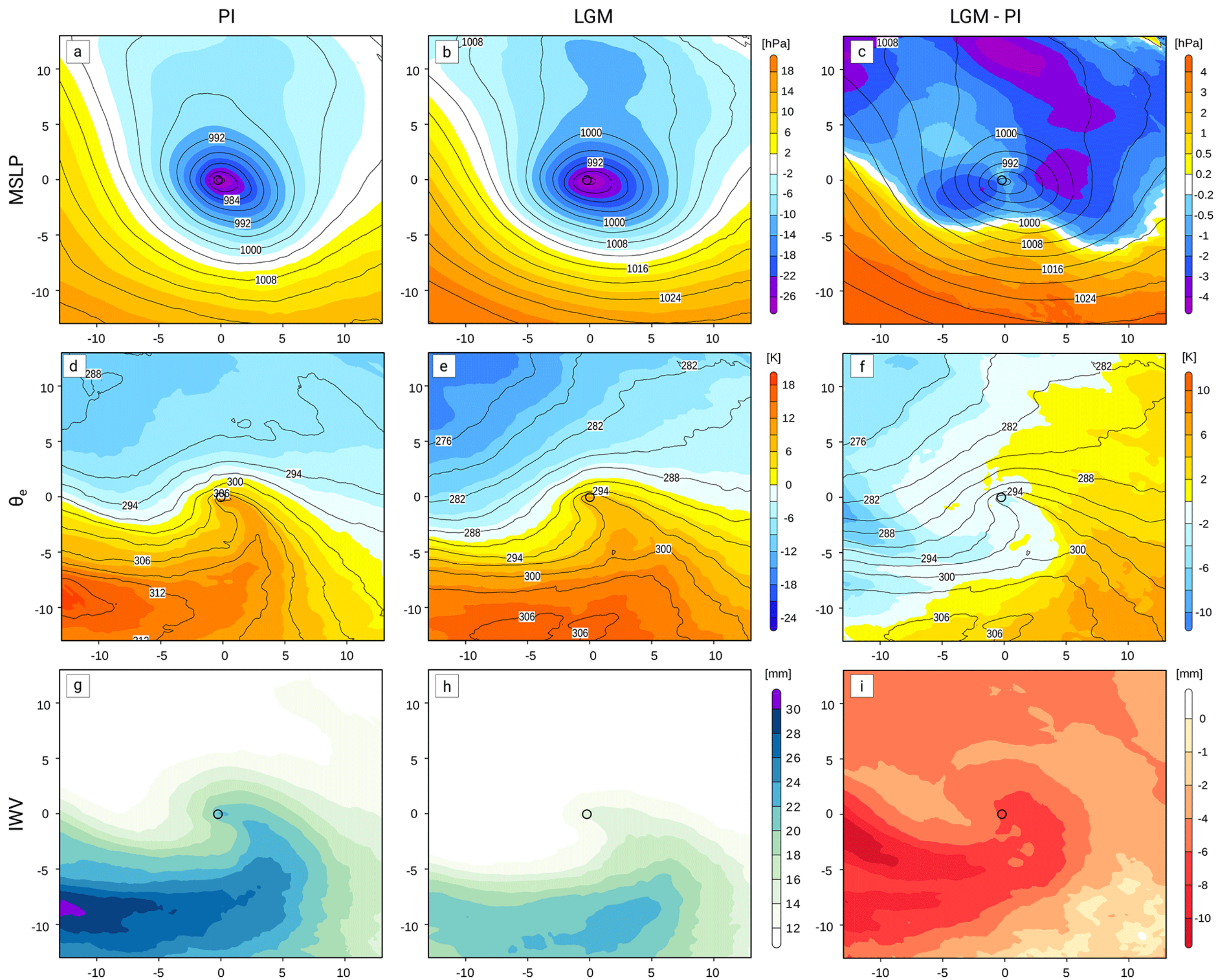


Figure 3: Composites of **(a–c)** mean sea level pressure, **(d–f)** θ_E and **(g–i)** vertical integrated water vapour (IWV) for PI, LGM and difference LGM – PI at peak intensity. **(a, b)** absolute MSLP values (lines; hPa), anomalies (hPa) from mean over displayed area (coloured); **(c)** absolute MSLP values (lines; hPa) from LGM, differences of the anomalies between LGM and PI in colours; **(d, e)** absolute θ_E values (lines; K) and anomalies (K) from mean over displayed area (coloured); **(f)** absolute θ_E values (lines; K) from LGM, differences of the anomalies between LGM and PI in colours; **(g, h)** absolute IWV values (mm); **(i)** difference (mm) LGM – PI.

Key Figures

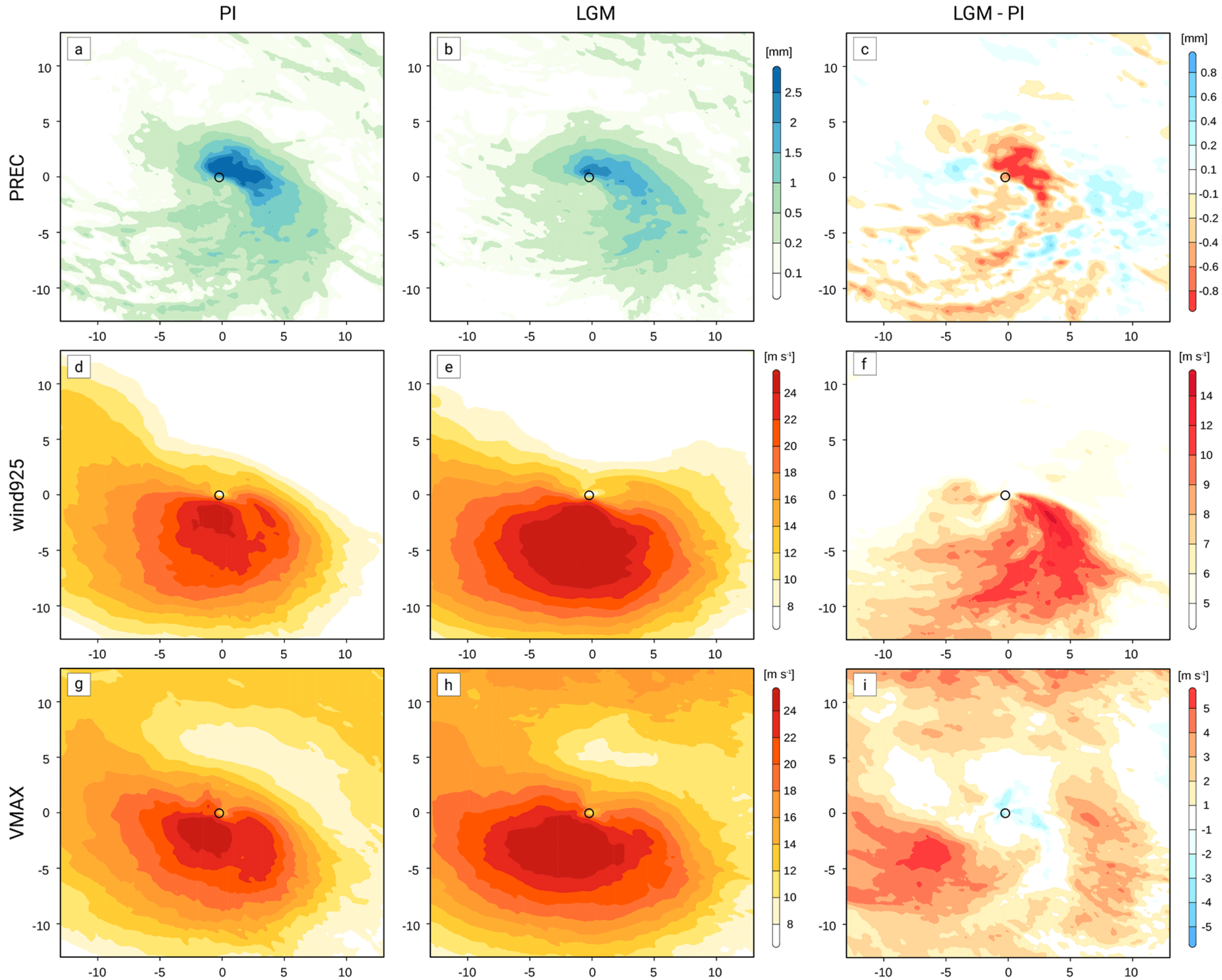


Figure 4: as Fig. 3 but for hourly precipitation (mm) **(a)** PI, **(b)** LGM, **(c)** LGM – PI, **(d–f)** wind speed in 925 hPa ($m\,s^{-1}$) and **(g–i)** maximum near-surface wind gust ($m\,s^{-1}$) at peak intensity.