The climate state in Southern Africa during the Last Glacial Maximum (SALMAX)

Investigation of the impact of large-scale climate feedback mechanisms on the Kalahari Desert region with the EMAC model system

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In Short

- The climate state during the Last Glacial Maximum (LGM) was globally characterized by colder and drier conditions.
- Highstands of departed paleo-lakes in the Kalahari during the LGM show a differing regional state.
- What are the reasons for this contrary climate response on regional scale?
- We address this question with simulations of a coupled atmosphere-ocean CCM.

Analyzing paleoclimate states reproduced by climate modeling is of central importance in the context of climate science in general. The investigation of paleoclimate simulations provides a unique opportunity to evaluate the commonly used models outside the variability of the past several decades, under which they have been developed and calibrated [1].
The LGM is one of the best-documented paleoclimate states, reconstructed by many paleoenvironmental proxy data, like ice cores and marine or terrestrial sediments. The LGM covered a period approximately between 24,000 and 18,000 years ago. Since the difference in the radiative forcing between the LGM and today is assumed to be of similar magnitude as the one predicted for the end of the 21st century [2], the investigation of the LGM climate could lead to a crucial advantage in evaluating models for future climate projections.
Reconstructions of the LGM climate state from paleoenvironmental proxy data (e.g., [3]) and numerical climate simulations (e.g., [4]) consistently show an annual-averaged global cooling. Furthermore, it is assumed that the decreased temperatures result in a worldwide weaker hydrological cycle. Thus, there is a general agreement about a global colder and drier climate during the LGM, which can be traced back to the external forcings of the climate system in terms of modulated Earth's orbital parameters and lower greenhouse gas concentrations resulting in greater extended continental ice sheets.
In contrast to the global climate response, more disagreement exists about regional climate aspects. In our project, we are focusing on the paleoclimate response of the southern African continent, especially the area of the Kalahari, which is nowadays indicated by a relatively dry climate.
Recent proxy-based studies [5],[6] assume a relatively warm and humid climate in the Kalahari during the LGM. Their assumptions are based on paleolake highstands. However, there is no final explanation for this deviation from the assumed global response of the climate system. Thus, the SALMAX project intends to analyze potential physical pathways of moisture transport into the Kalahari based on multidecadal timeslice experiments to understand the development of the mentioned paleolakes. The idea of a southward movement of the tropical precipitation belt faces the concept of a northward shift of the winter rainfall zone [5]. Figure 1 illustrates the current climate conditions for Southern Africa, indicating rainfall territories as well as the major atmospheric and oceanic circulation systems.
We will perform several numerical climate experiments using the chemistry-climate model EMAC [7]. SALMAX will incorporate a pre-industrial reference simulation and two simulations forced by LGM conditions. The strategy for composing the LGM

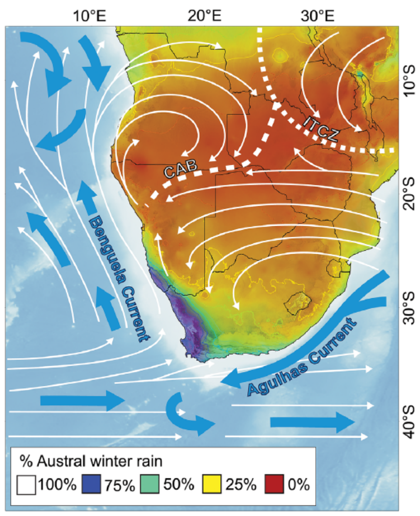

***Figure 1:** Map of southern Africa showing [present-day; author's note] seasonality of rainfall and sharp climatic gradients dictated by the zones of summer/tropical (red) and winter/temperate (blue) rainfall dominance from [9]. Winter rainfall is primarily a result of storm systems embedded in the westerlies. Major atmospheric (white arrows) and oceanic (blue arrows) circulation systems and the austral summer positions of the Inter-Tropical Convergence Zone (ITCZ) and the Congo Air Boundary (CAB) are indicated.*

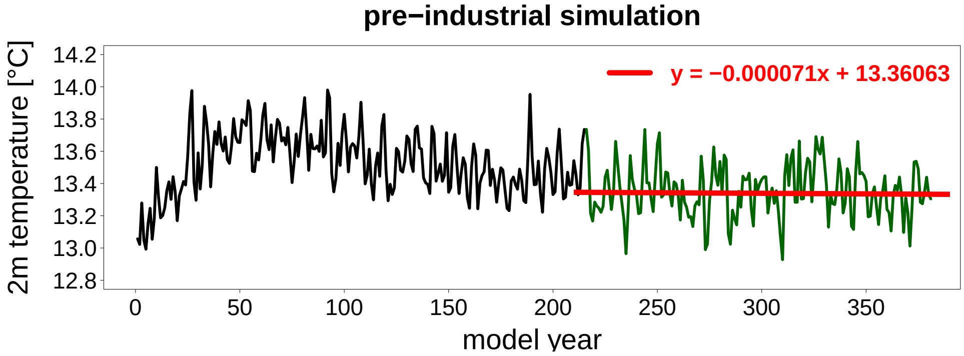

***Figure 2:** Modeled global annual mean 2m temperature of the pre-industrial reference simulation over currently integrated 380 model years. The green curve shows temperature development after a spin-up of circa 200 model years. The red line indicates the temperature trend after the spin-up.*

experiments is to gradually adjust the external forcings, beginning with a change in greenhouse gas concentrations, then modifying the Earth's orbital parameters and the distribution and altitude of the continental ice sheets.

One benefit of the EMAC model system is the implementation of the middle atmosphere. That allows us to investigate the effect of a changed stratospheric ozone distribution due to the integrated LGM boundary conditions forcing and if ozone could have played a significant role during the LGM climate formation. Besides the impact of ozone, the focus will lie on analyzing the uncertainty of ice sheet forcing and the examination of potential drivers for regional climate change, like an extension of Antarctic shelf ice, a changed Agulhas or Benguela ocean current (cf. Figure 1), or the ocean upwelling near the Namibian coast.

We will use EMAC as an atmosphere-ocean CCM coupled to the MPIOM ocean model [8]. Without a sufficient representation of the oceanic circulation, like the Atlantic Meridional Overturning Circulation (AMOC), temperature anomalies could be underestimated [4].

Figure 2 shows the current state of the pre-industrial reference simulation reaching equilibrium after a spin-up of circa 200 model years.

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https://www.geo.fu-berlin.de/en/met/ag/strat/index.html

More Information

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