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 Desert during the LGM show a deviant 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.

Simulating and analyzing paleo-climate states is of central importance in the context of climate science in general. Since commonly used climate models are developed and calibrated under the climate variability of the past several decades, the consideration of paleo-climate is significant for predicting future scenarios. The examination of climate states outside the range of the current variability helps to gain insights into the model's reliability for past and future climate projections.

The LGM is a well-documented paleo-climate era that can be reconstructed by many paleo-environmental proxy data, like ice cores, marine or terrestrial sediments. The LGM is dated 24,000 to 18,000 years before present and was characterized by large ice sheets extending far more south than today. The global ice volume was at its maximum, while the eustatic sea level was close to a minimum. Vegetational distribution was substantially different from today, expressed through less productive terrestrial ecosystems of different composition and generally shifted toward the equator [1].

Both reconstructions from paleo-environmental proxy data (see e.g. [1]) and numerical climate simulations (see e.g. [2]) consistently show an annual-averaged global cooling during the LGM. Furthermore, it is assumed that the decreased temperatures result in a worldwide weaker hydrological cycle. However, while many models capture the large-scale changes in the climate conditions of the LGM quite well, their ability to represent the magnitude of regional-scale patterns and their spatial distribution

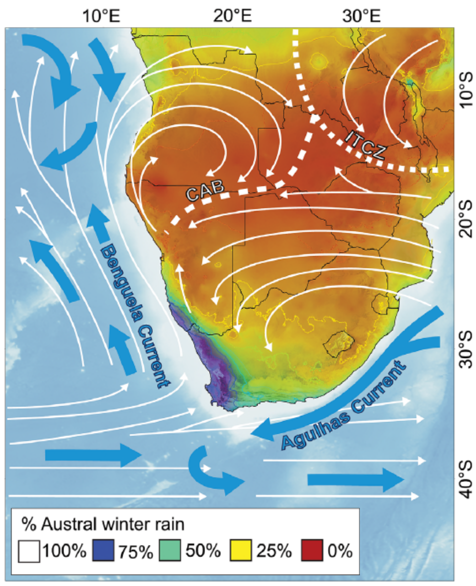

***Figure 1:** Map of southern Africa showing [present-day; author's note] seasonality of rainfall and sharp climatic gradients dictated by the zones of summer/tropical (red) and winter/temperate (blue) rainfall dominance from [8]. Winter rainfall is primarily a result of storm systems embedded in the 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.*

is limited. This limitation is more distinctive related to precipitation patterns than to temperature distributions [3]. Such inconsistency is observable for modeling results for Southern Africa, especially for the Kalahari Desert region. The models generally differ in the reproduction of precipitation patterns and additionally demonstrate uncertainty regarding the moisture transport mechanisms to the target region. The idea of a southward movement of the tropical precipitation belt faces the concept of a northward shift of the winter rainfall zone [4]. For comparison purposes, Figure 1 shows the current climate conditions for Southern Africa, indicating rainfall territories as well as the major atmospheric and oceanic circulation systems.

Recent geological and geographical field studies provide new insights associated with highstands of huge paleo-lakes in the Kalahari Desert, which are significant indications for a humid climate during the LGM [4],[5].

Since there is so much controversy about the climate conditions in Southern Africa during the LGM, we aim to gain more insights into the large-scale

processes influencing this specific region. Therefore, we will perform numerical climate simulations, by the means of time slice experiments, with a set of full forcing LGM boundary conditions with the CCM EMAC (ECHAM/MESSy Atmospheric Chemistry) with and without interactive chemistry [6].
One benefit of the EMAC model system is the implementation of the middle atmosphere, especially the stratosphere. For this reason, it is feasible to investigate 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. Therefore, we will use EMAC as an atmosphere-ocean CCM coupled to the MPIOM ocean model [7]. The integration of a three-dimensional interactive ocean is of significant importance. Without a sufficient representation of the oceanic circulation, like e.g. the Atlantic Meridional Overturning Circulation (AMOC), temperature anomalies could be underestimated [2].

WWW

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

More Information

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Project Partners

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