Paleoclimate Applications of Mixing Parameterizations in an Earth System Model

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In Short

- This project aims at performing state-of-the-art paleoclimate reconstructions using the isotope-enabled Community Earth System Model (iCESM1.2) with an energetically consistent vertical mixing parameterization that is Internal Wave Dissipation, Energy and Mixing (IDEMIX).
- Understanding the large-scale ocean circulation and mixing processes of the Last Glacial Maximum (~21 ka) and mid-Cretaceous (~90 Ma) periods is the main focus of this project.
- Isotopes of Oxygen (^{16}O and ^{18}O), and Carbon (^{12}C and ^{13}C) during the LGM will be compared to the benthic foraminifera proxy records.
- The performance of IDEMIX will be evaluated for paleoclimate applications with respect to the pre-industrial (PI) climate.

This project is a part of the Collaborative Research Center (CRC) - Energy Transfer in Atmosphere and Ocean (TRR181). It is funded by the Deutsche Forschungsgemeinschaft (DFG). In this project, we focus on the large-scale circulation and mixing-related processes in the ocean during the Last Glacial Maximum (LGM, ~21 ka) and mid-Cretaceous (~90 Ma) in the fully coupled isotope-enabled Community Earth System Model version 1.2 (iCESM1.2).

During the LGM, the sea level was lower by around 130 m than the present day, which may have shifted the tidal-energy dissipation from the continental shelves to the open ocean thereby enhancing vertical mixing in the interior ocean [5]. On the contrary, the global sea level was higher by around 160 m during the mid-Cretaceous, resulting in larger continental shelf seas, thus transferring the tidal energy dissipation from the open ocean to the shelf seas [3].

Despite having different atmospheric compositions, sea levels, and continental configurations, proxy data from both the LGM and mid-Cretaceous demonstrate that oxygen availability was low (disoxia during the LGM, and near anoxia during the mid-Cretaceous) in the deep ocean. In this project, we will implement IDEMIX (Olbers Eden, 2013) in the Parallel Ocean Program version 2 (POP2) of iCESM1.2. The IDEMIX parameterization is developed to estimate the diapycnal diffusivity induced by the breaking of internal gravity waves [4]. For our project, we will work only with tidal-induced mixing.

We expect that using IDEMIX in this project gives a better understanding of the ocean state during LGM and mid-Cretaceous and helps to clarify the discrepancy between the model simulations and the proxy data, mainly records of stable oxygen and carbon isotopes from fossil shells of benthic foraminifera.

Our results illustrate the LGM ocean as more vigorous than the PI ocean when IDEMIX is used. With IDEMIX, the diffusivities are enhanced by almost two orders of magnitude, as the internal waves break over the underlying rough bathymetry. This increase can be seen not just at the ocean bottom but also throughout the entire water column, especially near the internal wave generation sites where the tidal energy dissipation is strongest (e.g., the Mid-Atlantic Ridge, high latitudes in the Atlantic).

Overall, IDEMIX does not make significant changes to the Atlantic Meridional Overturning Circulation (AMOC). It alters the strength of overturning by 2 Sv for both climates. Despite this small difference, the change in the structure of the North Atlantic Deep Water (NADW) cell which got shallower and weaker supports the agreement with proxy data [1,2].

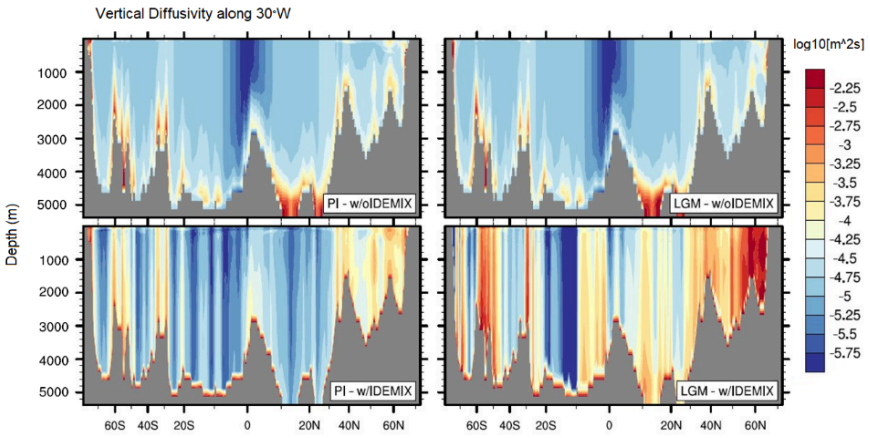

Figure 1. The vertical diffusivity log_{10} $[m^2/s]$ of PI and LGM along 30°W**,** with (bottom) and without IDEMIX (top)

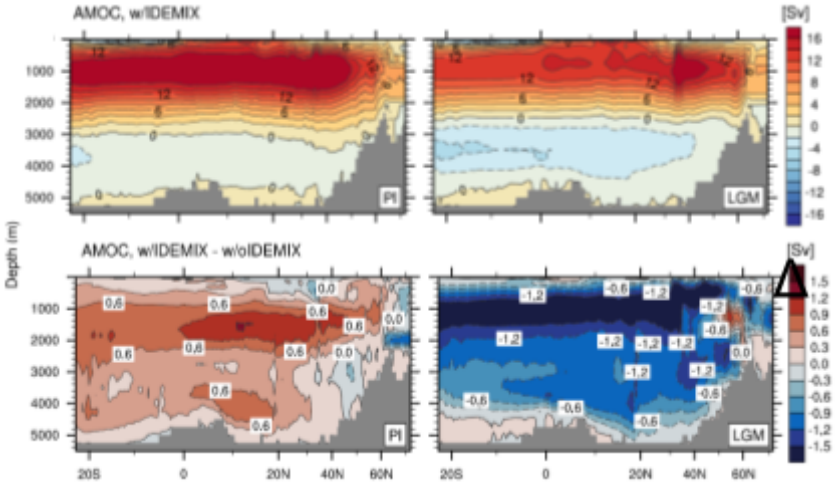

Figure 2. The mean of the last 100 years of AMOC Sv = 10^6 [m^3/s] of PI and LGM with IDEMIX (top), AMOC differences (ΔSv) for with and without IDEMIX cases (bottom)

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https://www.trr-energytransfers.de/

More Information

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Project Partners

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