Paleoclimate Applications of Mixing Parameterizations in an Earth-System Model

Studying the ocean circulation and biogeochemical cycles of LGM and mid-Cretaceous using iCESM1.2 with IDEMIX

H. Pilatin, S. Kattamuri, A. Paul, M. Schulz
MARUM - Center for Marine Environmental Sciences, University of Bremen

In Short

- This project aims at providing state-of-the-art paleoclimate reconstructions using the isotope-enabled Community Earth System Model (iCESM1.2) with an energetically consistent vertical mixing parameterization, Internal Wave Dissipation, Energy and Mixing (IDEMIX).
- Understanding the 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, ^{13}C, and ^{14}C) during the LGM and mid-Cretaceous will be compared to the benthic foraminifera proxy records.
- The performance of the IDEMIX module will be tested for paleoclimate applications.

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

During the LGM, sea level was lower by 130 m than the present day which may have shifted the tidal-energy dissipation from the continental shelves to the open-ocean enhancing vertical mixing in the interior ocean [3]. On the contrary, the global sea level was 100 m to 250 m higher during the mid-Cretaceous, resulting in larger continental shelf seas, thus transferring the tidal energy dissipation from the deep ocean to the shelf seas [1].

Despite having different atmospheric states, sea levels, and continental configurations, proxy data from both the LGM and mid-Cretaceous demonstrate that oxygen availability was low (deoxygenation during the LGM, anoxic conditions during the mid-Cretaceous) in the deep ocean.

In this project, we will implement the IDEMIX module (Olbers Eden, 2013) in the Parallel Ocean Program version 2 (POP2) of iCESM1.2. IDEMIX is an energetically consistent vertical mixing parameterization. It is developed to estimate the diapycnal diffusivity induced by breaking of internal gravity waves [2]. For our project, we will work only with tidal-induced mixing.

We expect that using IDEMIX in this compute 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.

We have conducted two PI test simulations with and without IDEMIX in Figure 1. Each simulation ran for 10 years. According to the depth-averaged vertical diffusivity, the dissipated energy is higher in the deep levels of the global ocean when the model runs without IDEMIX (Figure 1-i). Here, only a small portion of the energy is dissipated, and the rest is assumed to contribute to the background diffusivity. With IDEMIX, on the other hand, there is no background diffusivity or any other arbitrary energy source or sink. The diffusivities close to rough topography (e.g., North Atlantic Ocean, Southern Ocean, and some parts of the Pacific Ocean) are generally the same magnitude or even larger when IDEMIX is enabled in the model (Figure 1-ii). The IDEMIX coupled model can produce weak diffusivities for the regions with low tidal energy (e.g., near the Equator) and strong diffusivities for the regions with high tidal energy (e.g., North Atlantic Ocean).

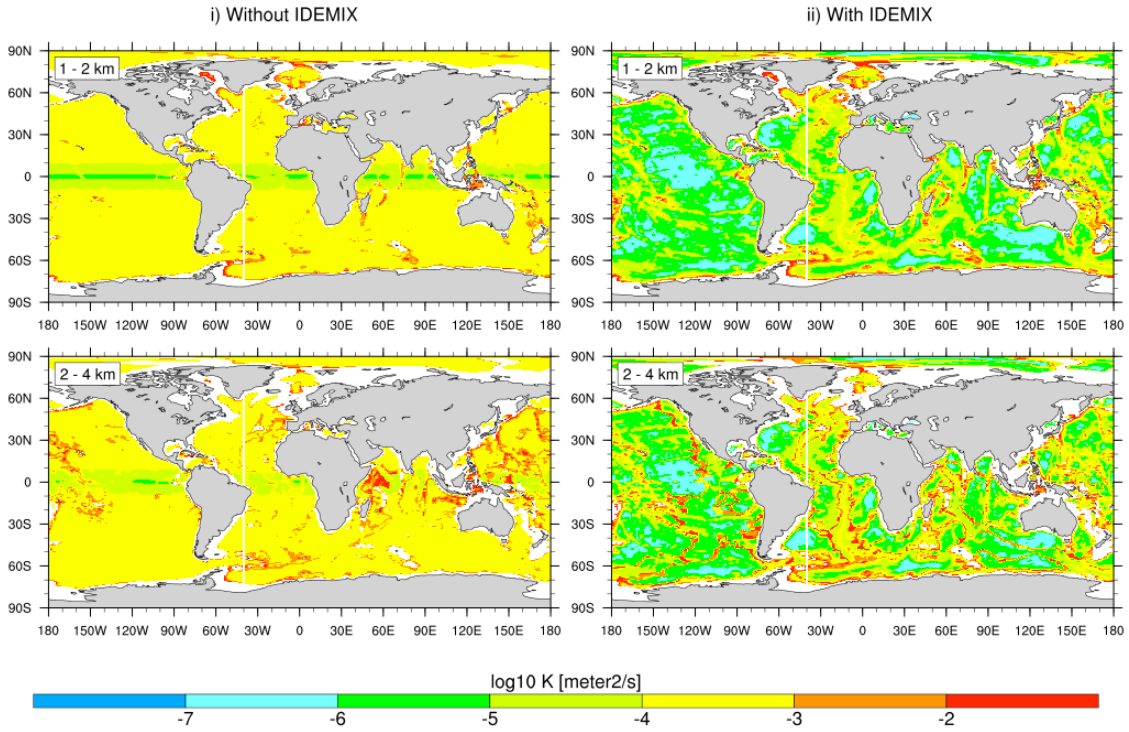

Figure 1: Vertical diffusivity averaged over 1-2 km and 2-4 km depths. i) Without IDEMIX ii) With IDEMIX

WWW

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

More Information

[1] Olbers, D.J., Eden, C. (2013). A Global Model for the Diapycnal Diffusivity Induced by Internal Gravity Waves. Journal of Physical Oceanogra- phy, 43, 1759-1779. doi: https://doi.org/10.1175/JPO-D-12-0207.1

[2] Sewall, J. O. (2007). Climate model boundary conditions for four Cretaceous time slices. Clim. Past, 11.

[3] Tarasov, L., Dyke, A. S., Neal, R. M., and Peltier, W. R.: A data- calibrated distribution of deglacial chronologies for the North American ice complex from glaciological modelling, EPSL,315–316,30-40, https://doi.org/10.1016/j.epsl.2011.09.010,2012

Project Partners

CEN, MARUM, Jacobs University, MPI, AWI, IAP, IOW, HZH, Universität Hamburg and Universität Bremen, Technische Universität Hamburg and Goethe-Universität Frankfurt.

Funding

Deutsche Forschungsgemeinschaft (DFG)