Modelling the ocean circulation of the mid-Cretaceous using the Community Earth System Model (iCESM1.2) and IDEMIX

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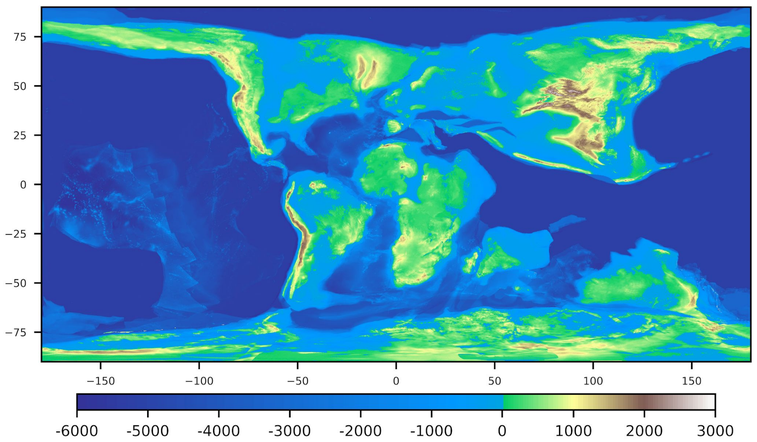
Motivation

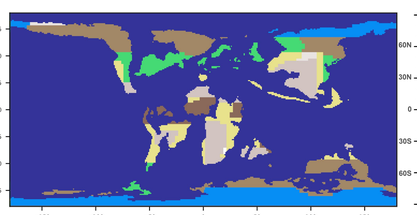
A higher sea level and larger continental shelf areas during the mid-Cretaceous might have impacted the tidal energy dissipation and ocean circulation and consequently favoured conditions for a near-anoxic deep ocean environment.

The aim is to test this hypothesis by studying the impact of the geophysical conditions of this period on tidally-induced turbulent mixing and ocean circulation using the energetically consistent “Internal Wave Dissipation, Energy and Mixing” (IDEMIX) parameterization in iCESM1.2.

Model setup

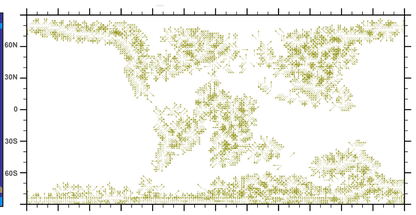


Elevation in metres for a +160 m highstand for the 90 Ma geography. Base geography adopted from Scotese and Wright 2018.

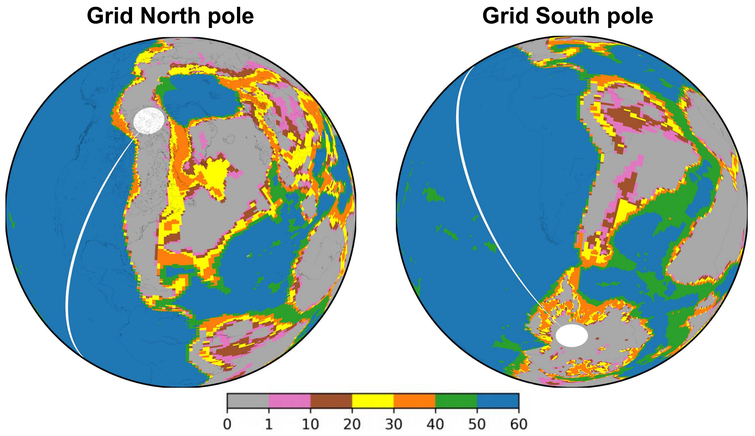


Land Surface Model (LSM) biome definition
cool needleleaf evergreen forest
warm needleleaf evergreen forest
savanna
cool forest crop
warm forest crop
evergreen shrubland
deciduous shrubland
semi-desert

Biomes with PFTs for the land model adopted from the 90 Ma vegetation distribution from Sewall et al. 2007

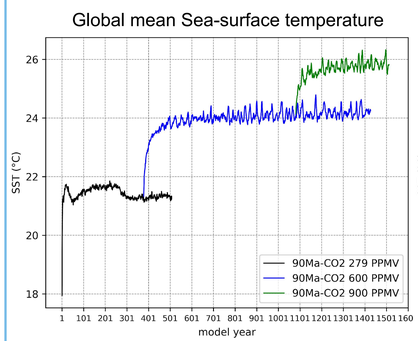


Runoff data for the River Transport Model prepared from the topography with vectors showing the direction of drainage

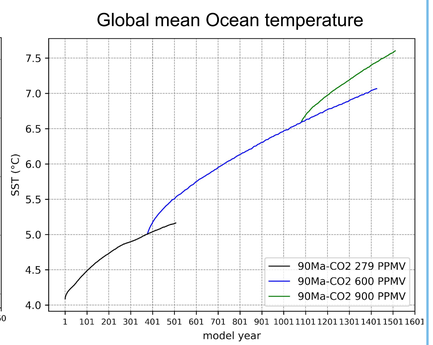


Elevation as KMT values on the dipole grid for the ocean model

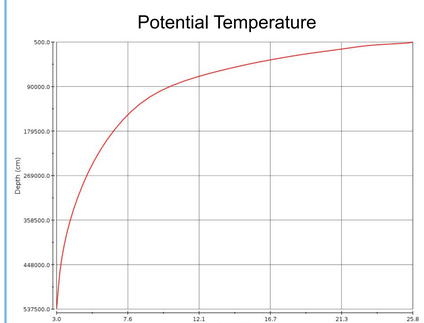
Simulations and first results



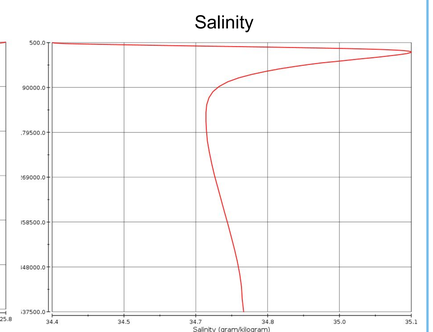
Sea-surface temperature for simulations with three different CO_2 concentrations



Mean ocean temperature for simulations with three different CO_2 concentrations

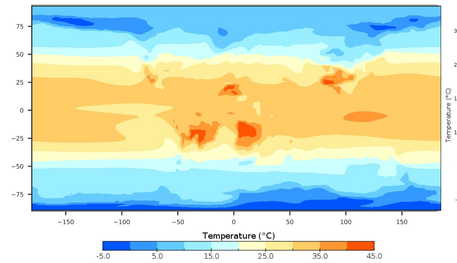


Temperature profile for 90Ma with CO_2 900 ppm

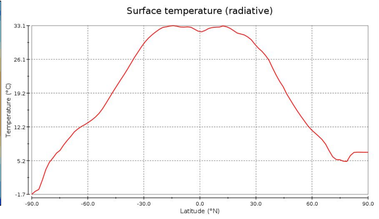


Salinity profile for 90Ma with CO_2 900 ppm

Atmosphere

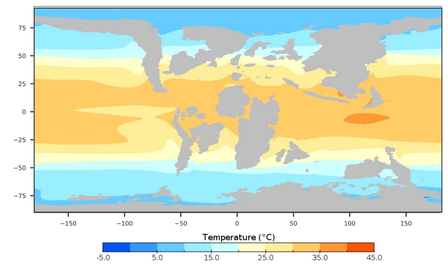


Near-surface air temperature for 90Ma with CO_2 900 ppm

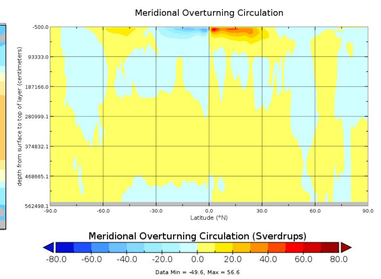


Zonal mean near-surface air temperature

Ocean



Sea-surface temperature for 90Ma with CO_2 900 ppm



Global meridional overturning circulation

Summary

- Boundary conditions for CESM1.2 model input were prepared for 90 Ma topography with an estimated sea level rise of 160 m.
- Simulations with an atmospheric CO_2 concentration of PI level (279 ppm), ~2x (600 ppm) and ~3x (900 ppm) were performed for ~500 years each.
- For these preliminary simulations, the tidal mixing component had to be turned off and constant background vertical velocity parameters were used instead, to avoid instabilities with the new geography.
- The global MOC for the 900 ppm simulation indicates weak overturning in the deep ocean and only a likely wind-driven circulation near the surface. This demonstrates the importance of tidal mixing parameterisation for mixing analytics in the ocean model.
- To continue the 900 ppm simulation, IDEMIX will be included and will be forced with tidal energy prepared from the bathymetry using the method from Jayne & St. Laurent, 2001. $E \simeq \frac{1}{2}\rho N_b \kappa h^2 u^2 . [\mathrm{Wm}^{-2}]$
- Sensitivity experiments will be performed with no shelves (+0m sea level) and for different tidal current velocities to understand the impact of these parameters on ocean circulation.