Impact of marine gateways on the Northern Hemisphere polar climate in the Late Cretaceous as simulated by an Earth System Model

Igor Niezgodzki1,2,3, Gregor Knorr2,3, Gerrit Lohmann3,4, Jaroslaw Tyszka1
(1) Institute of Geological Sciences Polish Academy of Sciences, Krakow, Poland; (2) Alfred Wegener Institute, Bremerhaven, Germany; (3) School of Earth and Ocean Sciences, Cardiff University, Cardiff, United Kingdom; (4) MARUM-Center for Marine Environmental Sciences, University Bremen, Bremen, Germany;

Maastrichtian, Late Cretaceous (70 Ma) set-up

Introduction

- We simulate Maastrichtian (70 Ma) climate using state-of-the-art coupled atmosphere-ocean general circulation model (AOGCM) COSMOS.
- The paleogeography is adjusted following Markwick and Valdes, (2004) to the AOGCM model (Figs 2 and 3a).
- Vegetation is prescribed (Fig. 4) following Sewall et al. (2007).
- CO₂ level is set to the 1120 ppm level (4xpre-industrial) and additionally to 280 ppm (1xpre-industrial) for the sensitivity tests. CH₄ and N₂O levels are set to pre-industrial levels.
- Orbital parameters are set to present day and solar constant is reduced by 1% and is equal 1353.33 W/m².

Results with standard paleobathymetry and 4xpre-industrial CO₂ level as simulated by AOGCM

Conclusions

- 4 times higher than pre-industrial CO₂ level is a sufficient factor to maintain Maastrichtian greenhouse world with warm northern polar region (Figs 1-3) and without existence of even seasonal sea ice (Fig. 9).
- Mixed layer depth is shallow on both hemispheres under high CO₂ level and overturning circulation is sluggish, so the latter can not be regarded as a dominant transporter of heat from low to high latitudes.
- Depth of mixed layer is controlled by CO₂ level and by the bathymetry (Figs 8 and 15).
- Arctic Ocean in the Late Cretaceous is brackish, the salinity in the ocean is controlled i.e. by the depth of the gateways between Arctic and Atlantic Oceans (Figs 13-14).
- Sensitivity tests

Sensitivity tests with varying depth of Norwegian-Greenland Sea

Results with standard paleobathymetry and 4xpre-industrial CO₂ level as simulated by AOGCM

Conclusions

- 4 times higher than pre-industrial CO₂ level is a sufficient factor to maintain Maastrichtian greenhouse world with warm northern polar region (Figs 1-3) and without existence of even seasonal sea ice (Fig. 9).
- Mixed layer depth is shallow on both hemispheres under high CO₂ level and overturning circulation is sluggish, so the latter can not be regarded as a dominant transporter of heat from low to high latitudes.
- Depth of mixed layer is controlled by CO₂ level and by the bathymetry (Figs 8 and 15).
- Arctic Ocean in the Late Cretaceous is brackish, the salinity in the ocean is controlled i.e. by the depth of the gateways between Arctic and Atlantic Oceans (Figs 13-14).
- Sensitivity tests

Sensitivity tests with varying depth of Norwegian-Greenland Sea

We set the depth of the Norwegian-Greenland seaway from the -1500 m to being entirely closed for different experiments. The paleodepth range follows realistic interpretations based on the sedimentary record and microfossil proxies, including foraminifers and dinoflagellate cysts.

Experiments reveal that the depth of the seaway has no impact on temperature in the Arctic Ocean nor on the precipitation-evaporation values in high latitudes. It changes however surface salinity in the Arctic Ocean which varies from around 7 psu (closed seaway) to around 24 psu (deep seaway).

The project has been financed from the resources of the National Center of Science based on the decision DEC-2012/07/N/ST10/03419.