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

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The greenhouse climate in the Late Cretaceous is considered as an analogue for the future as a result of greenhouse gases emissions. The northern polar region is particularly sensitive to anthropogenic changes and plays one of key roles in controlling global climate. This makes the region and the time frame significantly important for investigations. We investigate the impact of the gateways connecting the North Atlantic and the Arctic Ocean on the structure and ocean dynamics of the northern high-latitude marine basins and their overall effect on the Late Cretaceous climate. The main aim of this work is to analyze:
1. sensitivity of climate in northern polar region to the configurations and depths of the marine connections between the North Atlantic and the Arctic Ocean;
2. dynamics of marine basins in the northern high latitudes as a result of changes in the depth of the gateways between both basins;
3. Arctic Ocean ventilation changes as a result of different depths and configurations of the Norwegian – Greenland Sea.
The COSMOS Earth System Model was initialized with Maastrichtian boundary conditions (70 MA). The Norwegian – Greenland Sea is changed from 1500 m depth to being entirely closed. The paleodepth range follows realistic interpretations based on the sedimentary record and microfossil proxies, including foraminifers and dinoflagellate cysts.

Simulated Late Cretaceous climate with 4xpre-industrial (1120 ppm) CO_2 level and the original paleogeography show an almost absent of perennial sea ice in both Arctic and Southern Oceans. Additionally, the Arctic Ocean was brackish with annual sea surface salinity around 13 psu and higher than today annual surface temperatures of 5°C. Our studies reveal very week overturning circulation in the Pacific Ocean with convection sites in the southern high latitudes with a maximum depth of around 475 m and shallow northern Pacific with maximum depth of 300 m. The convection sites for pre-industrial (280 ppm) CO_2 level are much deeper with the depth of around 1150 m and 950 m for the southern and northern high latitudes, respectively. The simulations show that the Arctic Ocean is almost completely frozen for the pre-industrial CO_2 level. For the 4xCO_2 level, the annual surface air temperatures in the Arctic are above freezing and the equatorial temperatures can be close to 50°C in some areas over Africa and South America. The equator-to-pole surface temperature gradient is around 30°C, much shallower than for the present day situation.