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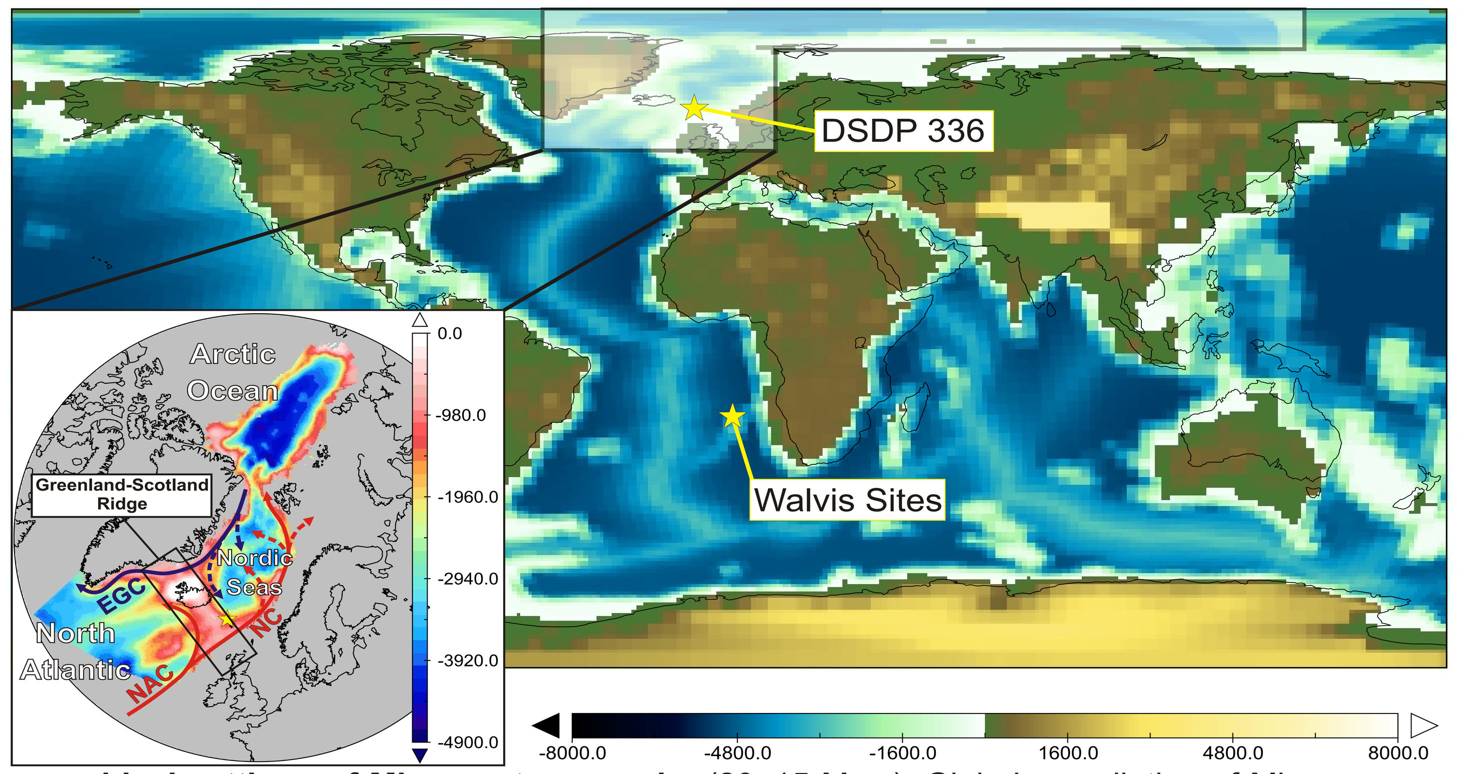
North Atlantic-Arctic circulation controlled by the Oligocene-Miocene subsidence of the Greenland-Scotland Ridge

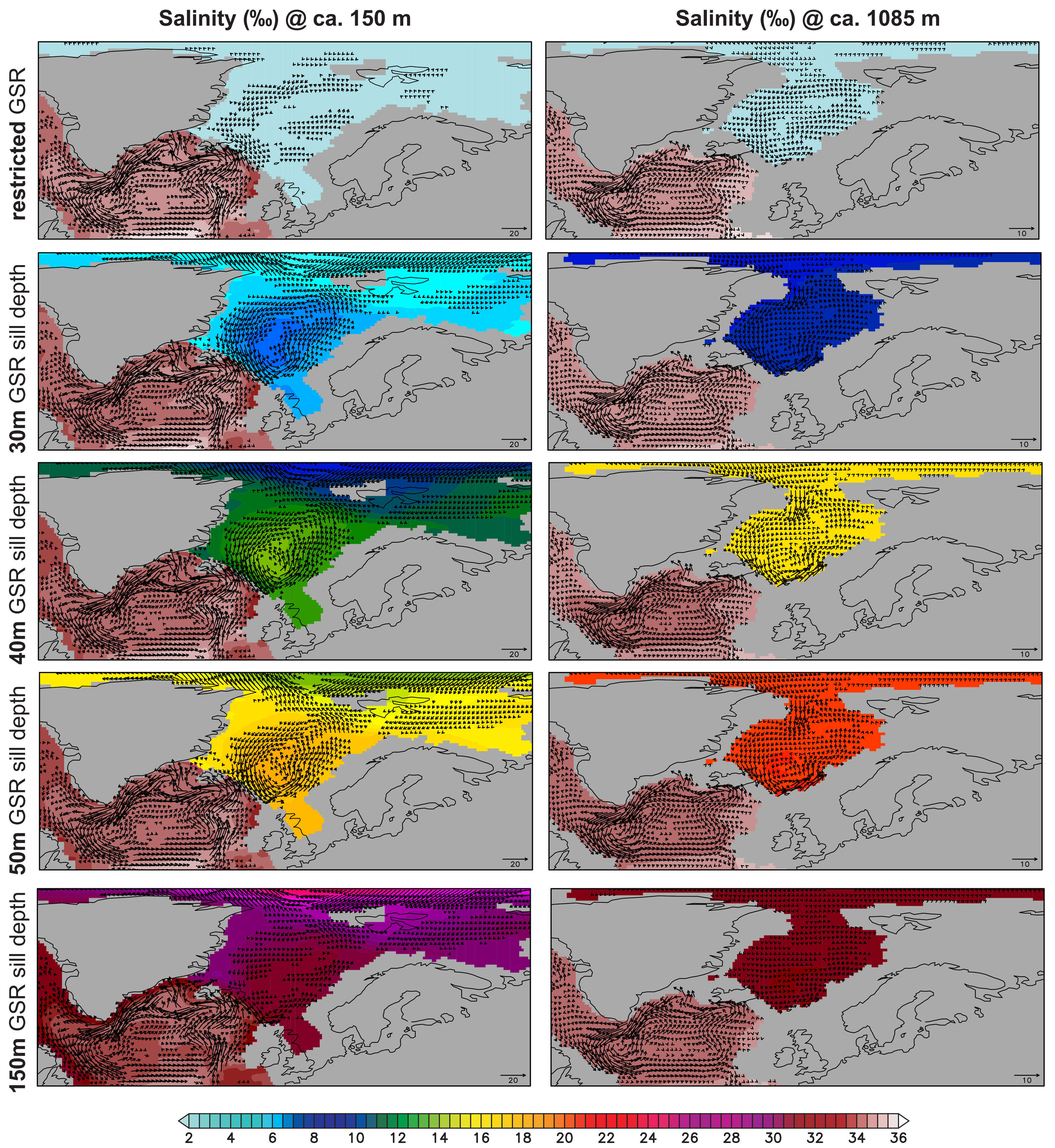
Background information

During the Oligocene/early Miocene interval (35–16 Ma), the subsidence of the Greenland-Scotland Ridge (GSR) from subaerial conditions towards a submarine rise constitutes an active ocean gateway control of North Atlantic-Arctic water exchange. Although the long-term evolution of such ocean gateway development on adjacent ocean water mass characteristics is generally accepted to induce basin-scale reorganizations, the climatic impacts, as well as the associated mechanisms of climate changes remain largely elusive. Here, we investigate the effect of the GSR subsidence with the aid of a fully coupled Earth System Model (ESM) COSMOS (see refs.):



Geographical settings of Miocene topography (20–15 Myrs). Global compilation of Miocene geography (elevation and depth in metres; modified data from Herold et al., 2008) embedding a high resolution (0.5°) bathymetric dataset comprising the northern North Atlantic, Nordic Seas and the Eurasian Basin in the Arctic Ocean (Ehlers and Jokat, 2013). The schematic circulation shows pathways of the North Atlantic Current (NAC), the Norwegian Current (NC) and the East Greenland Current (EGC). The yellow star reflects the location of DSDP site 336 (ref. 7) at the northern flank of the GSR.

Results

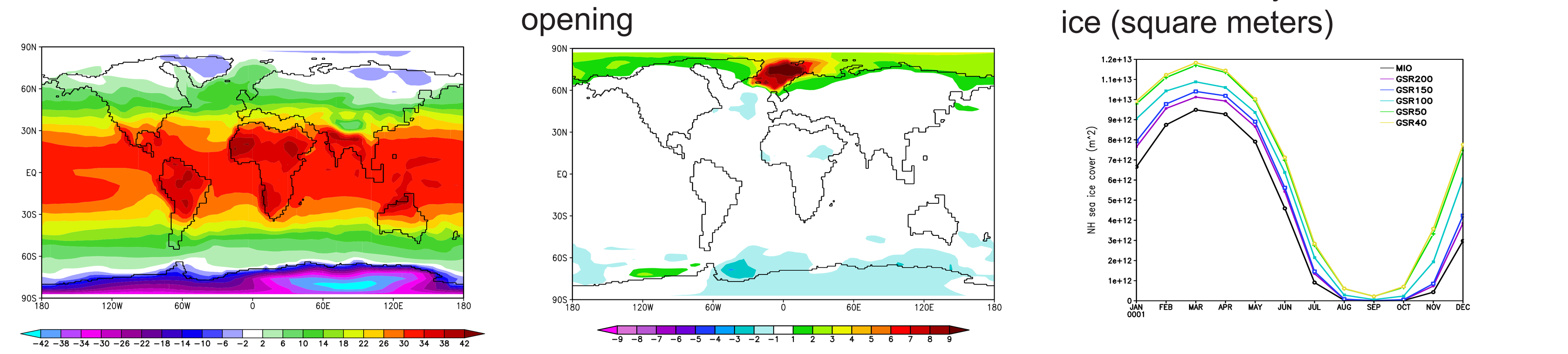


Seaway opening evolution in context of the Greenland-Scotland Ridge (GSR) subsidence history. **Salinity (‰) and ocean velocity** (**cm•s-1**; velocities <0.5 cm•s-1 are not shown) maps at shallow (150 m) intermediate water depths (1085 m) for the Miocene scenarios at different sill depths of the GSR.

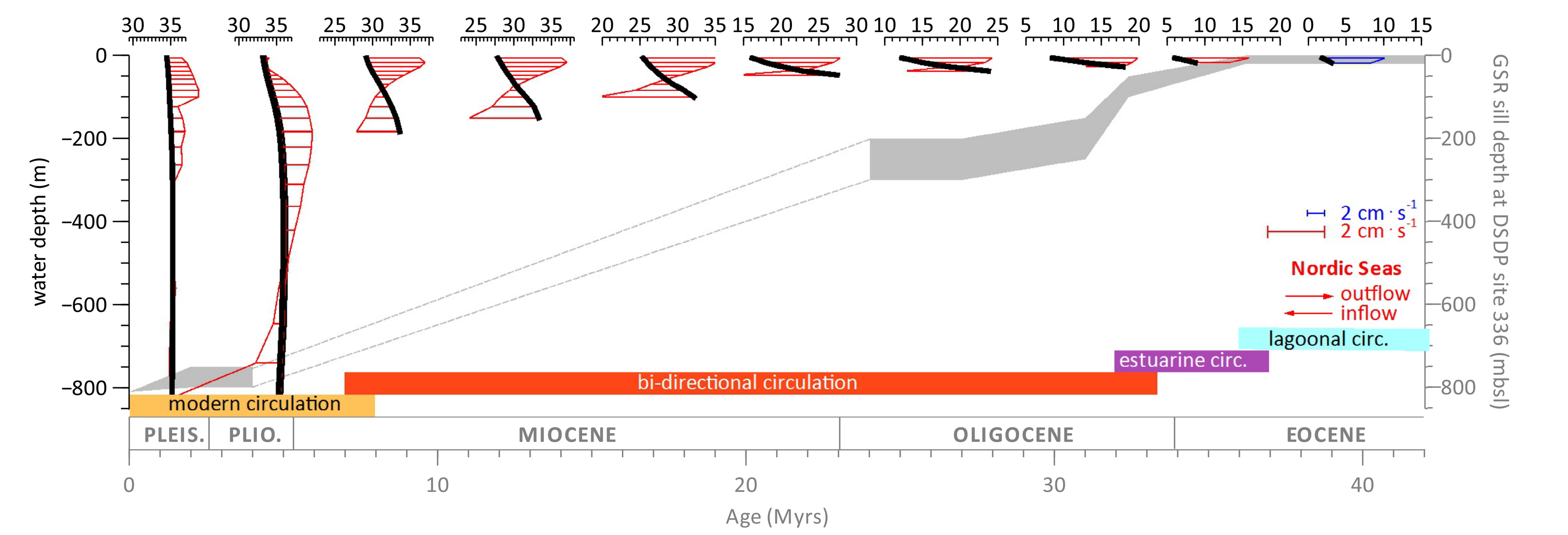
Absolute Miocene surface air temperature (°C)

Miocene surface air temperature anomaly (°C) induced by the seaway opening

effect of limiting the GSR seaway on the seasonal cycle of the Arctic sea ice (square meters)



Mean Miocene climate (left panel) and the impact of the Greenland-Scotland Ridge seaway opening on the surface air temperatures (°C, middle panel) and the seasonal cycle of the sea ice in the Northern hemisphere. The GSR seaway opening induces a pronounced warming in the high northern latitudes as well as the removal of perennial sea ice in the Arctic Ocean.



Seaway opening evolution in context of the Greenland-Scotland Ridge (GSR) subsidence history. Modelled salinity (black) and velocity (blue/red) profiles across the GSR section for the preindustrial and Miocene GSR sill depths are displayed in context of the subsidence evolution as derived from DSDP site 336 (Clift et al., 1995).

Conclusions

A deepening of the ridge to ca. 100 metres below sea-level forces major reorganizations in the North Atlantic-Arctic circulation associated with extreme salinity, temperature and sea ice changes in the Arctic Ocean. Taking uncertainties in timing into account this suggests that tectonic processes, which started at the late Eocene to Oligocene controlled the climate and circulation regime of the Arctic Ocean.

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