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The effect of a flexible hydrological discharge model on the climate of the Middle Miocene

Motivation and Setup

Uncertainties in deep time climate, i.e. the Middle Miocene (~20-14 Ma BP), and boundary conditions (e.g., CO2, ice sheets, topography, etc.) are considerably large (Fig. 1). Here, we study the climate effect of different methodological approaches of continental freshwater redistribution towards the ocean. We employ the standard hydrological discharge model (HD) of the Earth System Model (ESM) COSMOS (see refs.) with a flexible hydrological discharge model (FHD), both fully coupled in the ESM:

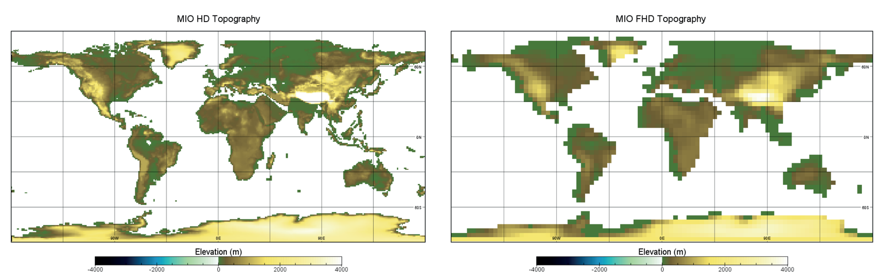
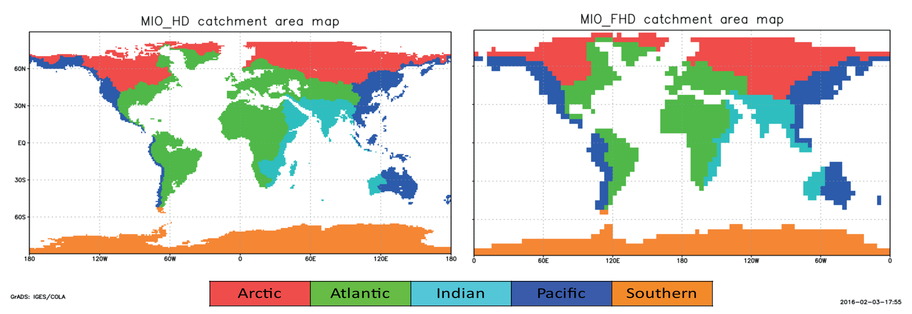


Fig. 1:
Middle Miocene topography (modified data from Herold et al., 2008) that is used by the HD model (left panel) and the FHD model (right panel).



Catchment areas for each respective ocean basin as represented in the HD model (left panel) and the FHD model (right panel).

The HD model uses high spatial resolution orography for the Middle Miocene to calculate river routing, following the steepest slope of the terrain, whereas the FHD uses orography at identical grid resolution as the atmosphere model, and takes the dynamic topography of continental water levels into account (Fig. 2):

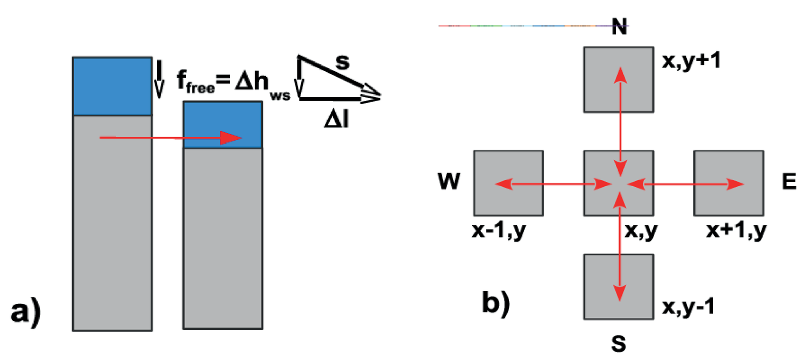
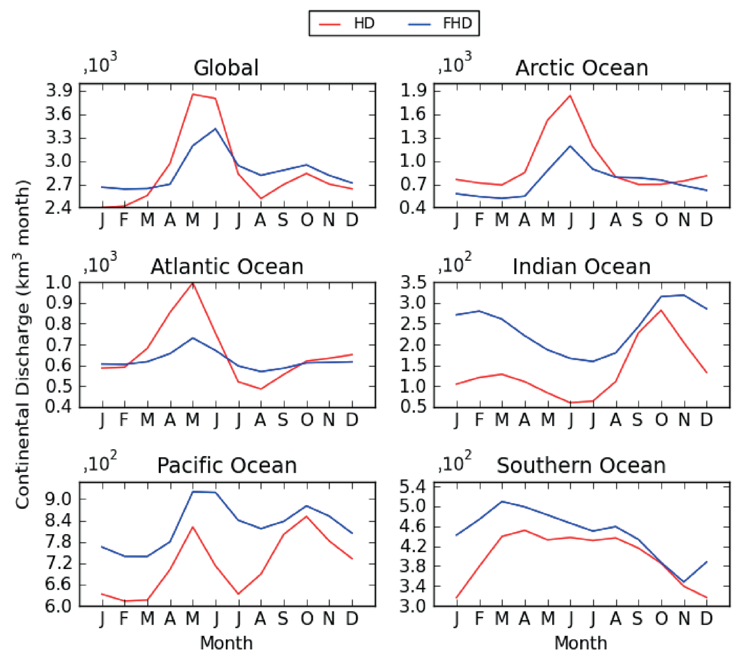
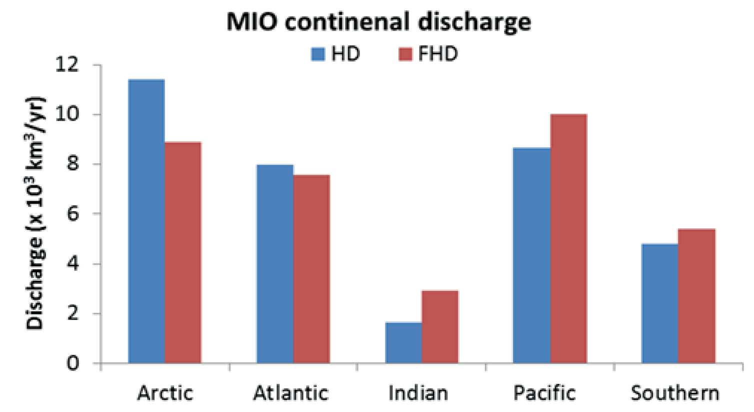


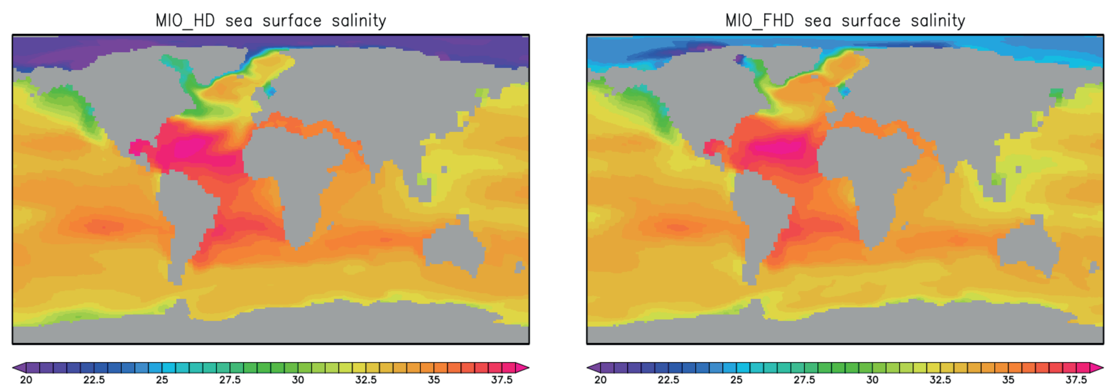
Fig. 2:
a) The **flow direction** (red arrow) of the FHD model follows the steepest slope of terrain and additionally considers the dynamic topography (water height).
b) Possible flow direction of discharge between neighbouring grid cells in the FHD.

Results

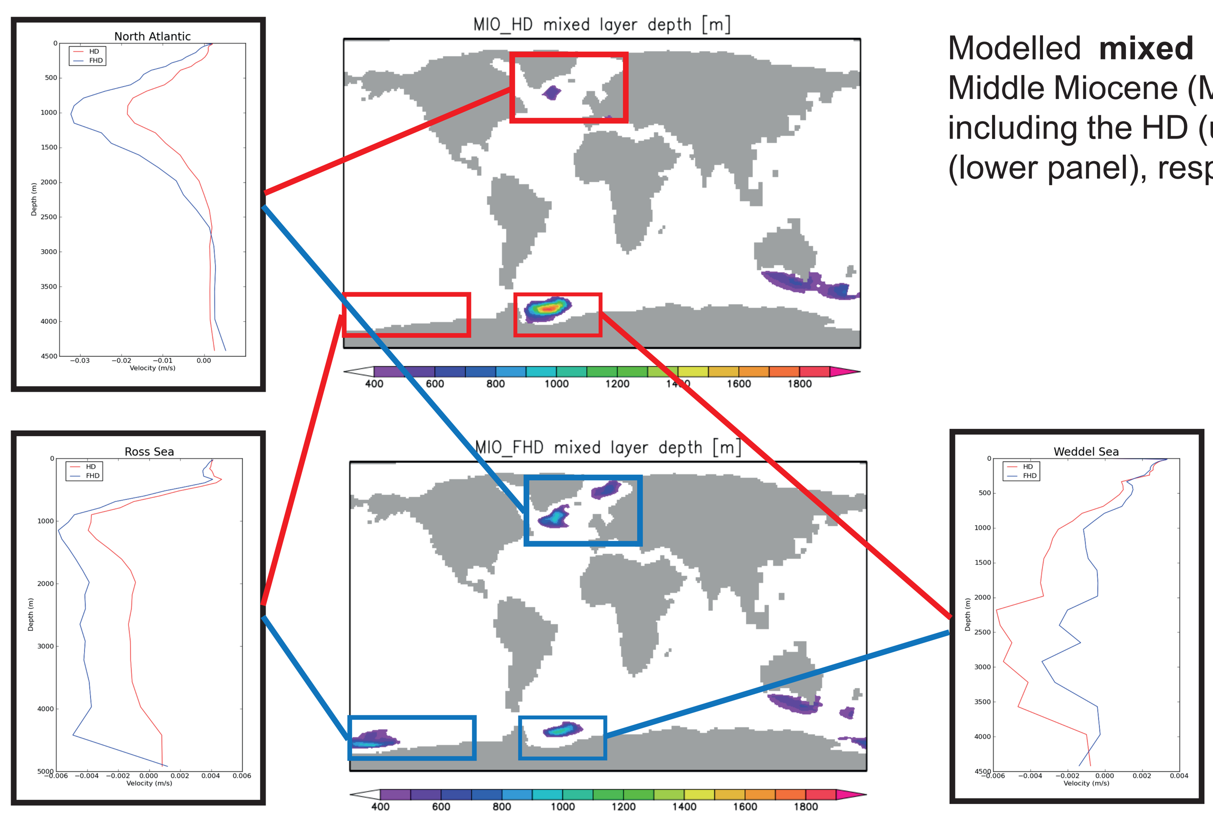




Continental discharge, as derived from the discharge routing with HD and FHD for the Middle Miocene (MIO). Right panel compares climatological mean, left panels compare the seasonal cycle of continental discharge between HD and FHD for each of the five ocean basins. Arctic Ocean changes are strongest.

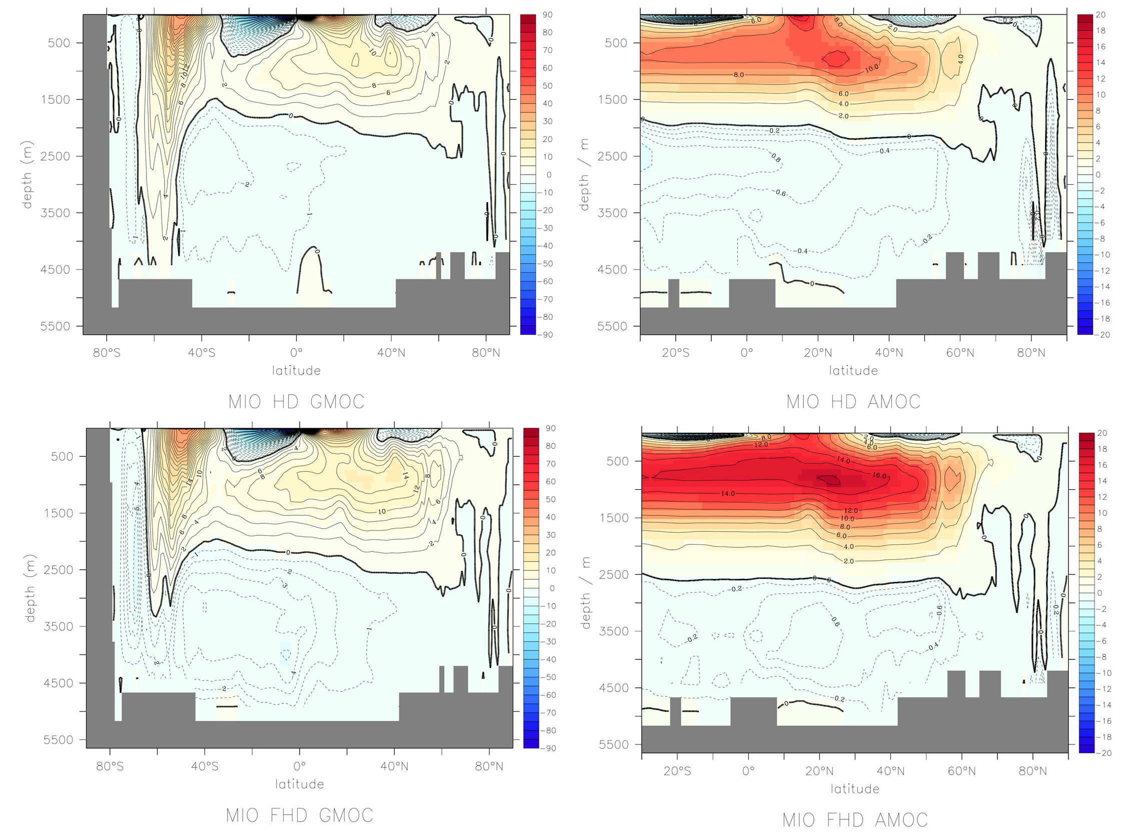


Modelled **sea surface salinity (per mille)** of the Middle Miocene (MIO), as simulated by the ESM with the HD (left) and the FHD (right), respectively. For the FHD, especially the Arctic Ocean exhibits a pronounced decrease in salinity compared to the HD.

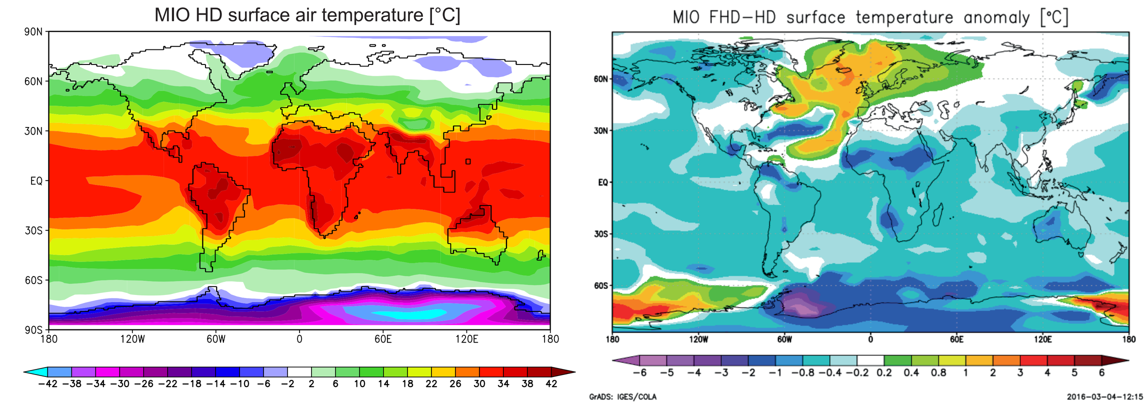


Modelled **mixed layer depths (m)** of the Middle Miocene (MIO), as given by the ESM including the HD (upper panel) and the FHD (lower panel), respectively.

Modelled **vertical velocity profiles** for the HD (red) and FHD (blue) at typical deepwater formation sites that are prone to sea surface salinity changes.



Global meridional overturning circulation (**GMOC**) and Atlantic meridional overturning circulation (**AMOC**) shown for the HD and the FHD. Compared to the HD-ESM, the FHD-ESM shows a more pronounced North Atlantic deepwater and Antarctic bottom water circulation, esp. in the Pacific sector.



Absolute **surface air temperatures (°C)** for the Middle Miocene, as given by the HD-ESM (left panel). Temperature anomalies of the FHD-ESM with respect to the HD-ESM (right) show the climate effect of an alternative treatment of continental freshwater redistribution to the ocean.

Conclusions

The alternative discharge transport models (HD vs. FHD) show a strong effect on ocean circulation and thus on the climate of the Middle Miocene. Due to the uncertainty in boundary conditions, in particular paleo-topography, the coarse resolution FHD seems to be a more reasonable choice for deep paleo-applications than the standard high resolution topography HD model. Based on our results, tectonic time-scale changes in the freshwater redistribution may have had a profound impact on ocean characteristics and on the climate of the past.

References
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