# Holocene simulations using a finite-element climate model FESOM-ECHAM6

**Xiaoxu Shi**[1] (xiaoxu.shi@awi.de), **Gerrit Lohmann**[1] (gerrit.lohmann@awi.de)

[1] Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI), Bremerhaven, Germany

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

## 1 Introduction

Sensitivity of the simulated climate to the Holocene insolation, greenhouse gases (GHGs) and topography is examined in this study by performing timeslice experiments under pre-industrial mid-Holocene and early-Holocene regimes using a state-of-the-art climate model ECHAM6-FESOM with unstructured mesh and high resolution.

FESOM is a hydrostatic ocean circulation model based on the finite-element approach and designed to work on unstructured meshes. The mesh nodes are vertically aligned to avoid difficulties in resolving the hydrostatic balance. The model uses variable resolution from about $200km$ in the open ocean to $20km$ alone coastlines as shown in Fig. 1.

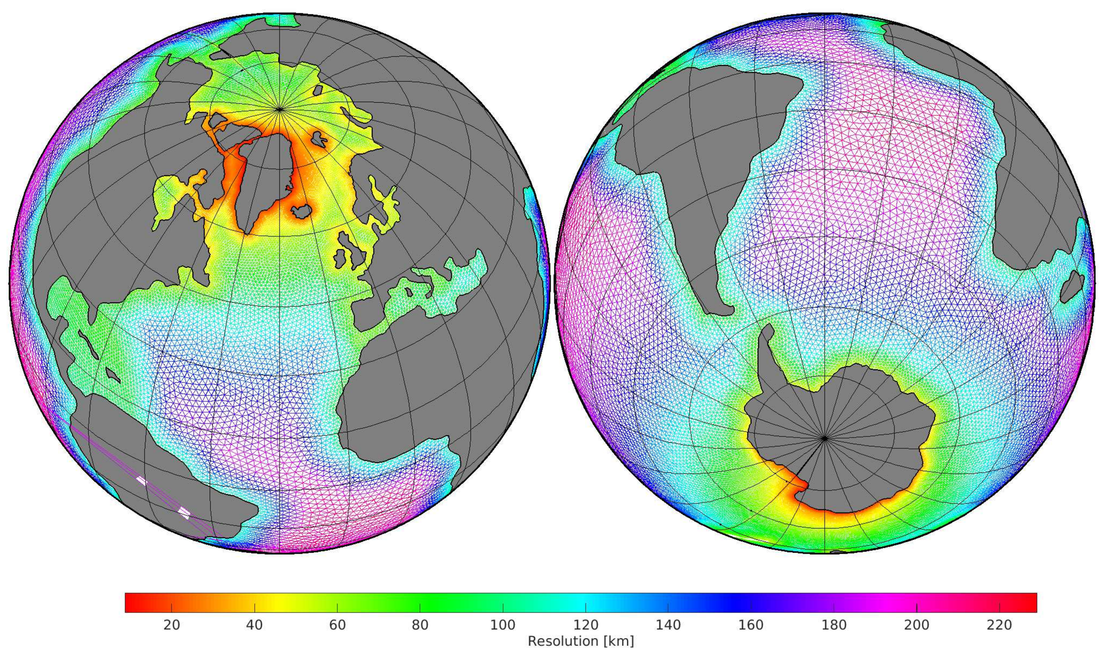


Fig. 1 FESOM mesh resolution applied in our experiments.

## 2 Experimental design

We perform four timeslice experiments, a pre-industrial control experiment (CTR), a mid-Holocene one (MH), and two different early-Holocene runs (EH_noLIS and EH_LIS), by prescribing the appropriate boundary conditions (Table 1). In EH_noLIS, we keep the topography the same as in the CTR, whereas the experiment EH_LIS uses the topography at 9k based on reconstruction from the ice sheet model ICE-5G (VM2) which decreases the global averaged sea level height by about 30 m.

Table 1: List of experiments and boundary conditions

| Experiment | CTR | MH | EH_noLIS | EH_LIS |
|---|---|---|---|---|
| $CO_2$ (ppm) | 280 | 280 | 260 | 260 |
| $CH_4$ (ppb) | 760 | 650 | 660 | 660 |
| $N_2O$ (ppb) | 270 | 270 | 260 | 260 |
| Eccentricity | 0.016724 | 0.018682 | 0.01928 | 0.01928 |
| Obliquity | 23.446 | 24.105 | 24.229 | 24.229 |
| Precession | 282.04 | 180.87 | 131.26 | 131.26 |
| Topography | Present | Present | Present | 9ka BP |
| Integration Time (year) | 460(160) | 460(160) | 260(160) | 260(160) |

## 3 Results

### 3.1 Surface properties

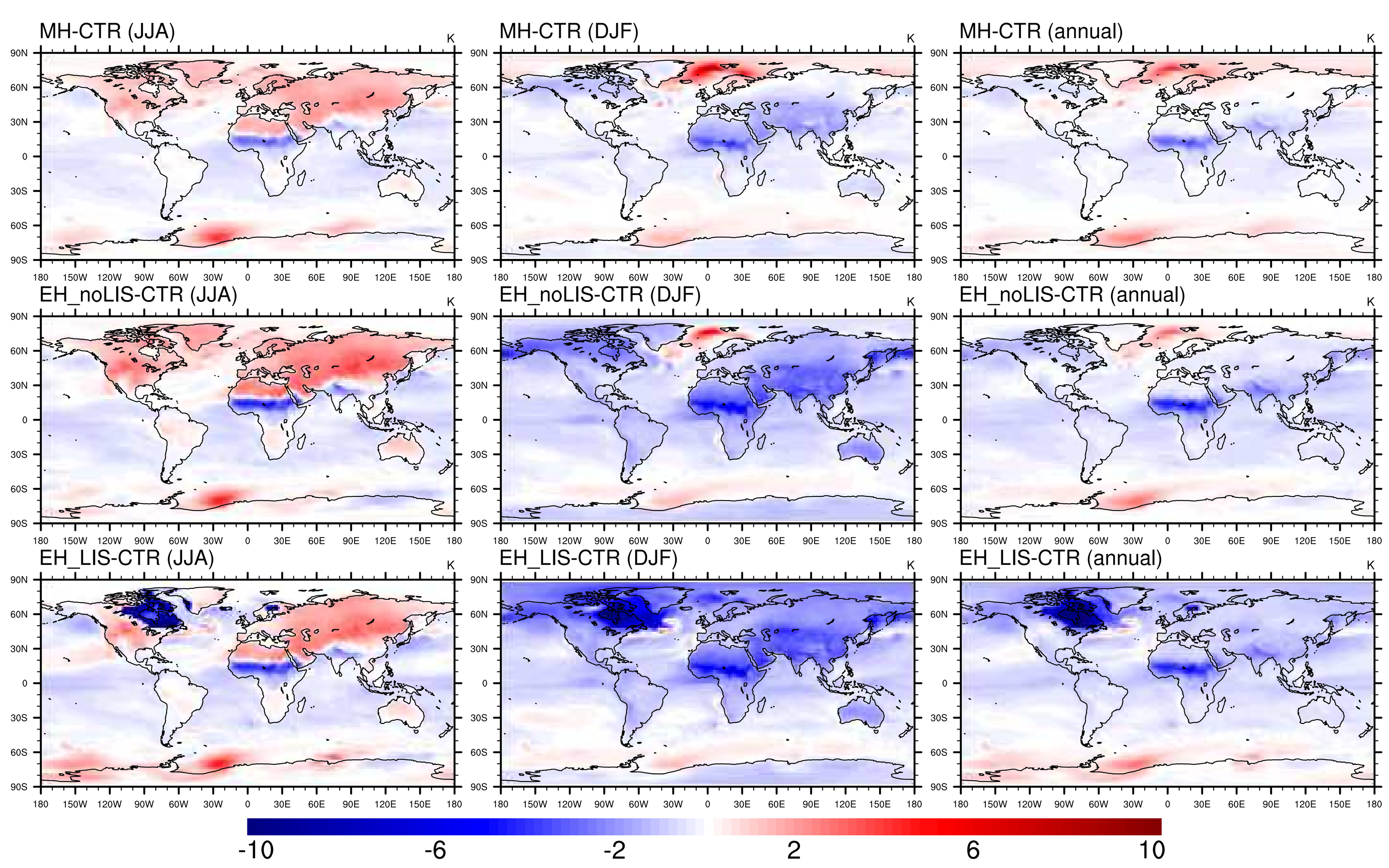


Fig. 2 Simulated anomalies of surface temperature.

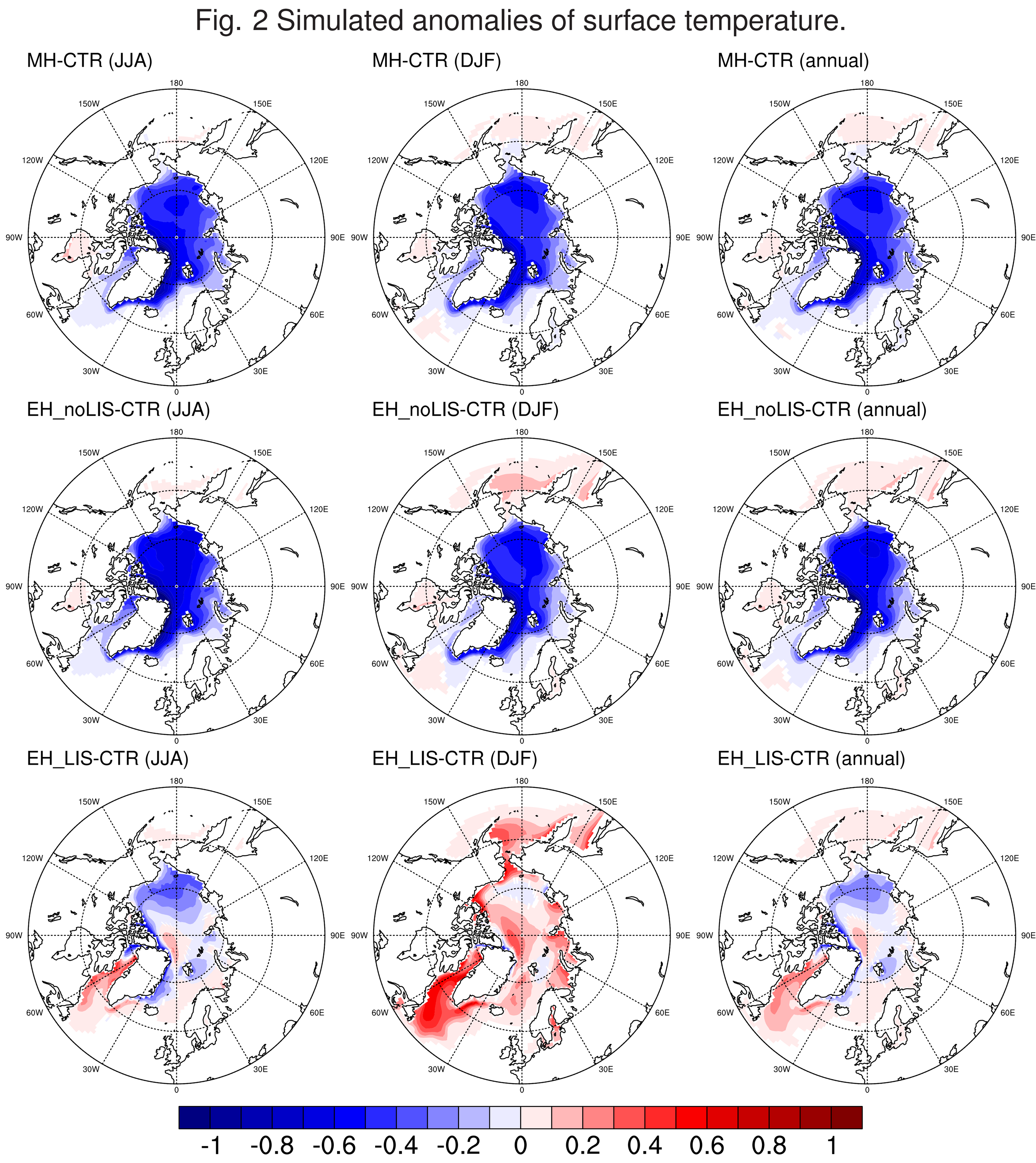


Fig. 3 Simulated anomalies of sea ice thickness.

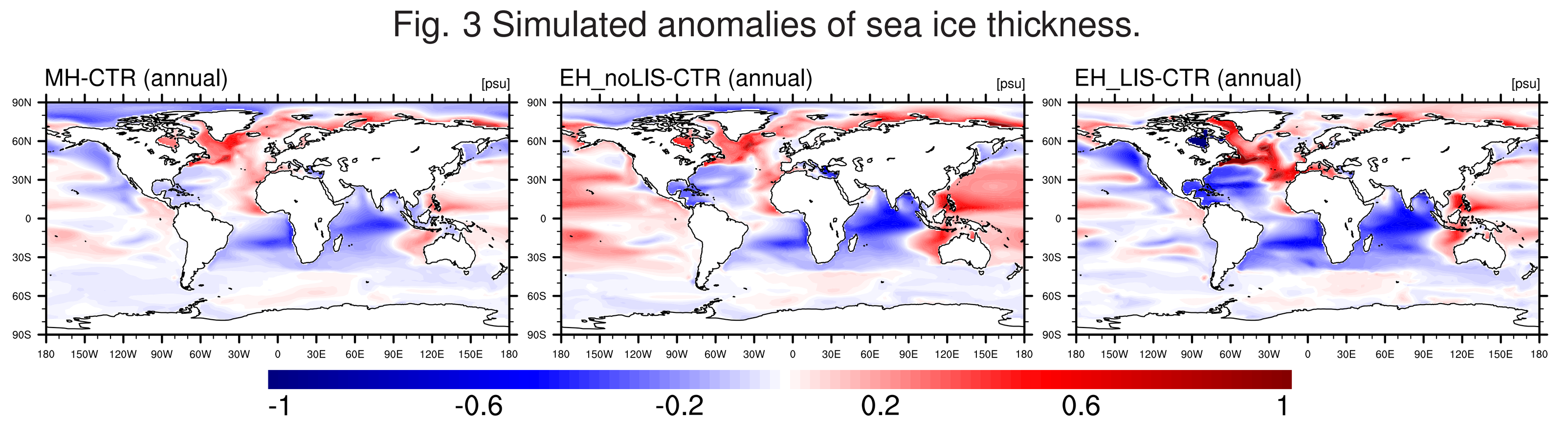


Fig. 4 Simulated anomalies of sea surface salinity.

### 3.2 Atlantic Meridional Overturning Circulation (AMOC)

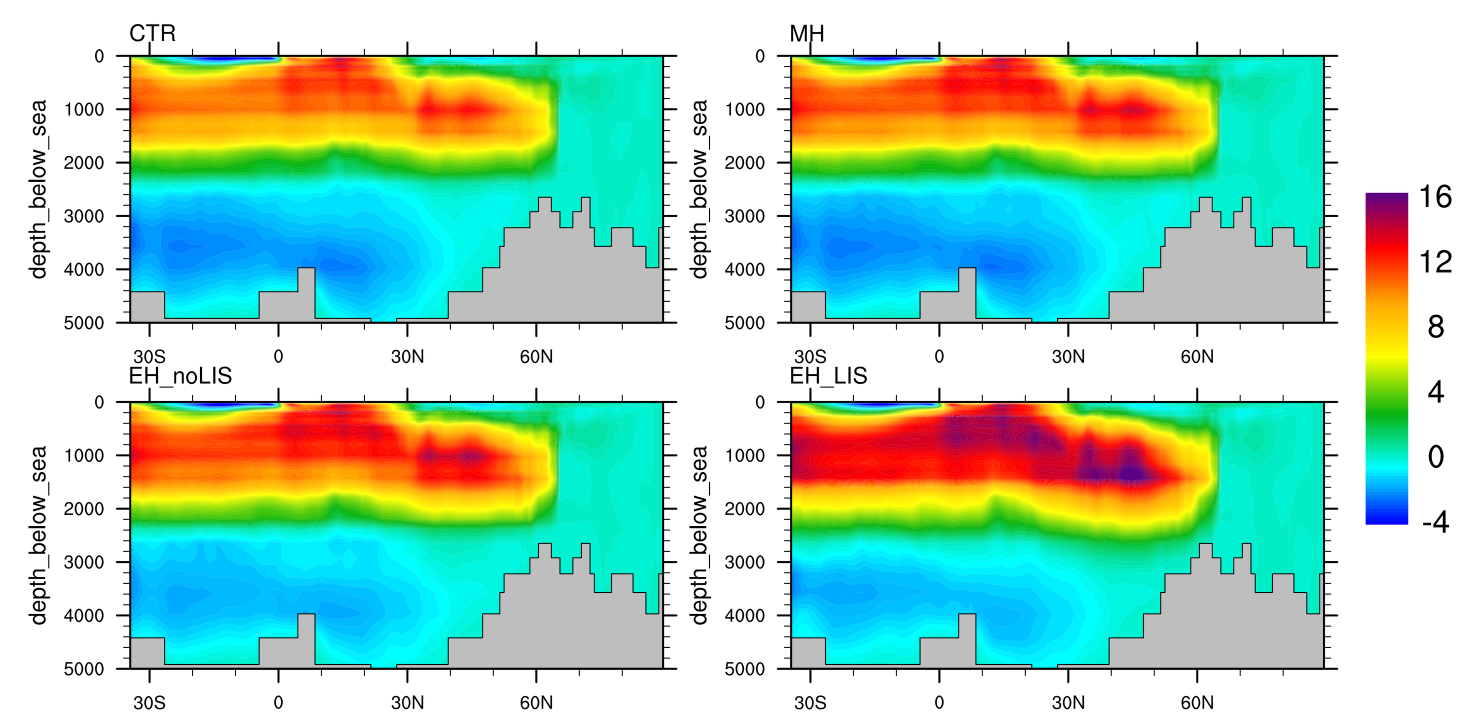


Fig. 5 AMOC streamfunction distribution.

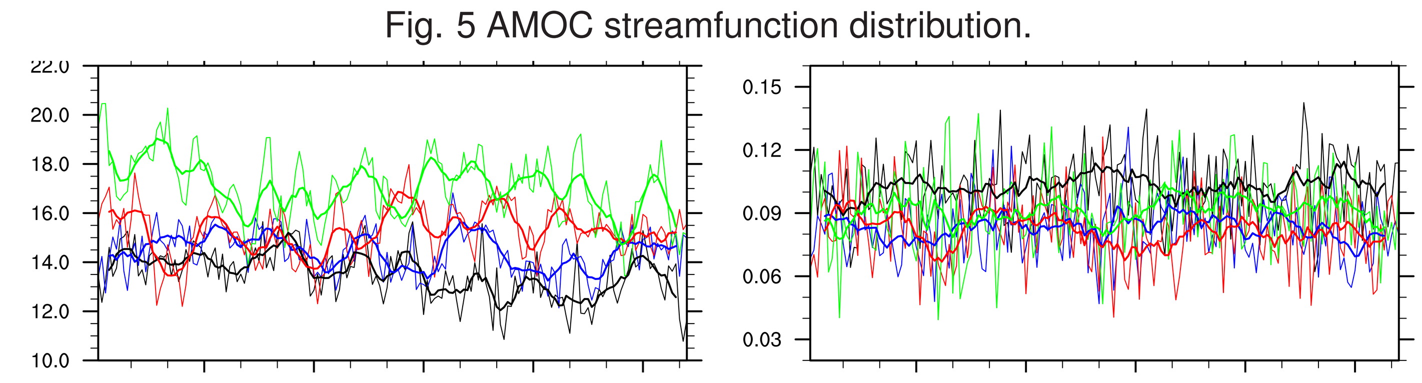

Fig. 6 AMOC indices (left) and Fram Strait sea ice mass transport (right).. Black: CTR; blue: MH; red: EH_noLIS; green: EH_LIS.

It is important to consider the ice mass transport through Fram Strait (ICEFS) for studies of the net freshwater input into the GIN Seas. The result shows significant negative ICEFS anomalies in sensitivity experiments relative to CTR, accounting for an averaged ice volume export of 419.35 km$^3$/year, 666.25 km$^3$/year and 374.54 km$^3$/year larger in MH, EH_noLIS and EH_LIS than the pre-industrial mean of 3242.16 km$^3$/year, respectively. Taking into account the lower density and salinity of sea ice as compared to sea water, this ice export anomaly represents a loss of freshwater in the GIN Sea and North Atlantic subpolar gyre, consequently, the important role of the ICEFS in the freshwater budget of those regions becomes obvious.

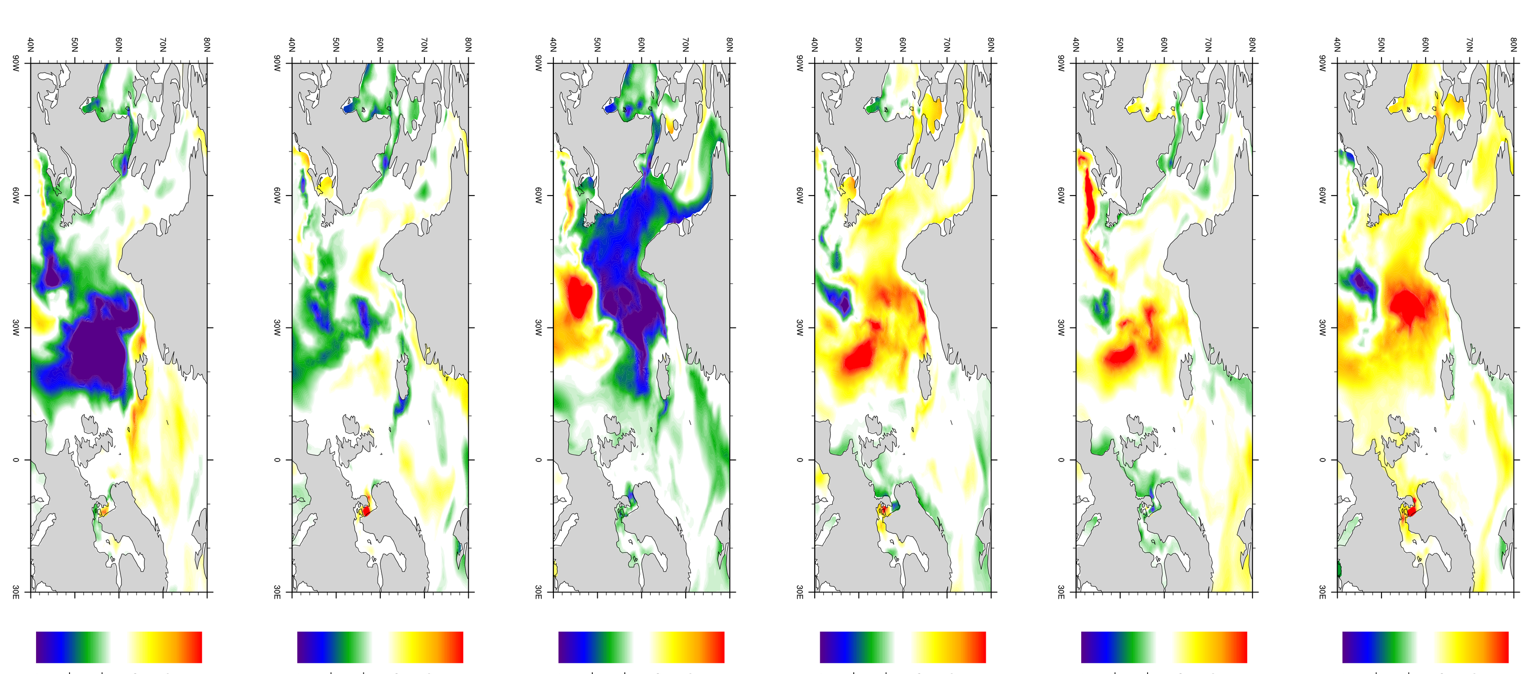

Fig. 7 Composite maps of sea surface salinity anomalies with high (left three: PI, MH and EH) and low (right three: PI, MH and EH) ICEFS, with a lag of 4 years.

## 4 Conclusions

- **Surface properties:**
  - Under the Holocene orbital plane and GHGs, the ECHAM6-FESOM simulation has a general JJA warming and DJF cooling over mid and high latitudes compared to pre-industrial; and a reduction of sea ice in both the Arctic and Southern Ocean.
  - With 9k topography, the continental ice sheet of North America is dominated by a great cooling year-round.
- **AMOC change and its mechanism:**
  - The reduced ICEFS importantly influences the strength of the thermohaline cell, which is the mechanism for a stronger-than-present AMOC in MH and EH.
  - The Laurentide Ice Sheet contributes to a denser North Atlantic Ocean by cooling the sea surface and increasing the sea ice production.