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AMOC recovery in a multi-centennial future simulation

Introduction

The Atlantic Meridional Overturning Circulation (AMOC) plays a major role in Earth's climate system. It can be affected by freshwater perturbations and changes in ocean temperature. Therefore, freshwater release from the Greenland Ice Sheet (GIS) may have effects on the AMOC. While many studies show a weakening of the AMOC in a warming future climate, only few of these studies include an explicit ice sheet model. Here, we show results of simulations run with our newly developed AWI Earth System Model AWI-ESM-1.2 for the two future scenarios RCP4.5 and RCP8.5.

Methods

Our model consists of the AWI Climate Model (AWI-CM) (Sidorenko et al., 2015; Rackow et al., 2018), but with interactive vegetation and Northern Hemisphere ice sheet. The atmosphere model is ECHAM6, which is run with the T63L47 setup (horizontal resolution of 1.85°x1.85°). FESOM1.4 is an ocean-sea ice model, that employs an unstructured grid, allowing for varying resolutions from 20 km in the northern North Atlantic to around 150 km in the open ocean (CORE2 mesh). For the ice sheet, the Parallel Ice Sheet Model PISM1.1 is used with a resolution of 5 km. We perform experiments with AWI-ESM with and without the interactive ice sheet component. For both model setups, control simulations (CTRL, CTRL-ice), simulations with historical CO2 forcing (HIST, HIST-ice), and the scenarios (RCP45, RCP45-ice and RCP85, RCP85-ice) are run.

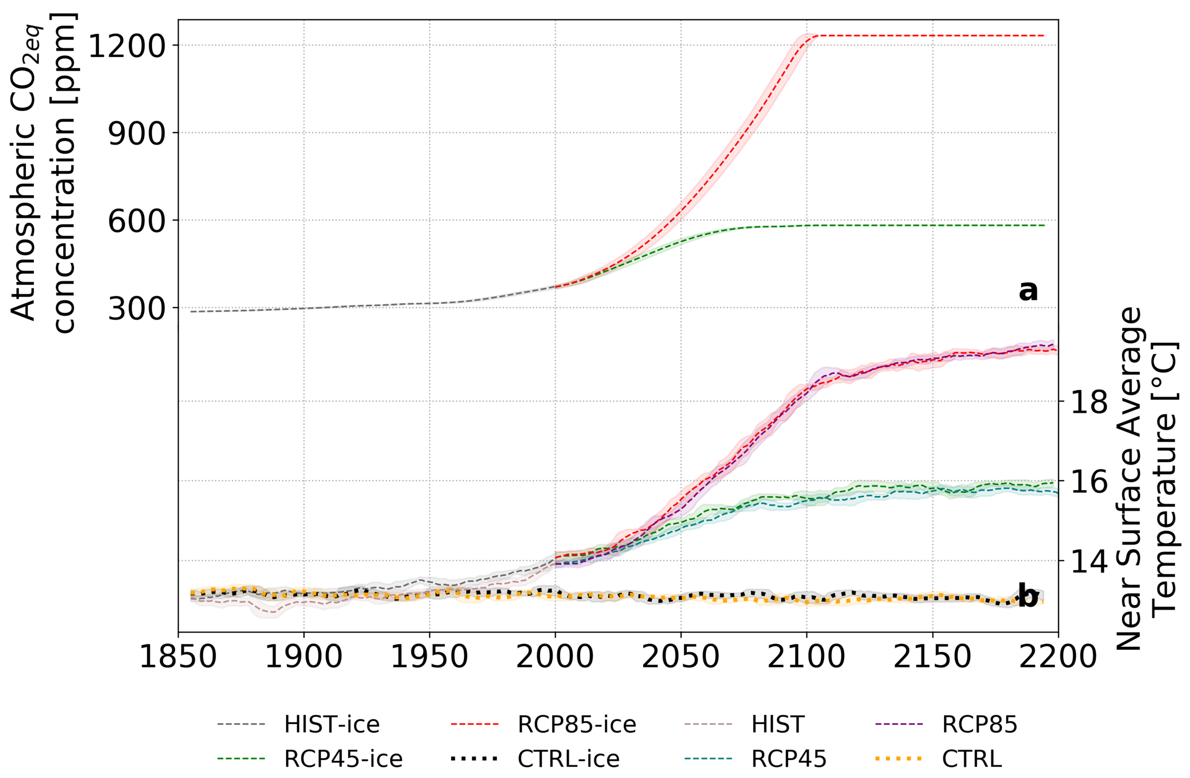

Figure 1: Timeseries of eleven-year mean a) CO2 forcing applied to simulations as CO2 equivalent and b) near surface average temperature for RCP4.5, RCP4.5-ice; RCP8.5 and RCP8.5-ice; shaded areas depict one standard deviation

AMOC Index

All scenarios show an AMOC slowdown. While the trend is very similar for the uncoupled and the coupled scenario runs, there is an offset of around 1 Sv. After the decline, the AMOC starts to recover around 2125 in the RCP8.5 scenario.

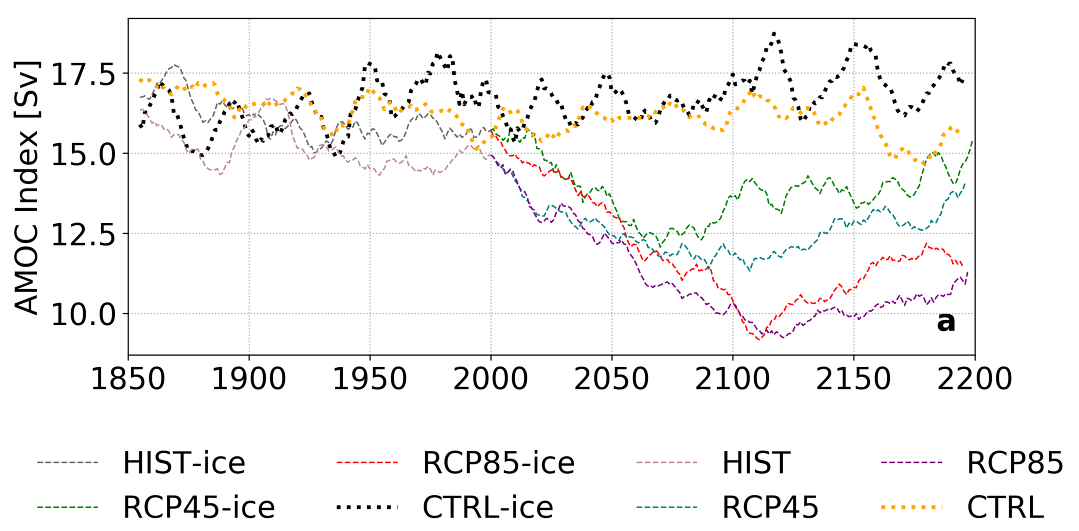

Figure 2: Timeseries of AMOC index, defined as the maximum of the streamfunction between 200-2,000 m depth and 30-60°N for RCP4.5; RCP4.5-ice, RCP8.5 and RCP8.5-ice

North Atlantic

Large areas of the North Atlantic show an increase in surface salinity, including the Labrador Sea, Irminger Sea and the Nordic Seas. A freshening can be seen around Greenland and along the Labrador Current. A strong subsurface warming leads to a decrease in potential density in the regions of deep water formation. Thus, the stratification is enhanced, and the production of North Atlantic Deep Water is hampered. The stratification stays relatively constant from the year 2100 onward. However, the AMOC is recovering.

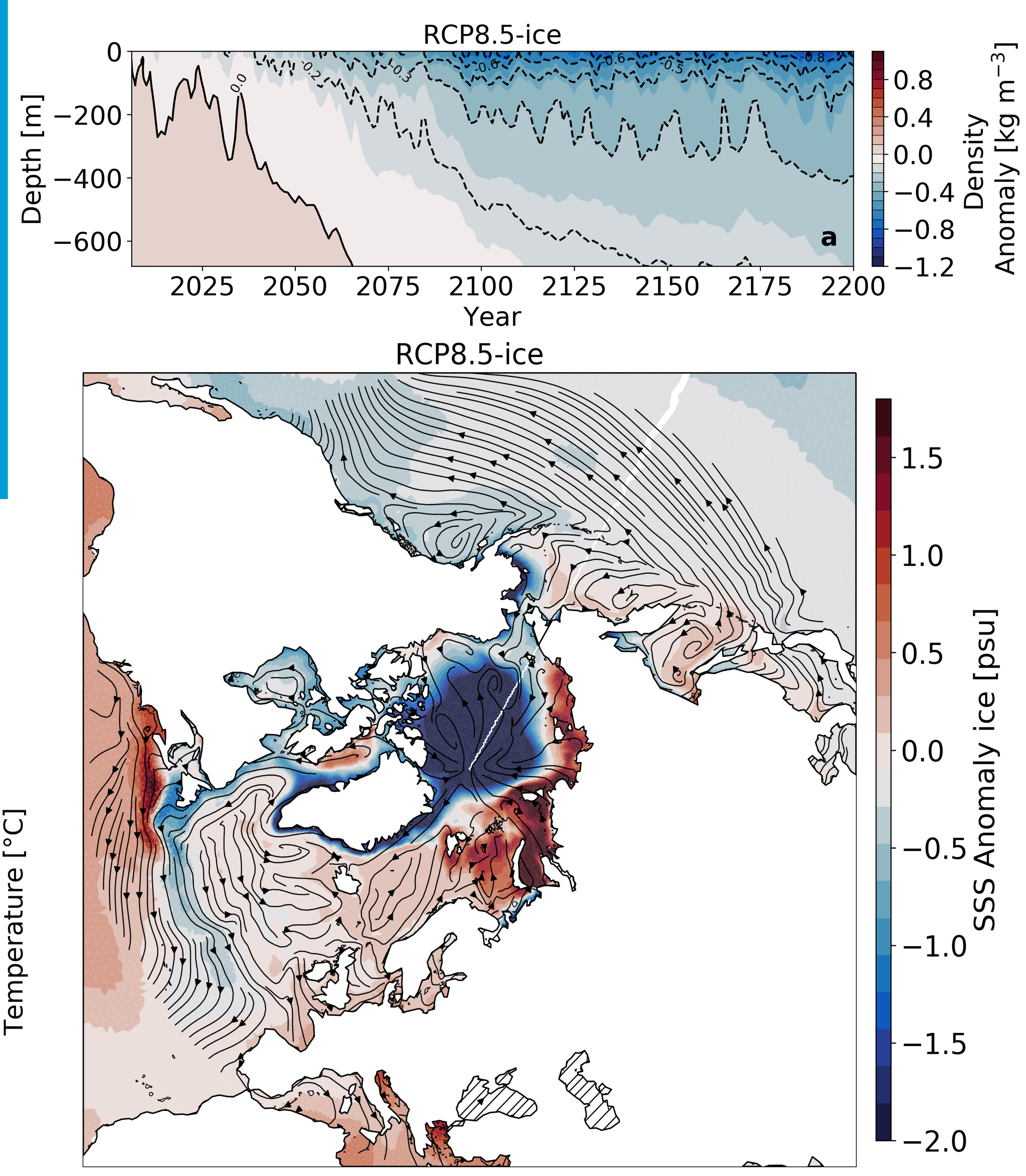

Figure 3: a) Anomaly of potential density integrated over regions of deep water formation in the North Atlantic for RCP8.5-ice; SSS anomaly averaged over 2170-2199 for RCP8.5-ice

Greenland Ice Sheet

Overall, the GIS is losing mass equivalent to around 0.12 m sea level rise in the RCP8.5 scenario until 2200. The integrated mass balance stays around zero until the year 2050, where it gets negative with decadal oscillation. Local ice sheet growth can be seen in South and West Greenland, whereas the GIS is losing mass in the west and along the margin.

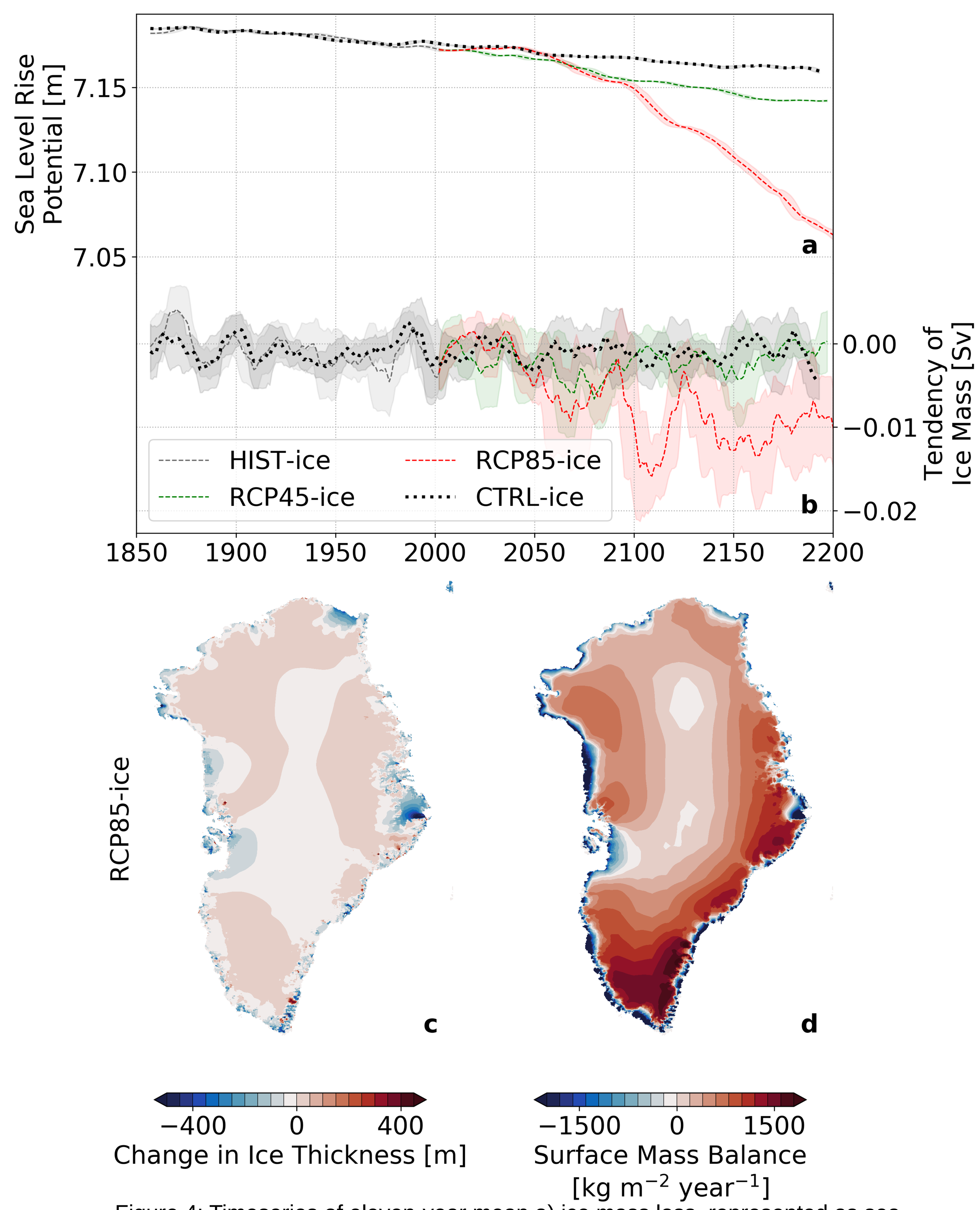

Figure 4: Timeseries of eleven-year mean a) ice mass loss, represented as sea level rise potential, and b) integrated mass balance for RCP4.5-ice and RCP8.5-ice; c) anomaly in ice sheet thickness and d) surface mass balance for RCP8.5-ice; shaded areas depict one standard deviation

Conclusion

We simulate the future warming scenarios with our newly developed climate-ice sheet model AWI-ESM, which allows us to resolve ocean boundary currents and regions of deep water formation. Both models, with and without dynamic ice sheets, show an AMOC recovery for the RCP8.5 scenario from the beginning of the 22[nd] century. The GIS is not only acting as a source of fresh water but also as a sink due to local growth. However, the ISM adds pronounced decadal variability to the surface runoff into the North Atlantic. As conventional climate models lack ice-sheet dynamics, this feature is not present in them. In a next step, the role of the Labrador Current on the GIS melt-induced freshening of the North Atlantic will be investigated.

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