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Achievements in 2016

<u>Evaluating the role of resolution-induced flux changes to the strength of the Atlantic meridional overturning circulation in MPI-ESM1.2</u>

The impact of increased model resolution is expected to lead to better representation of processes, reduce model biases, as well as provide more reliable climate prediction. However, we find that the Atlantic Meridional Overturning Circulation (AMOC) starting from an equilibrium state achieved from a lower resolution of MPI-ESM1.2 (HR; T127/TP04) breaks down at higher resolution (XR; T255/TP04). Hence, sensitivity experiments are performed (Table 1) to assess the role of resolution-induced flux changes to AMOC. Computational requirements for running XR simulations pose an additional challenge. Therefore, we adopt a strategy that uses HR model to mimic XR simulation by implementing a flux-adjustment at every coupling time step. The corrected simulation employs the mean fluxes from XR but with the variability of HR. This strategy is shown to work via the reproduction of AMOC slowdown (Fig. 1).

The adopted framework allows us to decipher the contribution of buoyancy and momentum fluxes to the decrease in the strength of the AMOC. These experiments suggest that both fluxes play a role in the slowdown of the AMOC. In particular, the dynamical effect of reduced winds in XR acts to spin down the subpolar gyre and consequently contributes to the reduction of heat and freshwater transport by the North Atlantic Current (NAC) into the Labrador Sea. This freshens and cools the subpolar North Atlantic, which decouples the deep ocean from the surface and weakens the convection, as well as promotes the formation of sea ice. Sea ice insulates heat loss during winter, which shuts down the deep convection in the subpolar North Atlantic and substantially weakens the AMOC. This further weakens the meridional transport of heat and freshwater into the subpolar North Atlantic, providing a positive feedback which reinforces the weakening of the AMOC and thus preventing AMOC recovery.

One of the biggest differences between XR and HR is that the entire wind system is globally weaker in XR than in HR. Our results suggest that weaker winds and the associated spin-down of the subpolar gyre seems to trigger the slowdown of AMOC in XR. As an attempt to reduce the slowdown of AMOC, we conducted a XR run with additional increased wind stress by a factor of 1.5. In this case, the subpolar gyre does not weaken, thus more salt and heat is transported northwards by the NAC, sea-ice cover does not extend over the entire Labrador Sea and deep convection is maintained. Hence, the AMOC slowdown is much less compared to the original XR (Fig. 1). This sheds light upon the need to increase surface winds in XR in order to obtain a reasonable strength of the AMOC. Preliminary results using XR configuration show that reducing orographic and non-orographic wave drag increases surface winds over the North Atlantic by approximately 20%, which corresponds to an increase of wind stress by a factor of about 1.4. This should help to stabilize the AMOC in the XR configuration.

Testing of PRIMAVERA boundary forcing applied to MPI-ESM1.2

For the PRIMAVERA simulations, a common boundary forcing – provided by the coordinating partner - is prescribed. The atmosphere stand-alone simulations will be driven with daily sea surface temperature (SST) and sea ice extent based on the HadISST dataset. We have successfully performed short (five year long) simulations with ECHAM6.3 in T127 configuration to test the performance of the prescribed daily SST and sea ice extent. For the coupled model simulations, the ocean initial state (temperature and salinity) will be taken from the EN4 dataset. We have adopted the following ocean initialization strategy: We perform a one-year-long simulation with MPI-ESM1.2 in T127/TP04 configuration, in which temperature and salinity are relaxed towards EN4 temperature and salinity (mean of years 1950 to 1954). The ocean and sea ice restart file from the end of this simulation will be used to initialize the ocean component in the PRIMAVERA coupled model simulations. To test the performance of MPI-ESM1.2, especially the state of the North Atlantic as manifested in the strength of the Atlantic meridional overturning circulation (MOC), when initialized with EN4, we have performed a 50 year long simulation with MPI-ESM1.2 in T127/TP04 configuration using above described ocean initialization. This simulation shows a stable MOC, indicating that the required ocean initialization with EN4 hydrography does not create any (additional) problems.

Table 1: List of sensitivity experiments conducted

Expt. name	Flux adjusted to XR
XR_orig (T255/TP04)	Control run at high resolution (pre-industrial)
HR_orig (T127/TP04)	Control run at low resolution (pre-industrial)
HR_XRalladjust	momentum, freshwater and heat fluxes
HR_XRbuoyancy	only freshwater and heat fluxes
HR_XRwinds	only wind stress over water
XR_1.5winds	XR with 1.5*(wind stress over water)

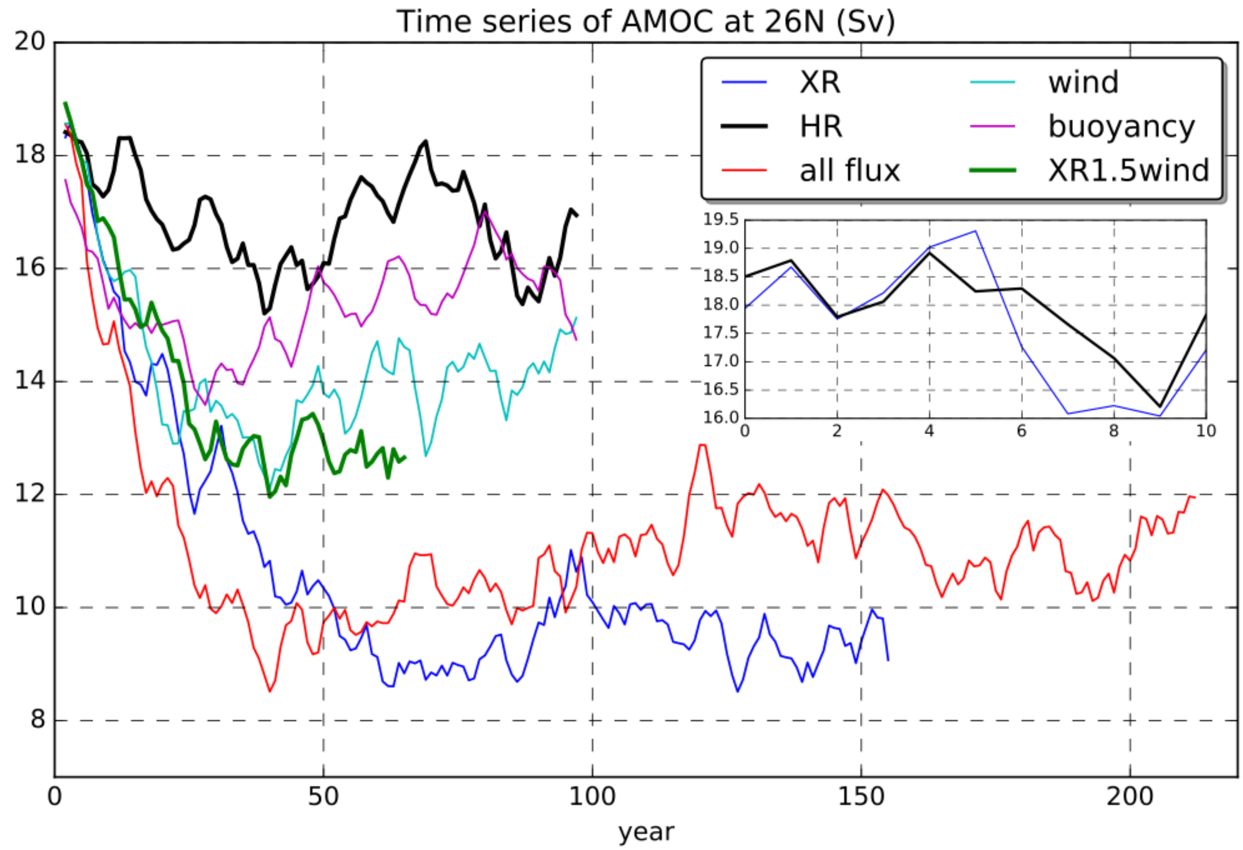

Figure 1: Time series of AMOC transport (Sv) over model integration years. *Inset:* First 10 years of AMOC transport (Sv) for high resolution (blue line; T255/TP04) run and low resolution (black line; T127/TP04) run.

Evaluating the role of ocean mixing in AWI-CM

The preliminary experiments focused on the high resolution AWI ocean model (HR AWI-CM which is ECHAM6.3 in T127L95 resolution and FESOM 1.4 on the BOLD mesh comprising 1.3 Million surface grid points) were done. We adjusted the mixing scheme in the ocean model component (FESOM) which almost eliminates the Labrador Sea cold bias in the model (Fig. 2) and keeps the AMOC on its observed value during the 150 years of simulation performed so far.

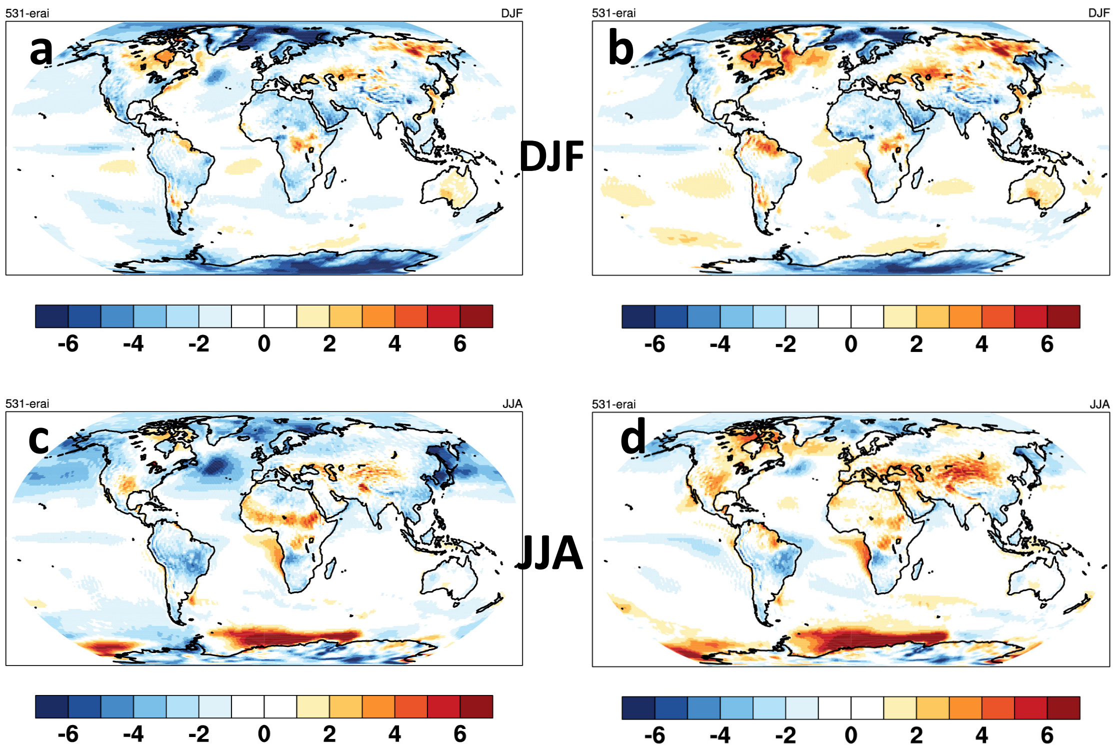

Figure. 2: 20-years seasonal mean 2m temperature bias. Left (a-DJF, c-JJA) PP mixing scheme, right (b-DJF, d-JJA): KPP mixing scheme.

Setting up and testing the frontier mesh

The frontier ocean mesh (Fig.3) comprising 5 Million surface grid points was set up and adjusted for the further PRIMAVERA simulations and tested in ocean-only mode. The mesh resolution was done according to the Rossby radius and observed upper ocean variability. The mesh should be finalized during the first half of next year.

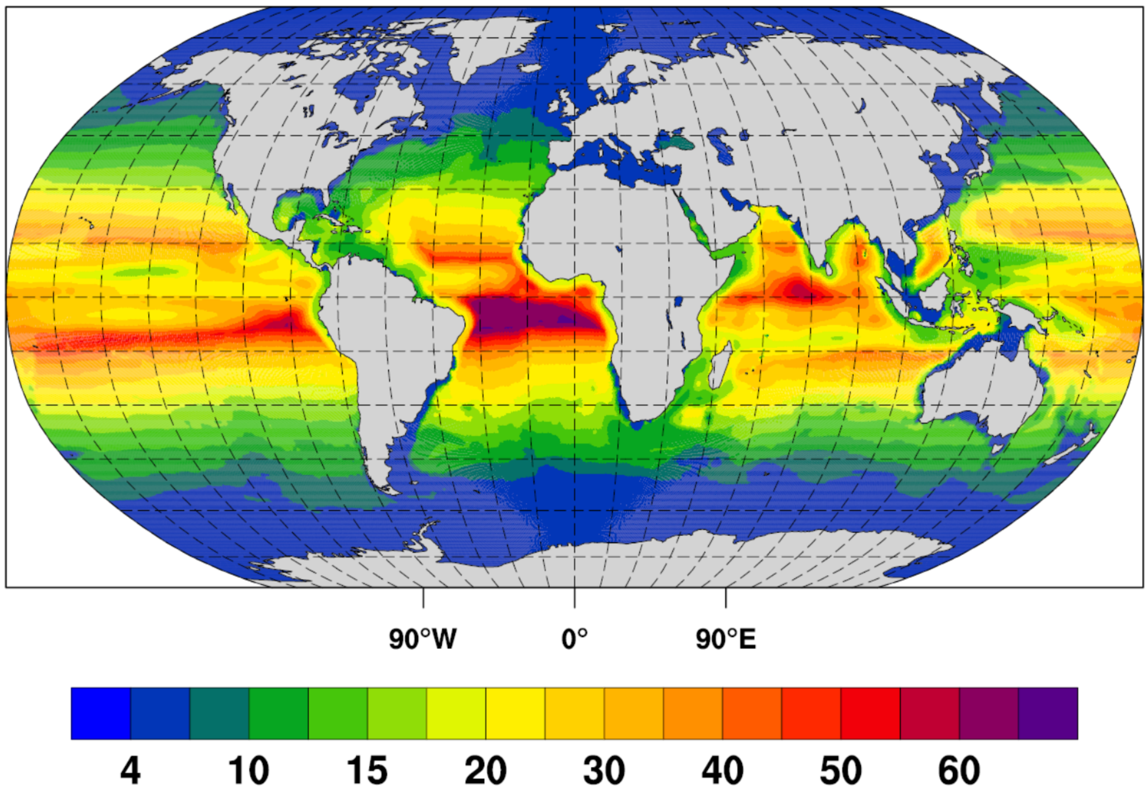

Figure. 3 Frontier ocean mesh resolution (km)