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Sensitivity of the AMOC to Atmospheric Resolution-induced Air-sea Flux Differences

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Increased model resolution is expected to lead to better representation of processes, reduce model biases, as well as provide more reliable climate prediction. However, in some models, the Atlantic Meridional Overturning Circulation (AMOC) starting from an equilibrium state achieved from a lower resolution (LR) breaks down at higher resolution (HR), simultaneously amplifying a cold bias in the North Atlantic. We find that this occurs with the Max Planck Institute – Earth System Model (MPI-ESM) when we compare the LR ($\sim$1 degree atmosphere) with the HR ($\sim$0.5 degree atmosphere), noting that both cases use the same ocean model with a resolution of about 0.4 degree. Hence, we design a suite of sensitivity experiments to assess the role of atmospheric resolution-induced flux changes to the AMOC. Extensive computational requirements for running HR pose an additional challenge. Thus, we adopt a strategy that uses the LR model to mimic the HR simulation by implementing a flux-adjustment at every coupling time step. This strategy is shown to work via the reproduction of the AMOC slowdown.

Our results suggest that, counter to the canonical surface buoyancy flux differences that typically weakens the AMOC, it is the dynamical effect of reduced winds in HR that play a bigger role in slowing down the AMOC. Weaker surface winds in HR 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, decoupling the deep ocean from the surface and weakening the convection, as well as promoting 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 abates the AMOC. This further weakens the meridional transport of heat and freshwater into the subpolar North Atlantic, providing a positive feedback which reinforces the decline of the AMOC and thus preventing AMOC recovery.

One of the biggest differences between HR and LR is that the entire surface wind system is globally weaker in HR runs, albeit stronger tropospheric jets. Our analysis suggests that weaker surface winds and the associated spin-down of the subpolar gyre seems to trigger the slowdown of AMOC in HR. In an attempt to reduce the slowdown of AMOC, we conduct a HR run with adjustments to the surface wind stress to that of the LR mean state. 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 HR run. This confirms the bigger role the dynamical effect of reduced winds in HR plays in slowing down the AMOC compared to atmospheric resolution-induced surface buoyancy flux differences.