Project: **371**
Project Title: **High resolution Initialized decadal PREDictions of Atlantic and European climate variations (HIPRED-II/HIGHPRED-Synthese)**
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Report

The ultimate aim of this project is to investigate the interannual-to-decadal variability and predictability of the North Atlantic circulation and of the surrounding continental regions (Europe, Nordic Seas) using a coupled model system with an extremely high resolution in the ocean component. Sensitivity studies and analyses of existing model simulations (hindcasts and forecasts) are carried out to investigate the role of the oceanic processes and of the ocean-atmosphere interactions in coarse-resolution, “eddy-permitting”, and “eddy- resolving” ocean model configurations. It is expected that an improved representation of the ocean dynamics as well as of the gyres and frontal regions will lead to better climate predictions over the next decade.

Towards an "eddy-resolving" MPI-ESM1.2 decadal forecast system

A realistic simulation of various climate processes and ocean-atmosphere interactions is key to reliable and skilful predictions (Matei et al., 2012). Such simulation quality improvements are expected to be found in high resolution coupled model configurations. In a joint effort with the EU H2020 project PRIMAVERA, higher resolution MPI-ESM1.2 (Mueller et al., 2018; Mauritsen et al., 2019) coupled model setups employing “eddy-permitting”, and “eddy-resolving” ocean model configurations have been tested following the HiResMIP protocol (Gutjahr et al., 2019). In preparation for the ongoing hindcast and forecast simulations, our RACE-II project has, in 2019, carried out the “historical” simulation (1950-2014) with the MPI-ESM-ER model, which includes the eddy-resolving ocean model MPIOM at 0.1^0 resolution. We have also carried out the assimilation experiment in which the MPI-ESM-ER coupled model is initialized with oceanic, atmospheric and sea ice observational estimates, followed up by a limited set of initialised 5-yr long hindcast simulations. The hindcast and forecast simulations will be continued in the first half of 2020.

As a first step towards the prototype "eddy-resolving" decadal prediction system, an un-initialized (historical) climate model simulation has been performed. In this experiment, the global climate model is driven by the observed historical radiative forcing over the period 1950-2014. The characteristics of key oceanic and atmospheric properties and modes of variability have been compared with observations and data from lower resolution (including eddy-permitting) climate model simulations.

The Atlantic Meridional Overturning Circulation caries the subtropical warm and salty subtropical water along the North Atlantic Current pathway into the Nordic Seas, and further towards the Arctic Ocean (ref.). Model biases could affect the realism of the simulated thermohaline linkages, with critical implications for interannual-to-decadal climate predictions. An Empirical Orthogonal Function (EOF) analysis of AMOC variations in the MPI-ESM-ER historical simulation indicates that its variability can be reconstructed by the first two EOFs (Fig. 1). The first EOF pattern has its maximum loading in the Tropical North Atlantic, thus explaining the variability of the subtropical AMOC. The second EOF pattern reaches the largest values over the Subpolar Gyre region between 40N-60N. The substantial reduction in the North Atlantic Cold bias identified in the MPI-ESM-ER model setup, together with a more realistic pathway of the North Atlantic Current, could also modify the AMOC climate impacts over the North Atlantic region. Indeed, as shown in Figure 2, an intensification of subtropical AMOC transport leads to a substantially enhanced warming over the Subpolar and Subtropical regions of the North Atlantic, and further into the Nordic Seas and the Arctic, about 6-to-9 years after the peak in AMOC. The delayed surface response to AMOC variations could lead to an increase in SST predictability over the North Atlantic and Arctic region. This aspect will be further evaluated in initialized decadal hindcasts with MPI-ESM-ER.

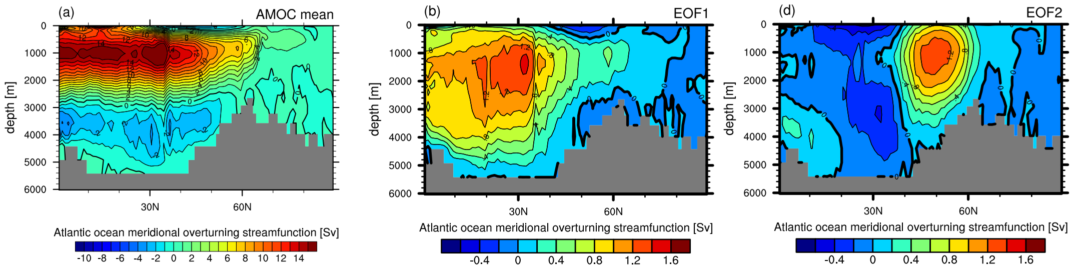

Figure 1: *Strength (a) and variability patterns (b, c) of the Atlantic Meridional Overturning Circulation in the MPI-ESM-ER „historical" experiment.*

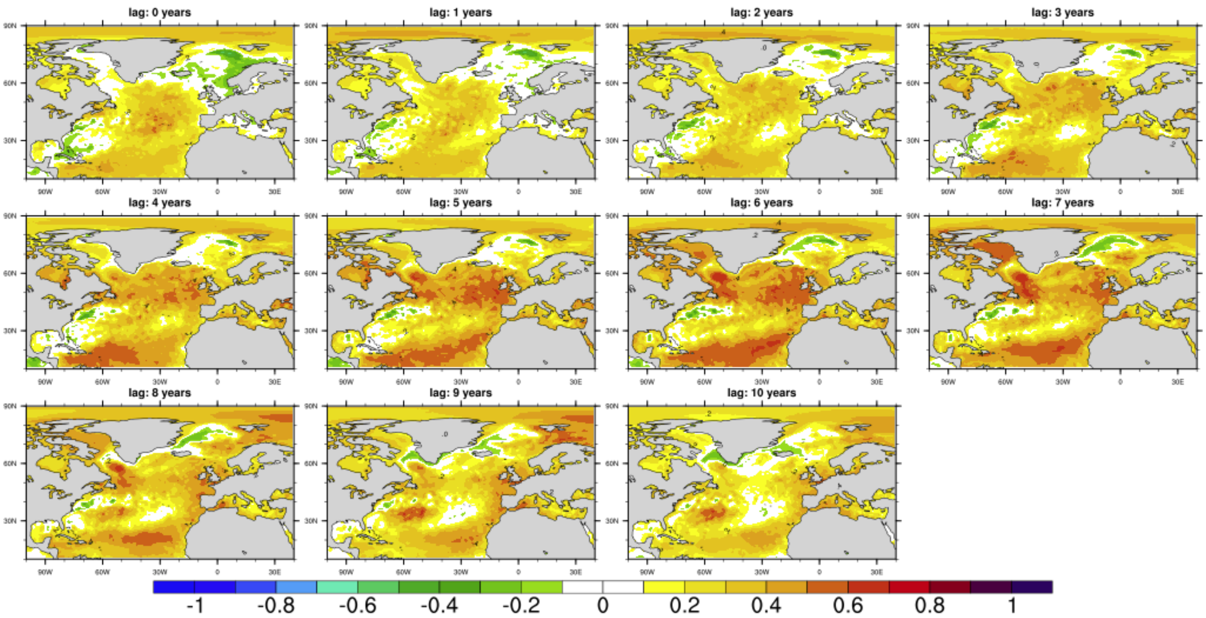

Figure 2: *Lag correlation between AMOC and 2m surface air temperature in the MPI-ESM-ER historical simulation. In both timeseries the impact of ENSO variability and model drift have been removed. The ocean is leading for positive lags.*

Recent studies, which are based on observations from the OSNAP Array in the North Atlantic (Lozier et al., 2019), have questioned the realism of the deep-water mass formation in climate models. A subsequent study (Zou et al., 2019) has found substantial differences in the relation between Labrador Sea convection, the production of Labrador Sea Water (LSW) and AMOC variations in different models. We have investigated such relation in MPI-ESM for non-eddy-resolving to eddy resolving resolutions (MPI-ESM-NR, HR, and ER). In Figure 3 we compare the correlation between meridional heat transports and Labrador Sea convection as function of lead/lag time and latitude. While all simulations feature relatively high correlation with the ocean heat transport following LSW variations, there are substantial differences in timing and shape of the influence region. These differences in signal propagation could have consequences for the predictability in the sub-polar North Atlantic region and will be investigated further in our hindcast simulations.

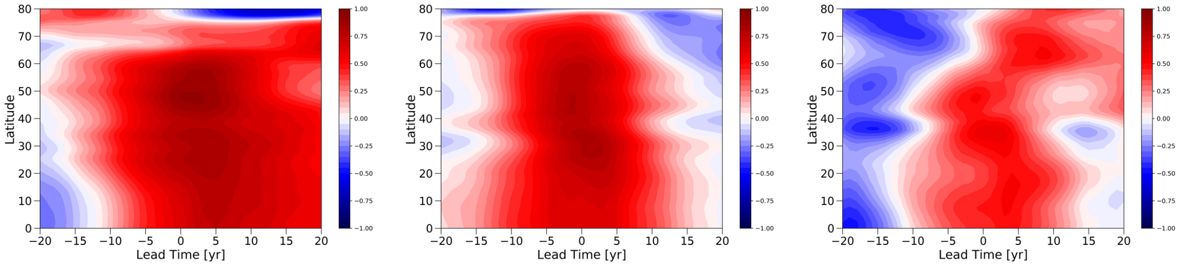

Figure 3: *Correlation (color shading) between the intensity of LSW formation and the meridional heat transport in the Atlantic as a function of latitude and time lag/lead for model set-ups with different resolution (left 1^0, middle 0.4^0, and right 0.1^0, all grid set-ups feature the same tripolar configuration in the Northern Hemisphere).*

References

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