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

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 hindcast prototype

A realistic simulation of various climate processes and ocean-atmosphere interactions is key to reliable and skilful predictions. Such simulation quality improvements are expected to be found in high resolution coupled model configurations. In joint efforts with H2020 project PRIMAVERA (responsible for the CMIP6 HighResMIP simulations), higher resolution MPI-ESM1.2 coupled model setups employing “eddy-permitting”, and “eddy-resolving” ocean model configurations have been tested following the HiResMIP protocol.

An increase of the atmospheric horizontal resolution alone (from T127 (~100 km, MPI CMIP6 standard resolution) to T255 (~50 km) in MPI-ESM-XR) did not necessary translate into an increase in the simulation quality and a better climatic state. Contrary to the expectations, the T255 atmosphere was found to substantially reduce the zonal wind speed (Putrasahan et al., 2018). The associated weakening of the North Atlantic gyre circulation led to a reduction in the meridional salt and heat transports, increase in sea-ice cover and a pause in the deep-water convection over the Labrador Sea. As a consequence, the AMOC slowed down to about 8Sv (blue line in Fig.1)

After intensive efforts, the choice of vertical mixing scheme was found to be key in stabilizing the AMOC in the XR configuration (Oliver et al., 2018, in preparation). Thus, exchanging the Pacanowski and Philander (PP) vertical mixing scheme with the K-Profile Parameterization (KPP) led to stronger open-ocean deep convection that spun-up North Atlantic gyres and lead to an AMOC strength comparable to the observational estimates of the RAPID Array (Fig. 1).

We have also tested an increase in the ocean horizontal resolution from the standard CMIP6 MPI-ESM TP04 (~0.4^{o}) level to TP6M (~0.1^{o}, "eddy resolving"), however due to the extremely high computational costs, only with the PP vertical mixing scheme. The "eddy resolving" ocean configuration exhibits not only a stable AMOC (lila line in Fig.1), but also substantial improvements in various oceanic and atmospheric quantities over the North Atlantic region (Fig. 2 and 3) that are key for the predictive activities of HIPRED. Of particular importance for our prediction experiments in RACE is the improvement in the sub-polar North Atlantic SST bias by more than 2K, which should influence ocean-atmosphere interactions, and possibly teleconnections to Europe. The eddy-resolving ocean does not only reduce the biases in the ocean interior and in the near-surface atmosphere, but also in the upper atmosphere. This leads to the important conclusion that ocean eddies have a major impact on the large scale atmospheric circulation.

During the 2018 allocation period we have made preparatory steps towards the first "eddy resolving" decadal hindcast prototype. Accordingly, a historical MPI-ESM-ER simulation forced with the CMIP6 radiative forcing is currently performed over the period 1950-2014. In early 2019, in a follow up step, an assimilation experiment in which the MPI-ESM-ER coupled model is initialised with oceanic, atmospheric and sea ice observational estimates will be performed, follwed up by a limited set of initialised 5-yr long hindcast simulations over the past two decades.

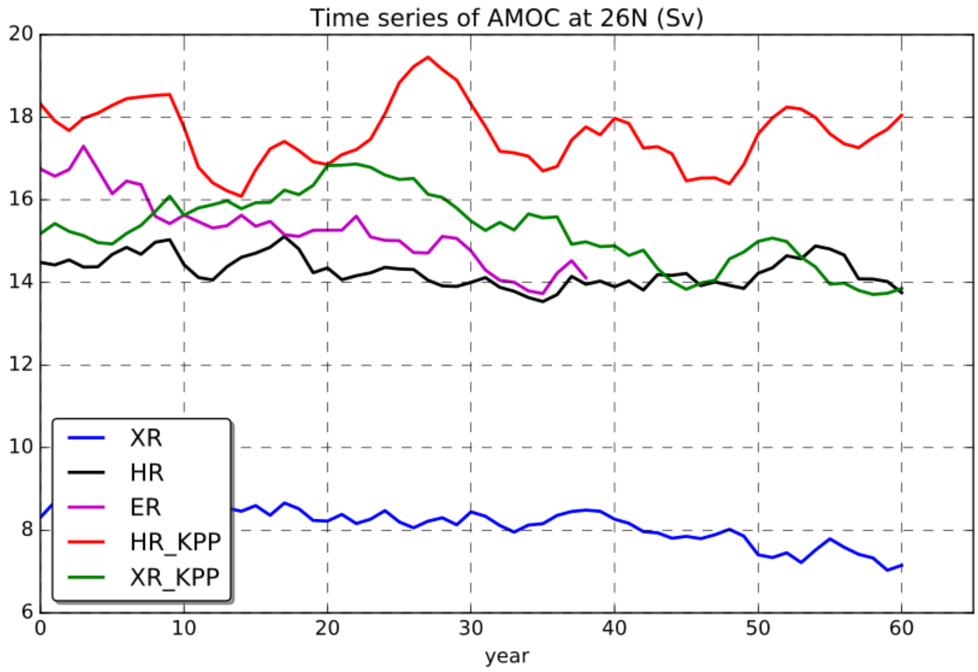

Fig. 1 The strength of the Atlantic Meridional Overturning Circulation in the MPI-ESM-ER Historical simulation (lila) and various MPI-ESM HR and XR HighRes Control experiments.

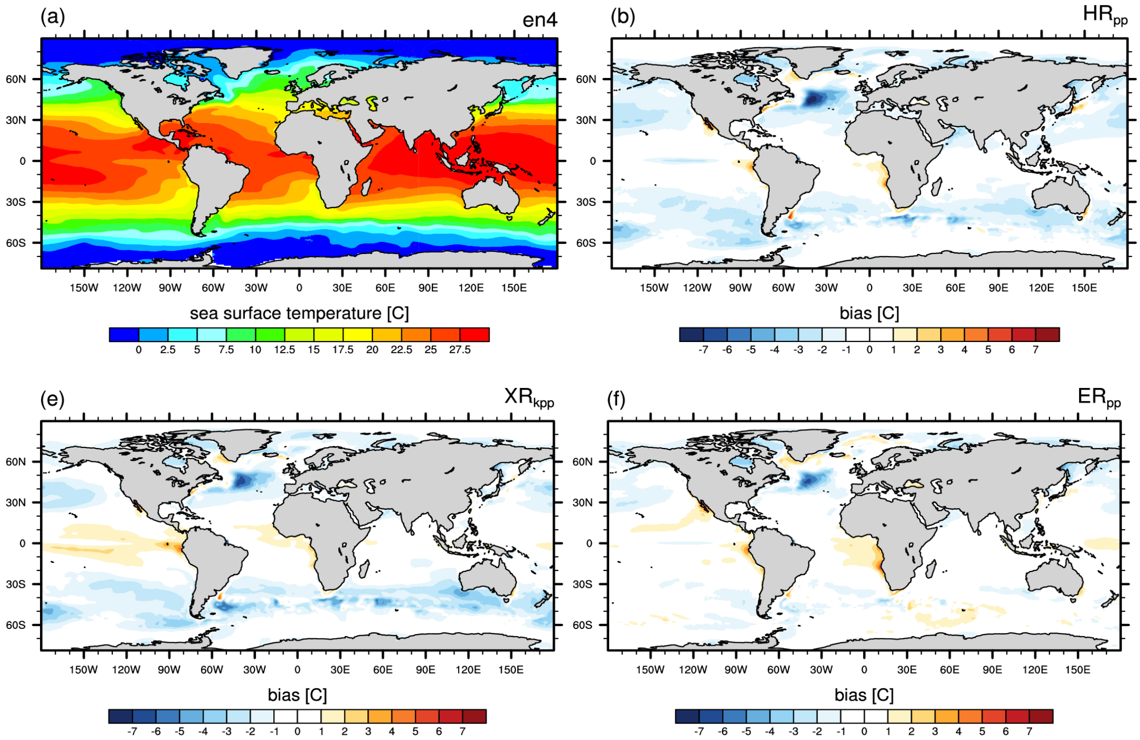

Fig2. Sea surface temperature from EN4 (averaged over 1945-1955) and the bias (MPI-ESM minus EN4) of HR_{pp}, XR_{kpp} and ER_{pp}.

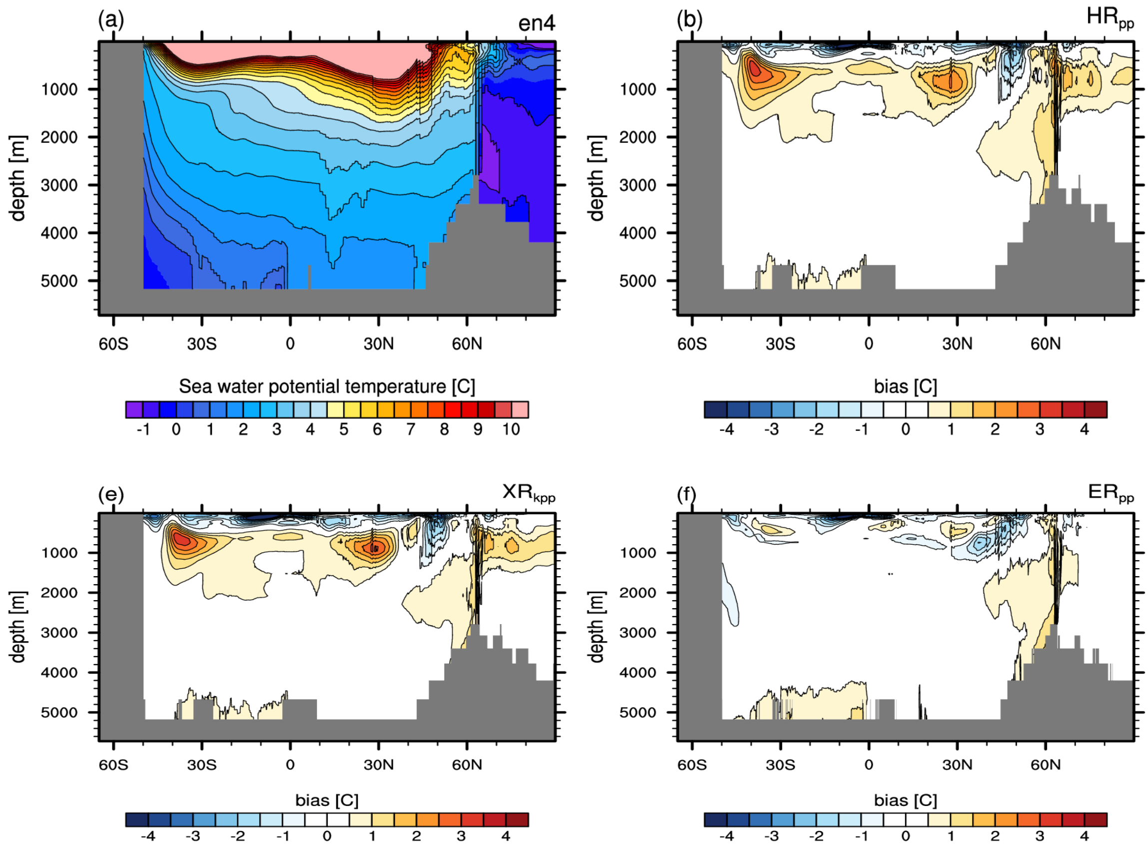

Fig. 3 Zonal mean temperature transect through the Atlantic basin and the Arctic Ocean of EN4 (averaged over 1945-1955) and the bias (MPI-ESM minus EN4) of HR_{pp}, XR_{kpp} and ER_{pp}.