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.

Mechanisms and predictability of sea surface temperature variations at the North Atlantic Ocean's getway to the Arctic

The Nordic Seas together with the Barents Sea constitute the Atlantic Ocean's gateway to the Arctic Ocean, and the Gulf Stream's northern extension brings large amounts of heat into this region, thus modulating the climate of northwestern Europe and impacting Arctic changes. In a recent study (Langehaug, Matei, Eldevik, Lohmann, Gao, 2016) based on retrospective predictions ("hindcasts") with several state-of-the-art climate prediction models, we took a first step and investigated the multiyear predictive skill of SST in the Nordic Seas and Barents Sea for the 50-year long time period 1961–2010. Although all investigated models exhibit significant predictive skill in specific regions at certain lead times, there is little consistency between them (not shown). Only the MPI-ESM-LR model has significant skill in predicting observed SST variability in the eastern Nordic Seas at longer lead times (Fig.1c), at COR levels higher than that of the statistical benchmark (persistence forecast). This underlines the potential role of ocean dynamics in bringing predictability to the Nordic Seas and Barents Sea. A similar result for the North Atlantic has been stressed using a different version of the MPI-ESM (Matei et al. 2012) as well as other models (Robson et al. 2012, Yeager et al. 2012).The economically important eastern Nordic Seas region is of particular promise in terms of predictability, as observed thermohaline anomalies are advected from the subpolar North Atlantic to the Fram Strait within the time frame of a couple of years. In the MPI-ESM-LR model, the predictive skill appears indeed to progress northward along a similar route, with domains of high skill propagating from the subpolar North Atlantic to the eastern Nordic Seas, and finally into the Barents Sea as forecast time evolves (6–8 years) (Fig.1a-c). In the present study, we also found a significant correlation between the AMOC (at 48°N) and SST in the eastern Nordic Seas for two of the investigated models (MPI-ESM-LR and IPSL-CM5), when AMOC is leading by 5 and 1–2 years (Fig. 1d), respectively. The time lag between the two appears to be related to the timing of predictive skill in the southeastern Nordic Seas in the respective models, confirming previous results (Matei et al., 2012) that indicate that the SST skill in the subpolar region at longer lead times is a consequence of an accurate initialization of AMOC variability. Our results also show that an enhancement in the horizontal resolution, particularly of the oceanic component, could lead to an increased predictive potential of SST over the Nordic Seas region.

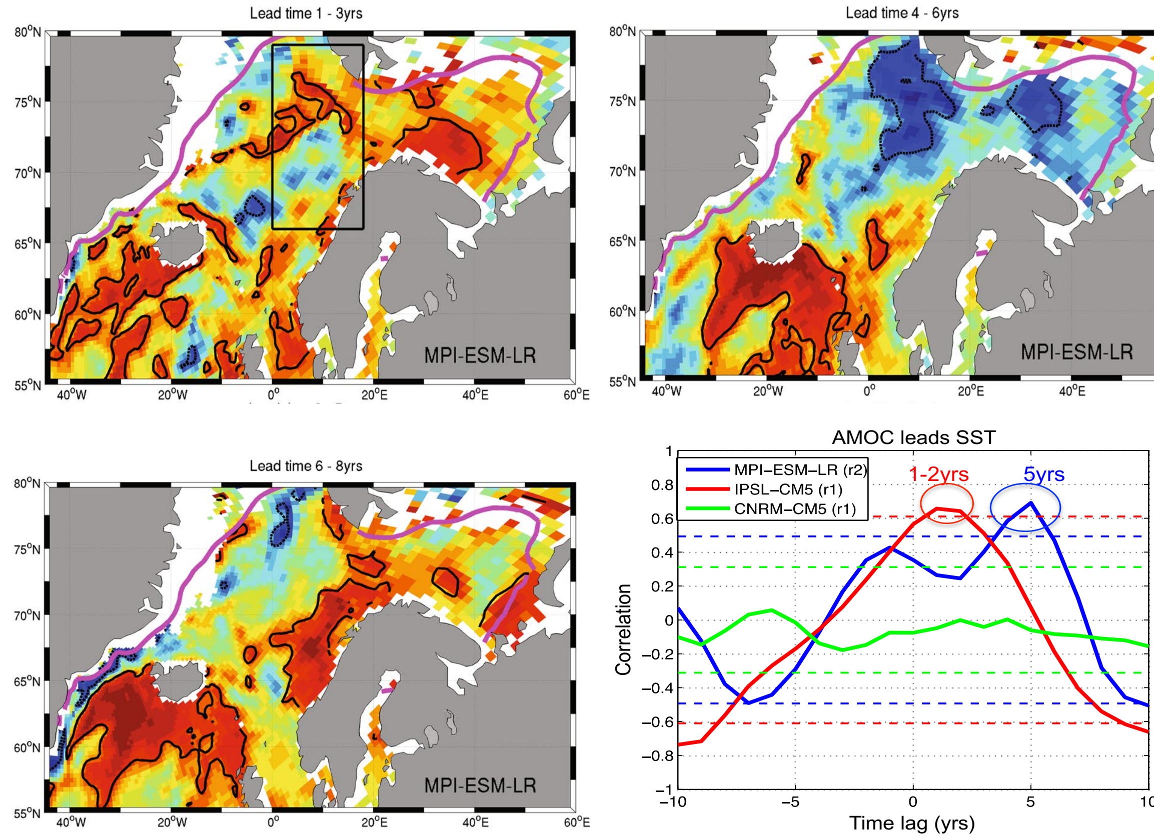

Fig. 1 Top and bottom left: *Anomaly correlation coefficient of winter SST for MPI-ESM-LR between HadISST data and the ensemble mean of the hindcasts at different lead times. Significant correlations at the 90 % level are embraced by the black solid (dashed) curves for positive (negative) correlations. At each lead-time, the time series are smoothed by a 3 year-moving average and the linear trend is subtracted prior to correlation. The magenta curve shows the position where the sea ice concentration is 50 %.* ***Bottom right:*** *Cross-correlation between AMOC at 48°N and SST in the eastern Nordic Seas for the period 1961–2010 based on ensemble members from the historical+ runs from the CMIP5 models. Significance levels are plotted as dashed lines.* ***The*** *time series are smoothed by a 3 year-moving average and the linear trend is subtracted prior to correlation. (From Langehaug, Matei, Eldevik, Lohmann, Gao, 2016)*

Impact of model resolution on North Atlantic physical climate and ecosystem predictability

We have also investigated whether the strong loss in predictive skill at intermediate lead times evident north of the Greenland-Scotland Ridge in the MPI-ESM prediction system (Fig.1 Top right) could be attributed to the rather simple MPI-ESM CMIP5 initialisation approach (with initial conditions taken from an MPI-OM ocean-forced simulation) or specific to MPI-ESM-LR model setup. Indeed, we found that independent of initialisation approach (CMIP5 vs. MiKlip Baseline 1, Fig.2 left), the strong negative skill over the Nordic Seas at intermediate times is a robust feature in all MPI-ESM-LR based hindcasts. However, an increase in ocean model resolution, from the rather course MPI-ESM-LR setup (nominal 1.5°) to the "eddy-permitting" MPI-ESM-MR setup (0.4°), led to a substantially enhanced predictability over the very important eastern Nordic Seas region and upstream into Barents Sea in both MiKlip b1 and CMIP5 decadal hindcasts (Fig.2 right).

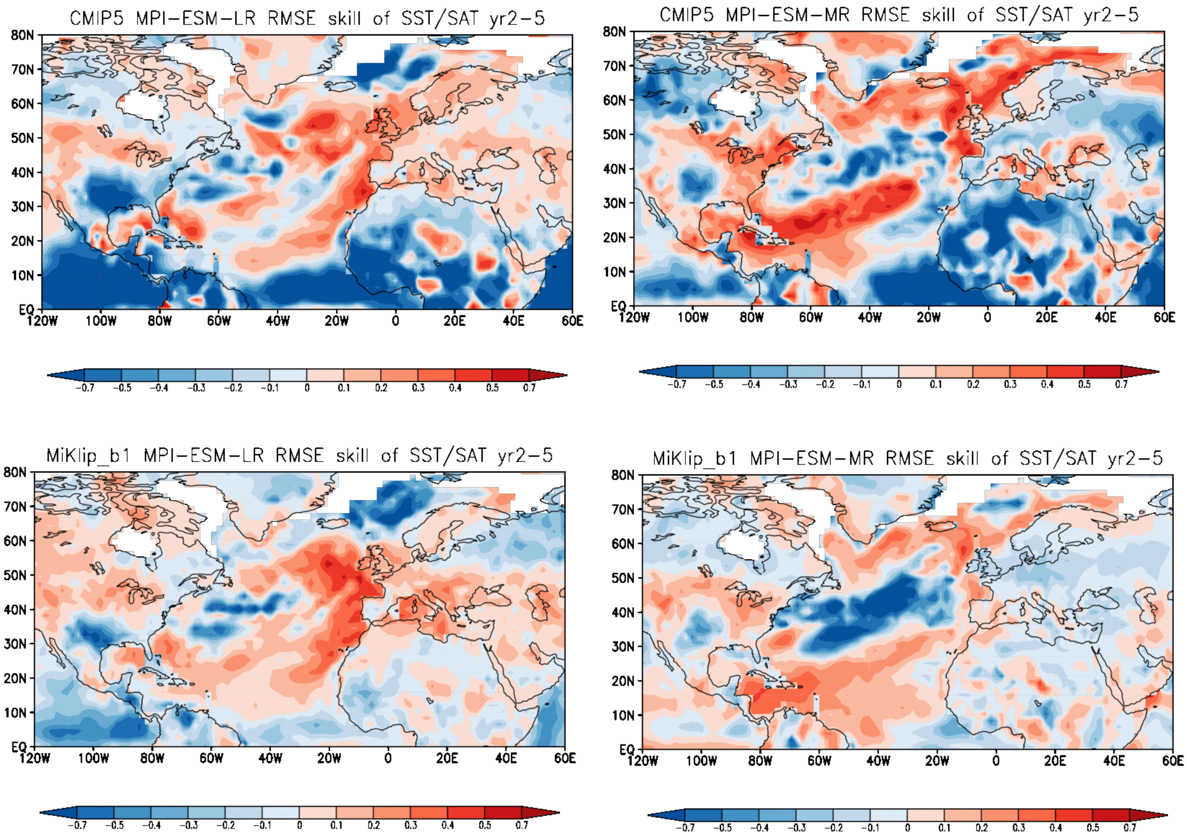

Fig. 2 *RMSE predictive skill (Matei et al. 2012) score of surface temperature referenced to the RMSE of the NonINIT experiments at lead time yr2-5 for the CMIP5* ***(Top)*** *and MiKlip Baseline1* ***(Bottom)*** *ensemble hindcasts.* ***Left (right)*** *plots present results from MPI-ESM-LR (MPI-ESM-MR) experiments. The observations are taken from the HadISST for the SST and GHCN-CAMS for SAT. (Matei et al., 2016).*

The beneficial impact of increased model resolution on the predictability of societal relevant quantities is not restricted to surface climate quantities, but also extends to marine ecosystem-related metrics. For example, in a pioneer joint study with collegues from DTU Aqua (Denmark) towards the development of prototype marine ecosystem decadal predictions, we have investigated the multiyear predictability of the bluefin tuna habitat over the northeastern North Atlantic (Fig.3). We found that the conditions favorable to the Bluefin tuna habitat distribution could be well predicted with up to ten years ahead at skill levels significantly higher than those of the statistical benchmark. The enhanced habitat distribution predictability when moving from MPI-ESM-LR to MPI-ESM-MR model setup is evident during the whole 10yr length of the forecast experiments across various regions (e.g. Irminger Sea, South of Island).

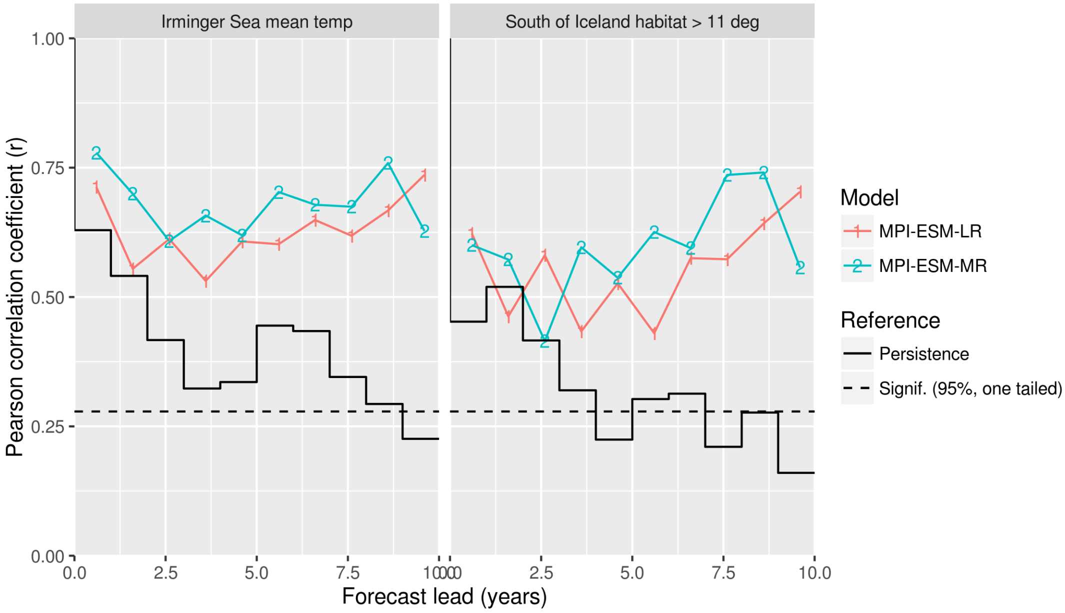

Fig. 3 *Anomaly correlation coefficient skill of Bluefin tuna habitat conditions in the MPI-ESM-LR vs. MPI-ESM-MR MiKlip Baseline 1 initialized decadal hindcasts. The solid staircase line shows the skil of the statistical benchmark (persisitence forecast), while the dotted line indicates the 5% significance threshhold. (from Payne, Matei, MacKenzie, 2016).*

Literature

Langehaug HR, Matei D, Eldevik T, Lohmann K, Gao Y (2016): On model differences and skill in predicting sea surface temperature in the Nordic and Barents Seas. *Clim. Dynamics*,1-21, doi:10.1007/s00382-016-3118-3.

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