Modeling anthropogenic Climate Change of the northwest European Shelves and the northeast Atlantic

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INTRODUCTION AND BACKGROUND

The global general circulation models applied in IPCC simulations are usually too coarse to reproduce many smaller scale processes, which could have an impact on the future climate change in regions such as the North Sea and Baltic Sea. We present a novel approach to downscale climate change scenarios and to investigate the interactions between the North Atlantic Ocean and the European shelves as well as their impact on the North Atlantic climate. A global ocean – sea ice – marine biogeochemistry model with regionally high horizontal resolution is coupled to an atmospheric regional model and global terrestrial hydrology model. The model approach and the results of downscaled A1B scenario for the North Atlantic and North European shelves are presented.

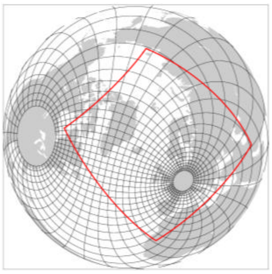

Fig.1 *Coupled REMO/MPI-OM configuration. Red rectangle indicates the domain of coupling. Only every tenth line of the ocean grid is shown*

MODEL SETUP

The REgional atmosphere MOdel **REMO** (37km resoluton) is coupled to the global ocean – sea ice – marine biogeochemistry model **MPIOM/HAMOCC** with increased resolution on the North-West European Shelves (up to 4 km in the German Bight). The coupled domain includes Europe, the North-East Atlantic and part of the Arctic Ocean (Fig.1). The models are coupled via **OASIS** coupler.

Exchange between ocean and atmosphere was made with 1 hour coupled time step. Lateral atmospheric and upper oceanic boundary conditions outside the coupled domain were prescribed using ECHAM5/MPIOM C20 20-th century and A1B scenario data (the total simulation period was1920-2100). The ocean tidal forcing was derived from the full ephemeridic luni-solar tidal potential .

The global Hydrological Discharge model (**HD**), which calculates river runoff (0.5º horizontal grid resolution), is coupled to both the atmosphere and ocean components.

MODEL VALIDATION

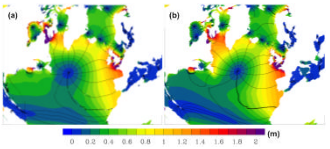

Fig. 2 *Observed (a) and modelled (b) M_2 tidal maps. Co-tidal lines are with 30º interval*

Ocean tides

The ability of the model to simulate tidal dynamics is shown on Fig.2. In the eastern part of the North Atlantic the agreement between the model and observation is reasonable for the climate model. The amphidromic points are captured well especially into the GIN and North seas.

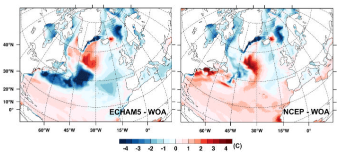

Fig. 3 *Mean SST difference. Model – WOA2009 climatology. ECHAM5 and NCEP on the figures denote the model forcing*

Sea Surface Temperature

To validate the model we additionally performed the simulation with NCEP/NCAR reanalysis forcing. On Fig.3 is shown that the strongest cold bias in the North Atlantic is caused by the ECHAM5 forcing. In the same model forced by NCEP/NCAR this bias disappears.

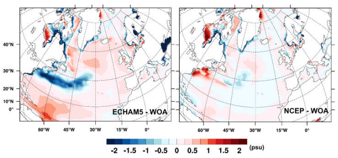

Fig. 4 *Mean SSS difference. Model – WOA2009 climatology. ECHAM5 and NCEP on the figures denote the model forcing.*

Sea Surface Salinity

As in the case with SST the stongest biases in SSS are mainly caused by the atmospheric forcing. While in the uncoupled domain the bias is very pronounced, in most part of the coupled area the disagreement with observations does not exceed 0.5 psu

ATMOSPHERIC CIRCULATION AND RIVER RUNOFF

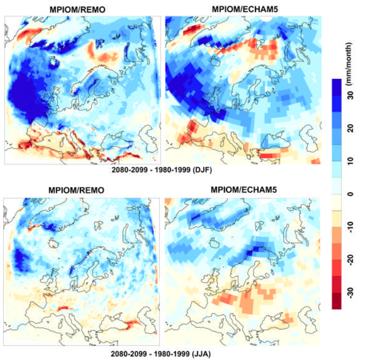

Fig. 5 *Changes in precipitation simulated by REMO/MPIOM (left) and ECHAM5/MPIOM (right)*

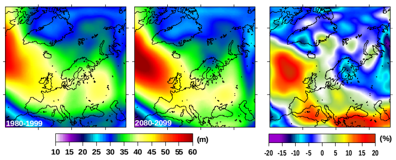

Fig.6: *Standard deviation of DJF 500 hPa height (m) due to transient eddies in the bandpass regime (2.5-6 days) and its relative change (right)*

Simulated by REMO/MPIOM large scale changes in precipitation are similar to those simulated by ECHAM5/MPIOM, but due to the higher atmospheric resolution in REMO they differ in small scale features, in particular in Northern Europe (Fig.5).
The cyclonic activity, shown on figure 6 in general tends to increase, mainly over the Atlantic ocean and Mediterranean (up to 20%) . In Northern Europe, no significant changes are evident.

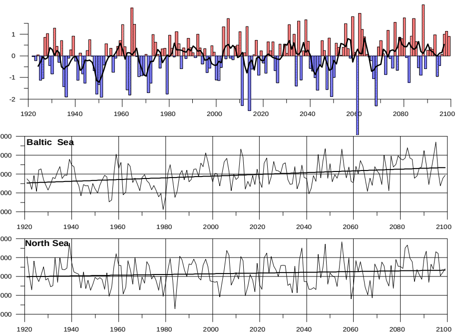

Fig. 7: *Simulated NAO (upper) and river runoff (m³/s) in the North Sea and Baltic Sea region*

The increase of precipitation in the Baltic Sea catchment causes an increase of mean river runoff in this region up to 20% (Fig.7). In the North Sea these changes are much smaller (less than 10%).

COMPARISON WITH ECHAM5/MPIOM IPCC SIMULATIONS

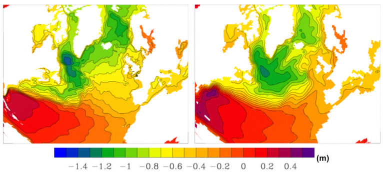

Fig.8 *Mean sea level. Left: MPIOM/REMO, right: MPIOM/ECHAM5 IPCC run*

The comparison between results obtained by the model presented in this study and ECHAM5/MPIOM IPCC AR4 simulations is shown on Fig.8 and Fig.9. The finer resolved ocean model is capable to reproduce some important features which are missing in coarser MPIOM IPCC version. For example the better representation of the Gulf Stream separation and the Labrador current (Fig.11).

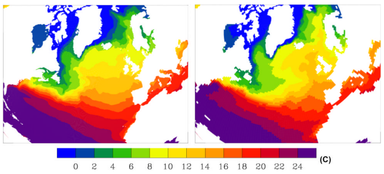

Fig.9 *Mean SST. Left: MPIOM/REMO, right: MPIOM/ECHAM5 IPCC run*

CHANGES IN NORTH ATLANTIC AND EUROPEAN SHELVES

North Atlantic SST is 2-3K warmer in 2080-2099 compared to 1980-1999 (Fig.10). The simulated cooling in the Labrador Sea (1-2K) and northern North Atlantic can be explained by the weakening of the Subpolar Gyre (SPG). This is caused mainly by increased fresh water export from the Arctic Ocean which reduces upper (0-100m) salinity, convection and consequent deep water production in the Labrador sea (Fig.13). On Fig.13 the mean sea level change indicates the SPG intensity decrease. Subsequently, the reduction in deep water convection enhances the freshening of the above mentioned area.

The simulated salinity reduction in North European shelves (about 0.5 psu and up to 2 psu in the Baltic Sea) is caused by increased precipitation (Fig.10 and Fig.5) and river runoff.

The simulated rise of the steric component of the sea surface height is about 2 mm/year (Fig.12). The most pronounced sea level change in the North Atlantic (up to 1 m, see Fig.12) can be explained by the northward shift of the Gulf Stream / North Atlantic current. Significant sea level rise is also simulated on the North European shelves. The local changes in sea level reach about 30 cm in the North Sea and up to 0.45 m in the Baltic Sea.

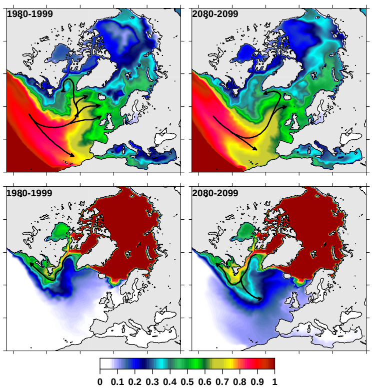

Fig. 11 *Horizontal distribution of vertical mean (0-100m) tropical (top) and polar (bottom) artificial tracers*

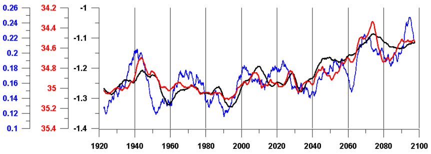

Fig.13. *Five years running mean of Arctic freshwater export (blue) through the Denmark Strait (Sv), 20-80m salinity (red) and mean sea level (m) without steric change contribution (black) at 52W, 57N*

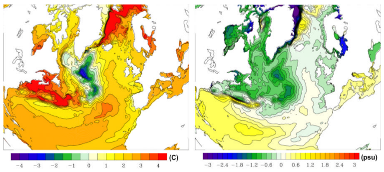

Fig.10 *Mean SST (left) and SSS (right) change 2080-2099 - 1980-1999*

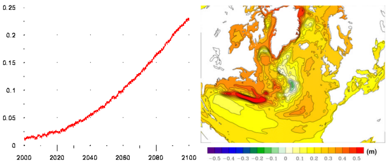

Fig.12 *Global steric sea level change (left) and sea level change in the North Atlantic (right) 2080-2099 - 1980-1999*

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