Future climate change A1B scenario downscaling - Results for the Baltic and North Sea

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1. Model setup

The REgional atmosphere MOdel **REMO** (Jacob, 2001) with 37km resolution is coupled to the global ocean – sea ice – marine biogeochemistry model **MPIOM/HAMOCC** (Marsland et al., 2003) 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 the **OASIS** coupler. The coupling procedure is similar to those described in Aldrian et al., (2005) but some additional processes were taken into account. We included into the coupled system the sea ice (Mikolajewicz et al., 2005), terrestrial hydrology and ocean biogeochemistry. In addition, the ocean model was run with ocean tides and better representation of the diurnal cycle (one hour coupled time step). The last two modifications make one of the major differences from the ECHAM5/MPIOM IPCC simulations, where the diurnal cycle and tidal dynamics were neglected. The ocean tidal forcing was derived from the full ephemeridic luni-solar tidal potential. The global Hydrological Discharge model **HD**, which calculates river runoff (0.5° horizontal grid resolution), is coupled to both the atmosphere and ocean components. Exchange of fields between ocean and atmosphere takes place every hour.

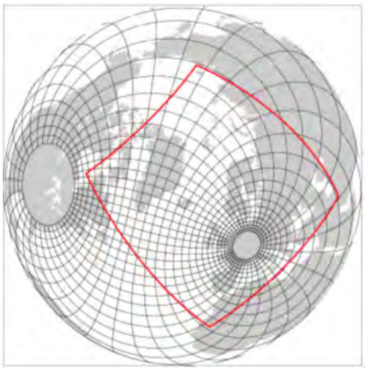

Figure 1. Grid configuration: the red “rectangle” indicates the coupled domain (REMO model) black lines indicate the grid of the MPIOM/HAMOCC. For the ocean/sea ice grid only every 15th line is shown.

Lateral atmospheric and upper oceanic boundary conditions outside the coupled domain were prescribed using NCEP/NCAR reanalysis for the hindcast simulations as well as ECHAM5/MPIOM C20 20-th century and A1B scenario data (the total simulation period was 1920-2100) for corresponding scenario downscaling. After the validation runs with NCEP/NCAR reanalysis the model was spun-up for the period 1920-2000. Then the **scenario** run (21st century) and in parallel a **control** run (20th century forcing) were carried out.

2. Hindcast simulations forced by NCEP/NCAR reanalysis: Comparison with observational data

The Simulated climatological sea surface temperature in the North Sea and the western part of the Baltic Sea is in a good agreement with observational climatologies (Fig.2). In the eastern part of the Baltic Sea, i.e. Gulf of Bothnia and Gulf of Finland, SST is underestimated by about 2K. This is mainly it is caused by a cold bias in the atmospheric model in this region, which is a subject of further investigations.

The largest disagreement of sea surface salinity with observational data occurs around Denmark, in the Gulf of Finland and at the Norwegian coast. Both vertical and horizontal resolutions of the ocean model are not sufficient enough for a realistic representation of the physical processes in these regions. The strong model bias in the Wadden Sea is a consequence of the coarse vertical resolution. The dipole structure of salinity bias along the Norwegian cost is caused by relatively “smooth” modeled Baltic water outflow. The strong observed meandering of this outflow (Johannessen et al., 1989) and a consequent increased horizontal mixing with North Sea water is not resolved in our MPIOM setup.

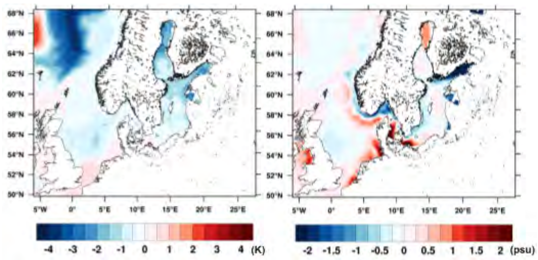

Figure 2. 1980-2000 mean SST (left) and SSS (right) difference: model – GDEM climatology (Carnes, 2009).

One of the most complicated tasks in the modeling of the water circulation in the Baltic and the North Seas is the representation of their exchange through the Danish straits. We realize that vertical resolution ca. 10 m and horizontal ca. 10 km is not sufficient to exactly reproduce the high frequency dynamics, associated with the pulse-like Baltic – North Sea water exchange through the small straits. Nevertheless, the modeled salinity of the Baltic is in relatively good agreement with the observational data. As we do not use any kind of fresh water flux correction or salinity restoring in this region, this indicates that the total exchange was in balance with precipitation and river runoff into the Baltic Sea.

3. Climate change: Precipitation and river runoff

The predicted large scale changes in precipitation are similar to those simulated by ECHAM5/MPIOM (Fig.3), but due to higher atmospheric resolution in REMO they differ in small scale features, in particular in Northern Europe. The stronger precipitation increase during winter time together with corresponding warming and reduction of snow cover leads to substantial increase of Baltic river runoff from November to March.

In general, the increase of precipitation in the Baltic Sea catchment causes an increase of mean river runoff in this region up to 20%.

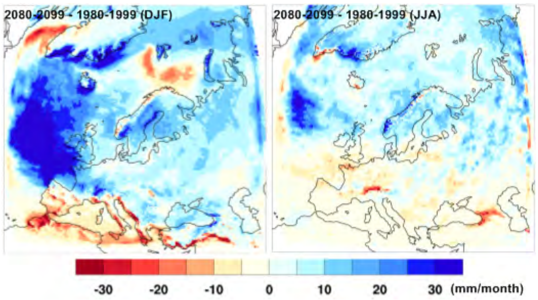

Figure 3. Changes in precipitation

4. Climate change. Sea surface temperature, salinity and sea level changes.

To analyze the climate changes in the Baltic and the North Sea regions we provide a comparison between two last decades of the 20th and 21st century. The warming of the North Sea (ca. 2K) is in a quite good agreement with the global ECHAM5/MPIOM IPCC A1B simulations. The simulated SST change in the Baltic by the end of the 21st century is much higher reaching up to 4K in its northernmost part (Fig.4).

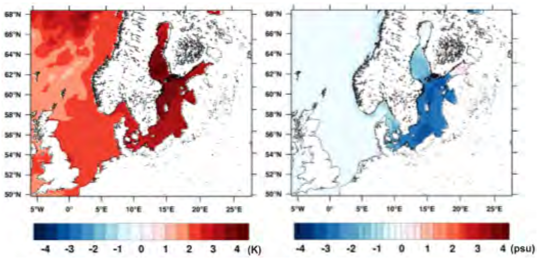

Figure 4. Mean SST (left) and SSS (right) change: 2080-2099 – 1980-1999

One of the most important "added value" in our IPCC scenario downscaling is a representation of salinity changes into the Baltic Sea. Almost all the global AO GCMs involved in IPCC scenario runs are to coarse to simulate realistic salinity in this region providing just a fresh water there. As a result, they do not show the changes in Baltic water salinity and subsequent changes in density and stratification. In our case we obtain a relatively strong freshening (by ca. 3 – 3.5 psu) at the end of 21st century. The main reason for this freshening is the simulated increase of winter precipitation in the Baltic Sea catchment area. While the water outflow is limited by the exchange "capacity" of the Danish straits, the increase of the river runoff tends to store more fresh water into the Baltic, causing its continuous freshening.

Considering the North Sea, our simulations do not show significant changes in sea surface salinity in this region as there is a vigorous water exchange with the open Atlantic.

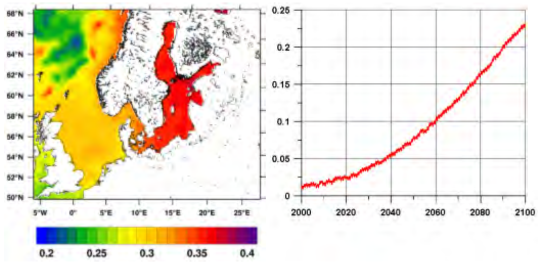

Figure 5. 2080-2099 – 1980-1999 mean sea level change (left) and global steric sea level change (right)

The simulated sea level change consists of the "global part", caused by the thermal expansion of the global ocean (steric change) and its local changes. The mean steric sea level rise estimation is about 2 mm/year (Fig.5) which is in a reasonable agreement with observations and global ECHAM5/MPIOM simulations. Note, that our model does not include glaciers melting, missing the eustatic sea level changes due to corresponding increase of the ocean volume. According to present day estimations it means that we underestimate the current global sea level rise for about 1.5 mm/year (Nerem et al. 2010).

5. Conclusions

The most pronounced changes corresponding to downscaled IPCC A1B scenario projection for the North European shelves were obtained in the Baltic Sea. Global warming will affect the Baltic Sea primarily through an enhancement of the hydrological cycle which delivers more moisture from the tropics towards the poles. The resulting increase of precipitation over the Baltic Sea catchment area leads to substantial increase of the river runoff which is much stronger than in surrounding areas. Sea level changes in the Baltic Sea are therefore much more pronounced then in the North Sea.

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