Coupled ocean - atmosphere feedbacks in Arctic

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1. INTRODUCTION AND BACKGROUND

Our study focus on the estimation of regional climate variability and its dependence on large scale atmospheric and ocean circulation. A global ocean – sea ice model with regionally high horizontal resolution is coupled to an atmospheric regional model and global terrestrial hydrology model. This art of coupling divides global ocean model setup into two different subdomains: coupled, where the ocean and the atmosphere are interacting, and uncoupled, where the ocean model is driven by prescribed atmospheric forcing and runs in a so-called stand-alone mode. Therefore, choosing a specific area for the regional atmosphere we can suppose that in that area ocean-atmosphere system is "free", whereas in the rest of the ocean its circulation is driven by prescribed atmospheric forcing without any feedbacks..

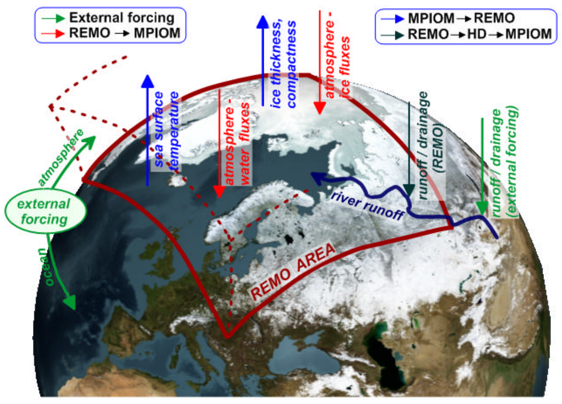


Fig.1 *REMO/MPIOM/HD coupling scheme*

2. MODEL SETUPS

The REgional atmosphere MOdel **REMO** is coupled to the global ocean – sea ice model **MPIOM** with increased resolution on the Arctic. The models are coupled via **OASIS** coupler. The coupling is schematically presented on Fig.1

Exchange between ocean and atmosphere was made with 6 hours coupled time step. Lateral atmospheric and upper oceanic boundary conditions outside the coupled domain were prescribed using NCEP/NCAR reanalysis data (the total simulation period was 1958-2007).

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

Five different coupled setups (Fig.2) were used for 5 ensemble simulations. Each ensemble contained 5 ensemble members.

The coupled domain of each setup includes the Arctic and additionally a specific region, i.e. Asia, Atlantic, Pacific, in order to investigate the impact of this region on Arctic climate variability (Fig.2). The smallest domain covering the whole Arctic and the northern North Atlantic is called the "Arctic" setup. The others are named according to region of extension. The Atlantic-Pacific (AP) setup was added after we obtained surprising results from the "Pacific" configuration. This setup (AP) is an extension of the last one to the North Atlantic.

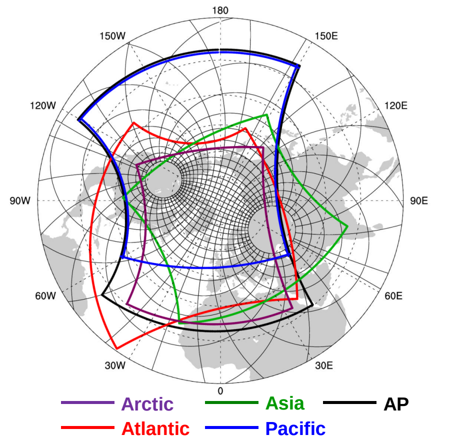


Fig.2 *Coupled REMO/MPI-OM configurations. Colored „rectangles" indicate the domains of coupling. Black thin lines – MPIOM grid. Only every 12th line of the ocean grid is shown*

3. COMPARISON WITH ERA40 REANALYSIS

The large scale atmospheric circulation of all of the model configurations, except the Pacific setup, shows good agreement with reanalysis data (ERA40). The model simulates Atlantic air transport over the Russian sector and Pacific transport over Canadian one (Fig.3-Fig.4). In the Asia setup the Atlantic transport into the Central Arctic is significantly overestimated, which causes during DJF strong warm bias (4-6K) there.

A much stronger bias in winter circulation is showed by the Pacific setup. The choice of the Atlantic model boundary destroyed the model consistency in reproducing NAO and caused a strong domination of the North Pacific air inflow over all the Arctic Ocean. This deficit of the North Atlantic heat transport into the Arctic causes the cooling only over the subarctic Eurasian continent, while whole the Arctic Ocean gets in winter much warmer: up to 4K in Central Arctic and up to 8 K at Canadian coast.

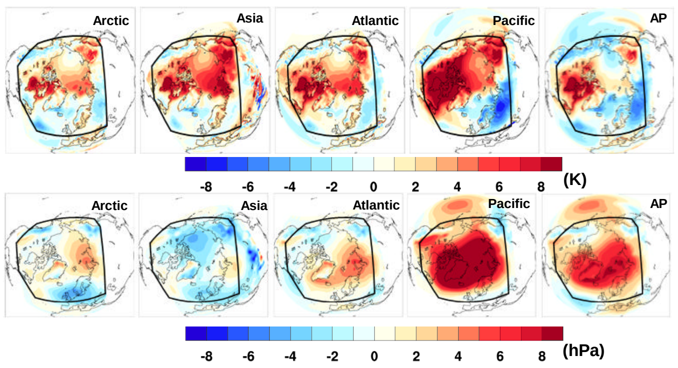


Fig.3 *Mean DJF difference (Model – ERA40). Upper: 2m temperature. Lower: mean sea level pressure*

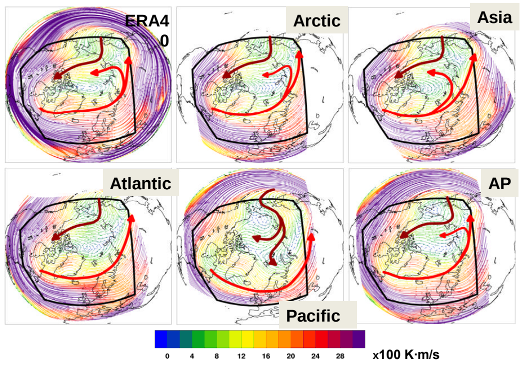


Fig.4 *Mean DJF 500 hPa heat transport (**v**·T)*

4. AO/NAO

Only two out of the five considered setups (Arctic and Atlantic) reproduce the observed AO spatial pattern correctly, as shown in In Fig.5 (right). The common feature of these two setups is that the Aleutian Low is prescribed. In the other configurations it mostly or totally belongs to the coupled area.

Considering the impact of the different regions on the AO/NAO time evolution (Fig.5 left), we can conclude that the large scale atmosphere – ocean coupled modes like AO are strongly influenced by the Pacific Ocean. While in the Arctic, Asia, Atlantic setups the simulated AO show a correlation with observations of 0.7-0.8, both the setups where the coupled area is extended to the Pacific simulate an AO that have a rather low correlation with observations (about 0.2). This fact means that if you include the North Pacific into the coupled domain, the AO becomes an "internal" mode, which is not the case when the North Atlantic is included in the coupled area.

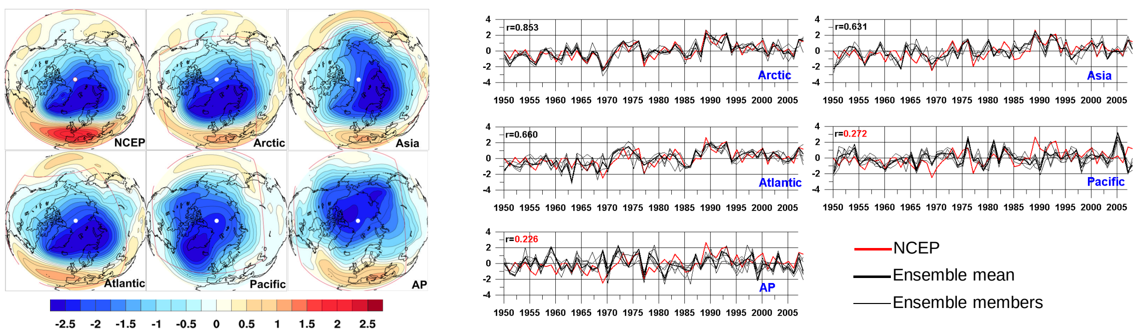
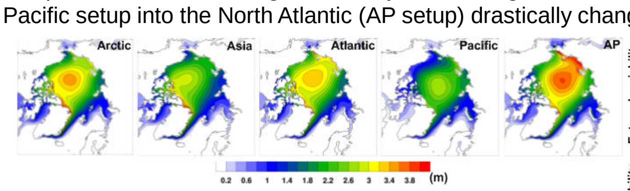


Fig.5 *Left: Leading EOF of DJF SLP anomalies over NH (20° -90° N), red line indicates the coupled area. Right: its normalized principal components. The numbers on time series plots: correlation between ensemble means and reanalysis,*

5. SEA ICE THICKNESS

Winter sea ice thickness as well as its variability are presented in Fig.6. The strong reduction of sea ice in the Pacific setup reflects the warming caused by dominating heat transport from the North Pacific (Fig.4). But an extension of Pacific setup into the North Atlantic (AP setup) drastically changes the ice formation into the coupled domain.



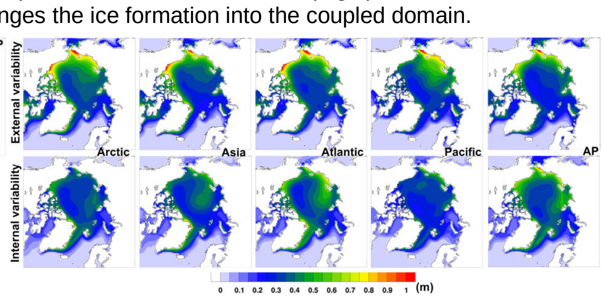


Fig.6 *Mean DJF sea ice thickness (upper) and its external (standard deviation of ensemble mean) and internal (ensemble spread) variability (right).*

6. ARCTIC CLIMATE VARIABILITY

To estimate the impact of different regions on Arctic climate variability we split the model climate variability into "external" and "internal" parts. The first one should be the common part of all the ensemble members, indicating the impact of the external forcing, e.g. boundary conditions. It is calculated as the standard deviation of ensemble mean. The internal variability should represent the oscillations generated in the coupled domain by the model itself and was calculated as the deviation of ensemble members from ensemble mean. The splitting on external and internal modes is presented for winter sea level pressure in Fig.7 and 2m temperature in Fig.8.

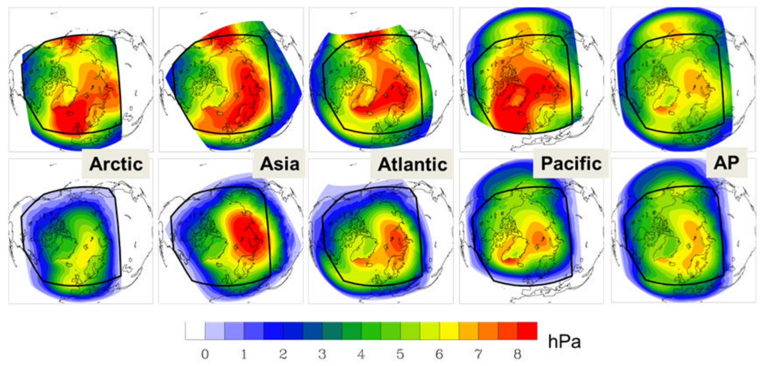


Fig.7 *Mean DJF external (upper) and internal (lower) sea level pressure variability. Black poligon indicates the common area of all the five coupled domains*

Fig.7 shows that the ocean plays a stabilizing role in the coupled ocean-atmosphere-land system. From all the setups the Asian one has much more land inside the coupled domain and also exhibits the strongest internal variability. This fact has a clear explanation: dynamically, the ocean, being a flat surface, disturbs the atmosphere less than land. Thermodynamically, it is more inertial and damps the temperature variations in the near-surface atmosphere.

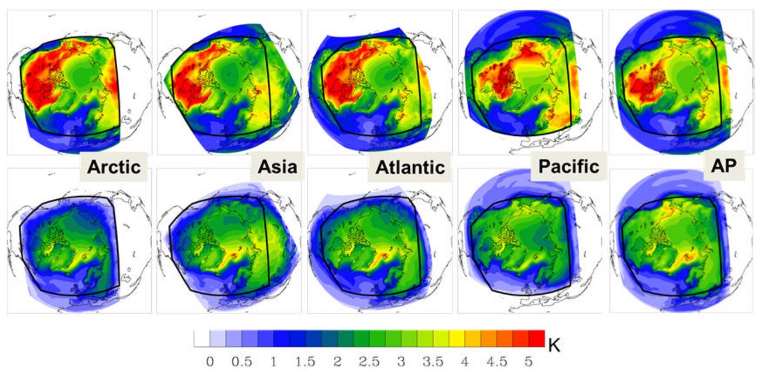


Fig.8 *Mean DJF external (upper) and internal (lower) 2m temperature variability. Black poligon indicates the common area of all the five coupled domains*

Thep AP setup in general produces much less variability then the others. While reduced interannual variability is a commonly known feature of global climate models, we can conclude that the coupled region in AP setup represent a relatively closed system which includes most important areas influencing on climate variability in the northern high latitudes.

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