Fresherwater anomalies in the Arctic and North Atlantic

Being connected by a network of currents, the Arctic and North Atlantic Oceans exchange a large volume of water of different characteristics. As a consequence, their freshwater budgets are also connected.

Averages for two decades before 2000 picture an approximate balance between Arctic freshwater imports and exports. However, freshwater fluxes to and from the Arctic Ocean, and thus the storage of freshwater are not constant, and have not been in recent years either. According to observations, the liquid freshwater content of the Arctic Ocean increased by around 10,000 km³ between 1992-2012 (Flude et al., 2014, Fig. 3). The freshwater system of the Arctic linked to the North Atlantic appears to be dynamic with changes and anomalies on different time scales. The comparison of the freshwater content anomalies of the Arctic Ocean, and the Subpolar North Atlantic and the Nordic Seas shows a significant anti-correlation (95% confidence). Moreover, the similar size of freshwater anomalies suggest an oscillation (Horn et al. in prep. Fig. 2).

The evolution of liquid freshwater content in the Subpolar North Atlantic correlates with time series of cumulative AD and NAO indices (Horn et al. in prep. Fig. 3).

What is the future of the NAO?
Predominant high NAO index, a positive trend that could continue into the 21st century.

Hypothesis and Aims

The freshwater budgets of the Arctic and the North Atlantic oceans are linked. The distribution of freshwater in their basins is subject to significant changes. The hypothesis is that these changes are driven by atmospheric forcing:

Freshwater distribution in the Arctic and North Atlantic oceans is governed by wind stress forcing.

The aim is to investigate the role of atmospheric forcing in shaping freshwater reservoirs and exchanges between different subregions of the Arctic and North Atlantic oceans. What are the processes affecting the circulation? What role does wind stress play?

What changes of freshwater do different NAO state favor, where and how does it influence the distribution?

Methods – MPI-ESM and Modini

The tool for experiments is the fully coupled Earth System Model of the Max Planck Institute (MPI-ESM), using a partial coupling technique (Modini-MPI-ESM), to incorporate reanalysis wind fields to enable studies with different wind stress scenarios.

The Modini approach is a partial coupling technique which enables the MPIOM, the ocean component of the MPI-ESM (Fig. 5) to be driven by prescribed 6 hourly wind stress anomalies, while maintaining consistency of heat and energy exchanges between the atmosphere and ocean. External wind forcing can be enabled or disabled in a flexible way, while the rest of the coupling remains the same as in the original MPI-ESM configuration. Thus the atmospheric model component ECHAM6 still computes its own wind field and responds to the external forcing only through receiving coupled parameters from MPIOM (Thoma et al., 2015).

The wind forcing of Modini brings an improvement between the correlation of the modeled and observed SST. The improvement is most pronounced in the Pacific and Indian oceans, but there is an increase in the Arctic too (Fig. 6). The upwelling regions of the North Atlantic suffer from known biases in the MPI-ESM as in most Earth system models, however, an improvement is still visible from wind forcing, especially in the Labrador Sea (Fig. 6).

External forcing data:

Experiments:

How do different NAO states affect the distribution of freshwater? How do they influence the AMOC?

Modini applicability and experiment design

Methods

Drivers of freshwater distribution in the Arctic and Atlantic Oceans

T. Kovacs1,2,3, M. Horn1, R. Gerdes1,2
1. Alfred Wegener Institute, Bremerhaven, Germany
2. Jacobs University, Bremen, Germany

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References

Flude et al., 2014
Horn et al., 2015
Thoma et al., 2015

47 vertical levels

24 hour cycle

Coupling – OASIS: exchange of fluxes and state variables

4. Improvement of the correlation between the model and the reference (HadISST) SST (Extended annual mean from 1860 (SHAP) and 1880 (MaxInv-NCEP)).

5. MPI model configuration with NCEP wind forcing (Thoma et al. 2014).

Fig. 4. Improvement of the correlation between the model and the reference (HadISST) SST (Extended annual mean from 1860 (SHAP) and 1880 (MaxInv-NCEP)).

Fig. 5. Model-MPI-ESM structure and model components (Giorgetta et al., 2012).

NCEPECSR data from 1981 to 2010

Fig. 7. Monthly evolution of AMOC strength (as % of the original MPI-ESM) as in the CMIP5 experiments (red) and Modini-MPI-ESM experiment (green). Reference (black) is ERSST-cleaning array data (Thomson et al., 2010).

Fig. 6. Improvement of the correlation between the model and the reference (HadISST) SST (Extended annual mean from 1860 (SHAP) and 1880 (MaxInv-NCEP)).

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