Wind forcing of the Arctic and North Atlantic freshwater system

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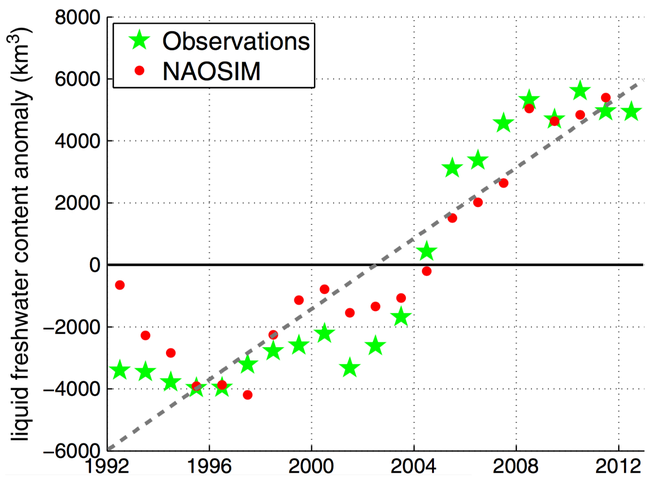
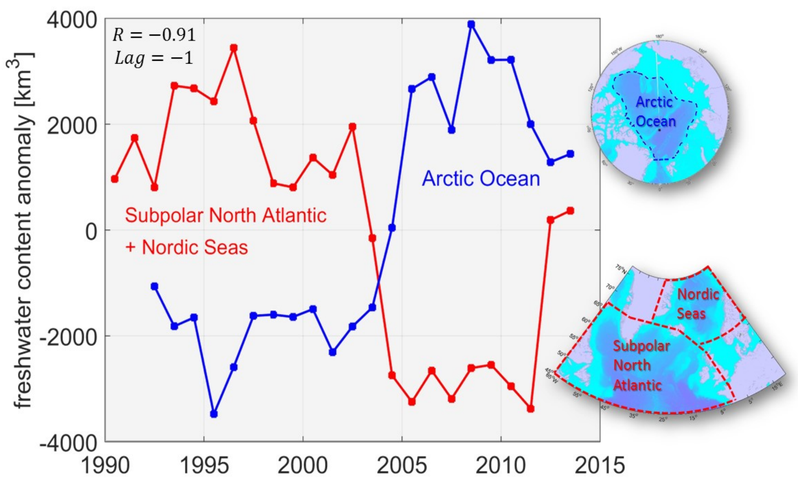
Motivation

Freshwater content anomalies in the Arctic and North Atlantic oceans: What is the effect of wind forcing?



According to observations, the **liquid freshwater content of the Arctic Ocean increased** by around 10,000 km³ between 1992-2012 (Rabe et al. 2014).

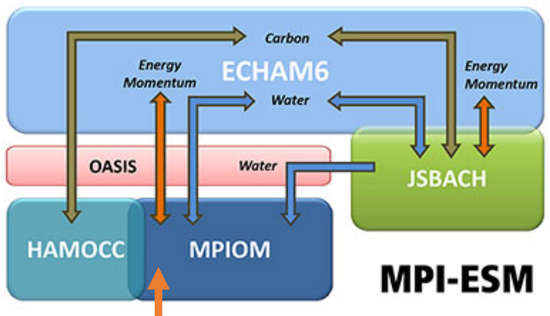


The **freshwater content anomalies of the Arctic Ocean**, and the **Subpolar North Atlantic and the Nordic Seas** show a significant anti-correlation (95 % confidence). Moreover, the similar size of freshwater anomalies **suggest an oscillation** (Horn et al. in prep).

Methods

Modeling experiments with MPI-ESM + Modini

MPI-ESM-LR (low resolution)



MPI-ESM structure of model components (Giorgetta et al., 2013)

Observations
Energy/Momentum

Modini

Thoma et al. 2015

The Modini approach is a partial coupling technique which enables the MPIOM, the ocean component of the Earth System Model of the Max Planck Institute (Fig. 3) to be driven by **prescribed 6 hourly wind stress anomalies**, while **maintaining consistency** of heat and energy exchanges between the atmosphere and ocean.

External forcing data:

NCEPcfsr (Saha et al. 2010) → Anomalies, applying them to model climatology (Wind speed data) → Interpolation, Calculation from ocean momentum (Wind stress data) → **Wind stress anomalies**

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).

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Results

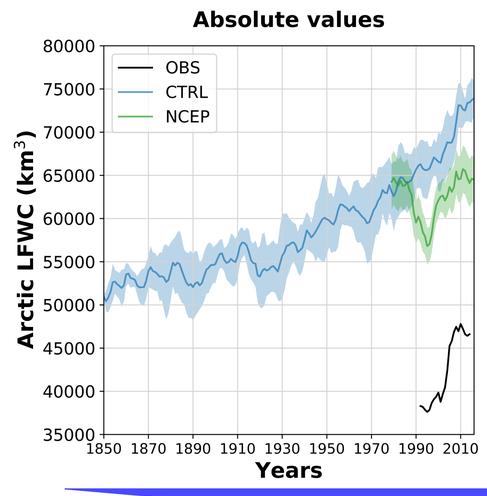
1850 — 1979 — 2016

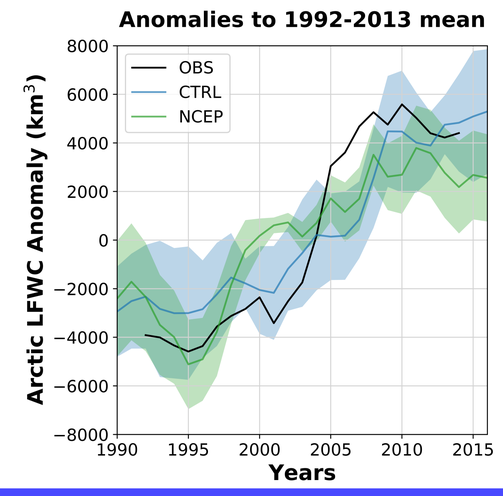
CTRL fully coupled control runs

NCEP runs with external wind forcing

Comparison of model results from **fully coupled** and **partially coupled** runs.

Arctic Liquid Freshwater Content

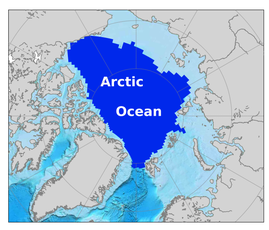




Arctic Liquid Freshwater content.
Time series of annual means from fully coupled (blue – CTRL) and partially coupled (green – NCEP) runs. Solid lines indicate the mean, the shaded area the standard deviation of 5 ensemble members. Observational data (black – OBS) is from Horn et al. in prep.

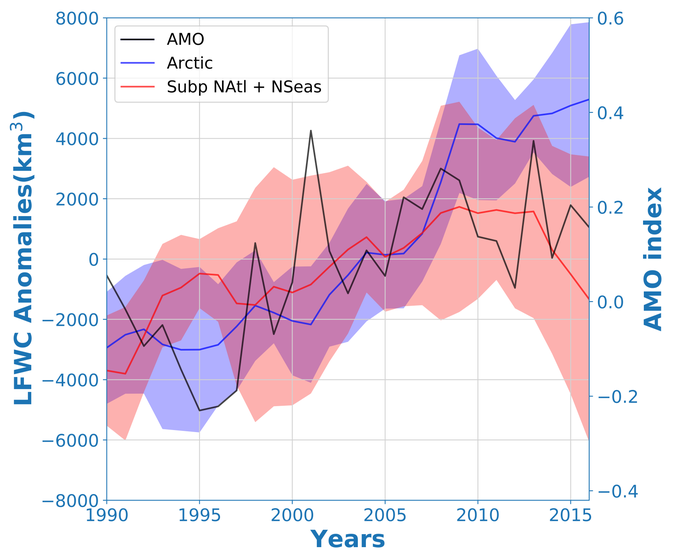
$$LFWC = \oint \int_{z=0m}^{h} \frac{S_{ref} - S}{S_{ref}} dz\ dA$$

$S_{ref} = 35$
h = depth of 34 isohaline

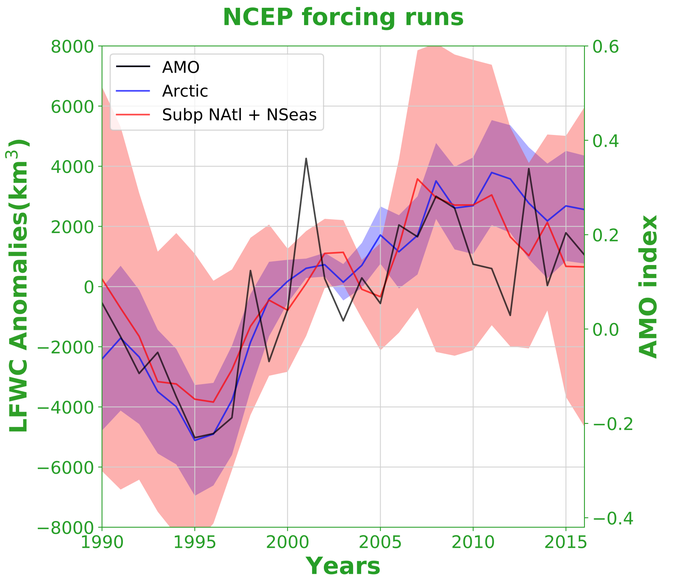


Arctic Ocean

Control runs



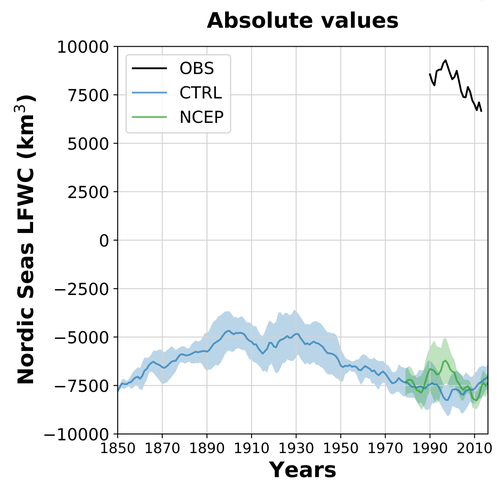
NCEP forcing runs

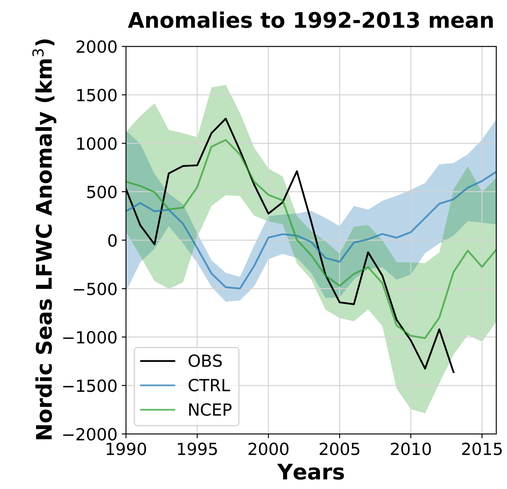


Time series of annual liquid freshwater content anomalies from fully coupled (left) and partially coupled (right) runs. Connection between the Arctic Ocean (blue lines), and the Subpolar North Atlantic Ocean and the Nordic Seas (red lines, multiplied by -1). Solid lines indicate the mean, the shaded area the standard deviation of 5 ensemble members. Annual means of the Atlantic Multidecadal Oscillation are plotted with a three-year lag and are from Enfield et al. 2001.

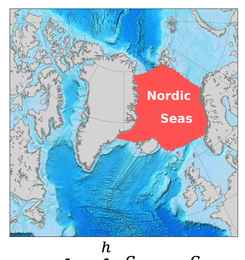
Nordic Seas + Subp. N.Atlantic

Nordic Seas Liquid Freshwater Content





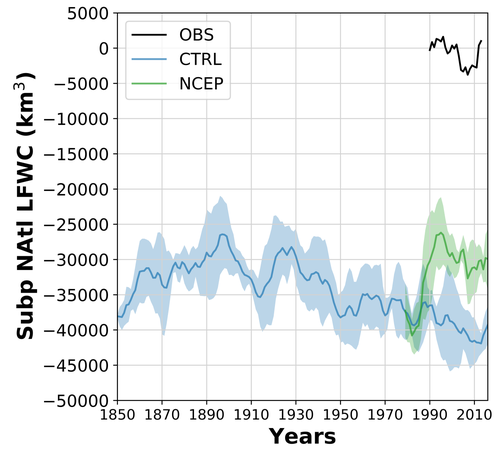
Nordic Seas Liquid Freshwater content.
Time series of annual means from fully coupled (blue-CTRL) and partially coupled (green – NCEP) runs. Solid lines indicate the mean, the shaded area the standard deviation of 5 ensemble members. Observational data (black – OBS) is from Horn et al. in prep.

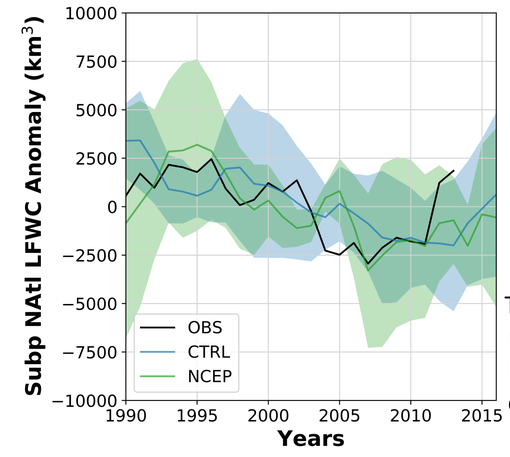


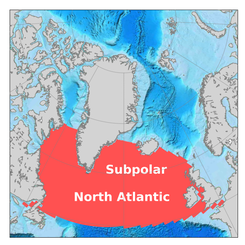
$$LFWC = \oint \int_{z=0m}^{h} \frac{S_{ref} - S}{S_{ref}} dz\ dA$$

$S_{ref} = 35$
h = 2000 m

Subpolar North Atlantic Liquid Freshwater Content







Subpolar North Atlantic Liquid Freshwater content.
Time series of annual means from fully coupled (blue – CTRL) and partially coupled (green – NCEP) runs. Solid lines indicate the mean, the shaded area the standard deviation of 5 ensemble members. Observational data (black – OBS) is from Horn et al. in prep.

Summary

In comparison with the freshwater content of the fully coupled control runs, the Modini-MPI-ESM runs with prescribed wind forcing are closer to observations in terms of reproducing

- absolute values (although a bias is still present)
- trends and interannual variations
- the connected freshwater system of the Arctic and North Atlantic oceans