Bundesministerium für Bildung und Forschung

Projektträger Jülich Forschungszentrum Jülich GmbH

ALFRED-WEGENER-INSTITUT HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

HELMHOLTZ GEMEINSCHAFT

RACE TP 2.1

Arctic Circulation as part of the North Atlantic current system

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Aims of the subproject

The main aim of this project was to document the climate relevant circulation changes in the Arctic Ocean according to changes in the mass setup, to understand the responsible key processes, and to investigate the predictibility of changes.

In detail we pursued the following questions:

- Which seasonal to decadal changes have been in the mass setup of the Arctic Ocean since 1950? Which relation exists with changes in the circulation of the upper and intermediate cantral basins and with the excahnge wih the shelfes and the subpolar North Atlantic?
- Which key processes controls the freshwater content and distribution in the Arctic Ocean? Which consequences for the freshwater pool does a reduced ice cover? Which role does changes in the distribution of freshwater (continental run-off) play? Which influence do local changes of wind stress have?

Variability of Atlantic Water Recirculation in Fram Strait

In Fram Strait, the Atlantic Water (AW) flow bifurcates with some AW directly recirculating southwards in Fram Strait and another part taking the long route through the Arctic Ocean. This has profound impacts on the AW in the deep water formation regions offshore of the East Greenland shelf, but currently the dynamics of this bifurcation are poorly understood.

In winter, the WSC is more baroclinic (higher shear) and is weakly stratified. As a result it is more baroclinically unstable. The Ri≈3 then correspond to e-folding growth rates of 1/3days compared to Ri≈30 and 1/10days in summer.

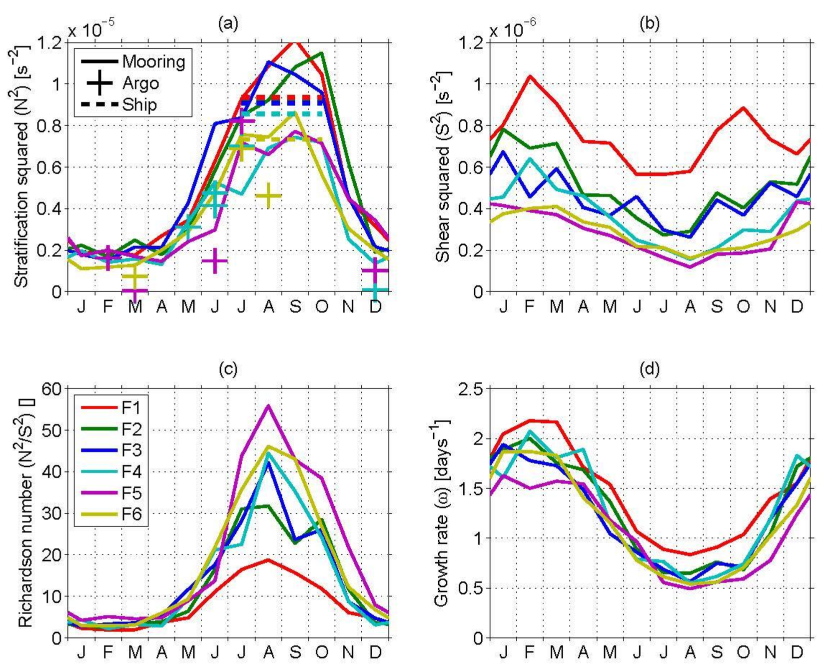


Figure 5: Seasonal progression of (a) stratification, (b) shear, (c) Richardson number, and (d) growth rate of baroclinic instability in the WSC (5° E-9° E) (von Appen et al., 2016).

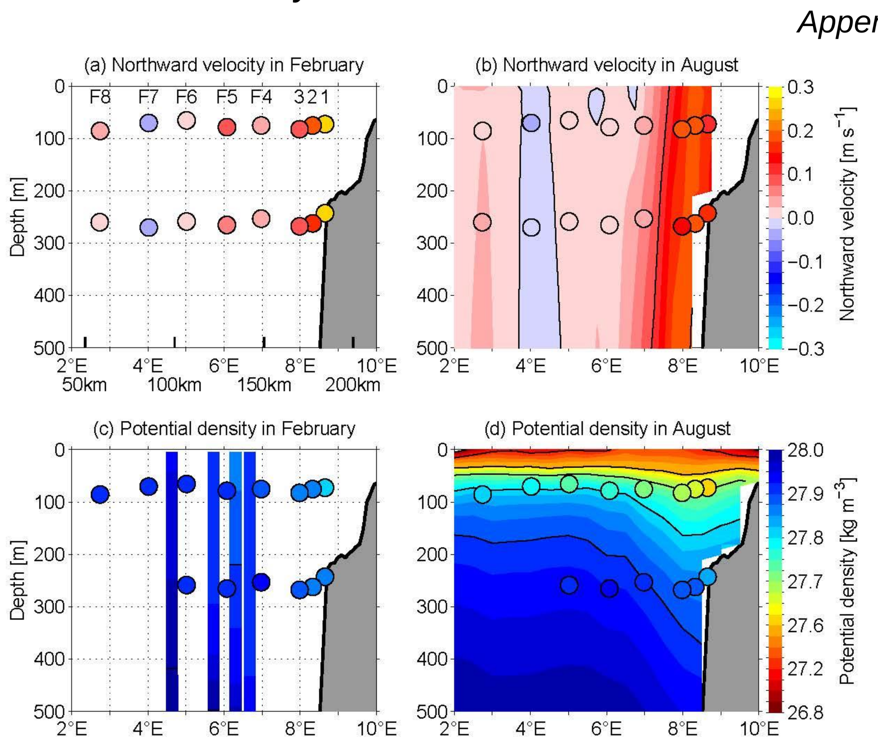


Figure 6: Seasonal variation in the WSC from moored instruments: northward velocity (a,b) and potential density (c,d) in February (a,c) and in August (b,d). The summer density section from CTD sections is overlain in (d) (von Appen et al., 2016).

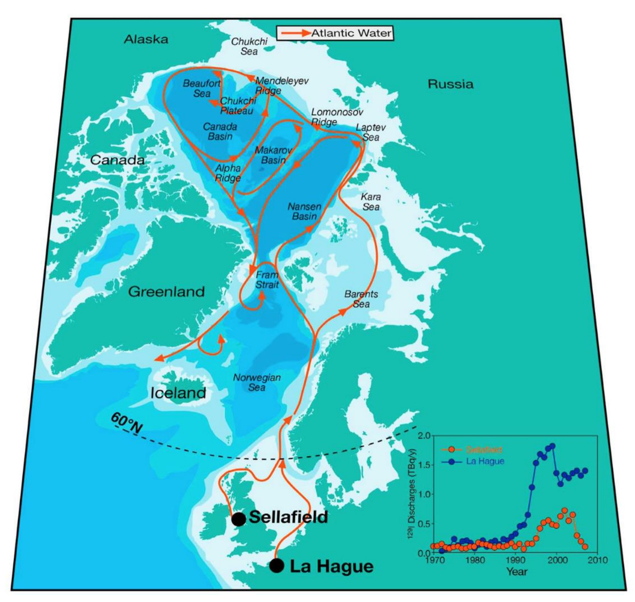


Figure 7: Atlantic Water (AW) pathways in the Arctic Mediterranean as visualized by 129I tracer. The AW flow is sub-surface in the Arctic proper.

Freshwater variability in the Arctic Ocean and the North Atlantic

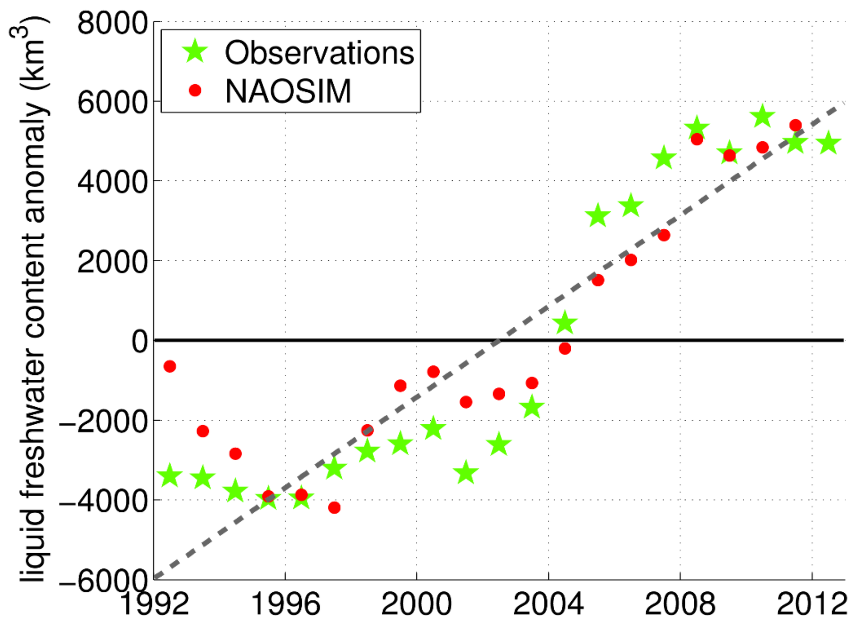


Figure 1: Annual mean liquid freshwater content (FWC) of the upper Arctic Ocean basins (surface to 34 isohaline). The observations show a positive trend of 600±300 km³ yr⁻¹ over 21 yrs, equivalent to about 12000 km³ or a 3 m layer of freshwater (Sref=35). Values from observations and NAOSIM agree well over most of the time period (Rabe et al., 2014; GRL).

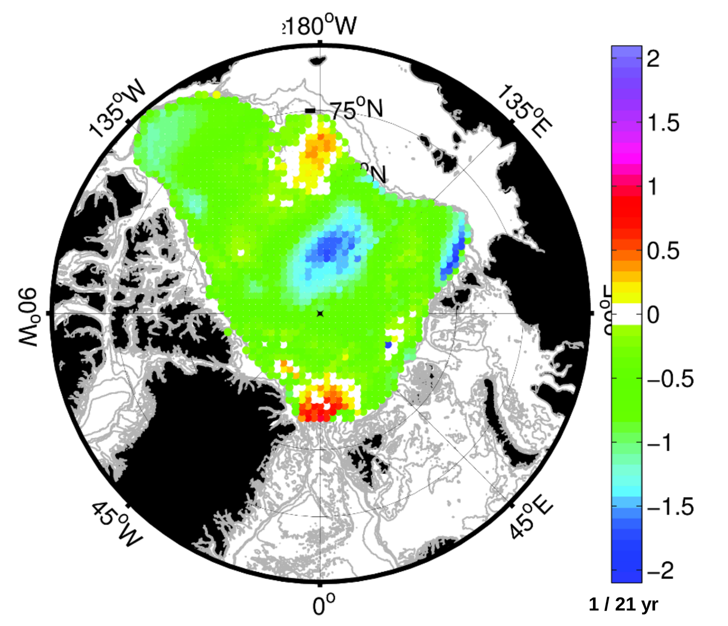


Figure 2: Observational horizontal distribution of the trend in depth-mean salinity in the layer from the surface to the 34 isohaline during 1992-2012. The salinity decreased almost everywhere in the Arctic basins, affecting a freshwater increase of about 8000 km³ over the 21 years for this component (c.f. total increase 12000 km³).

Our coupled ice-ocean model shows a decrease of Arctic freshwater from the 60s to 90s by ~12000 km3. In the same period the freshwater content in the subpolar North Atlantic has risen by 15000 km^3 (Curry and Mauritzen, 2005)

The freshwater content increased in the Arctic since the 90s by 10-12000 km^3 (model and obs), which is mainly due to a decrease in the mean layer salinity and only minor due to an increase in layer thickness. In the same period the freshwater content in the subpolar North Atlantic has dropped by ~8000 km^3 (Mauritzen et al.; 2012; Curry and Maurizen, 2005)

These results indicate a role of the Arctic Ocean as an important source for decadal salinity variations in the subpolar nort Atlantic.

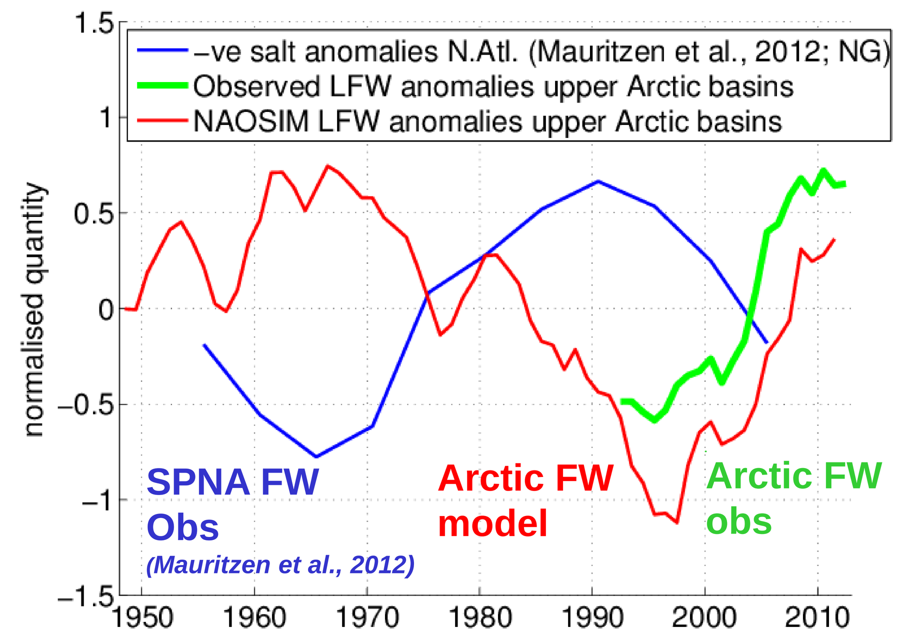
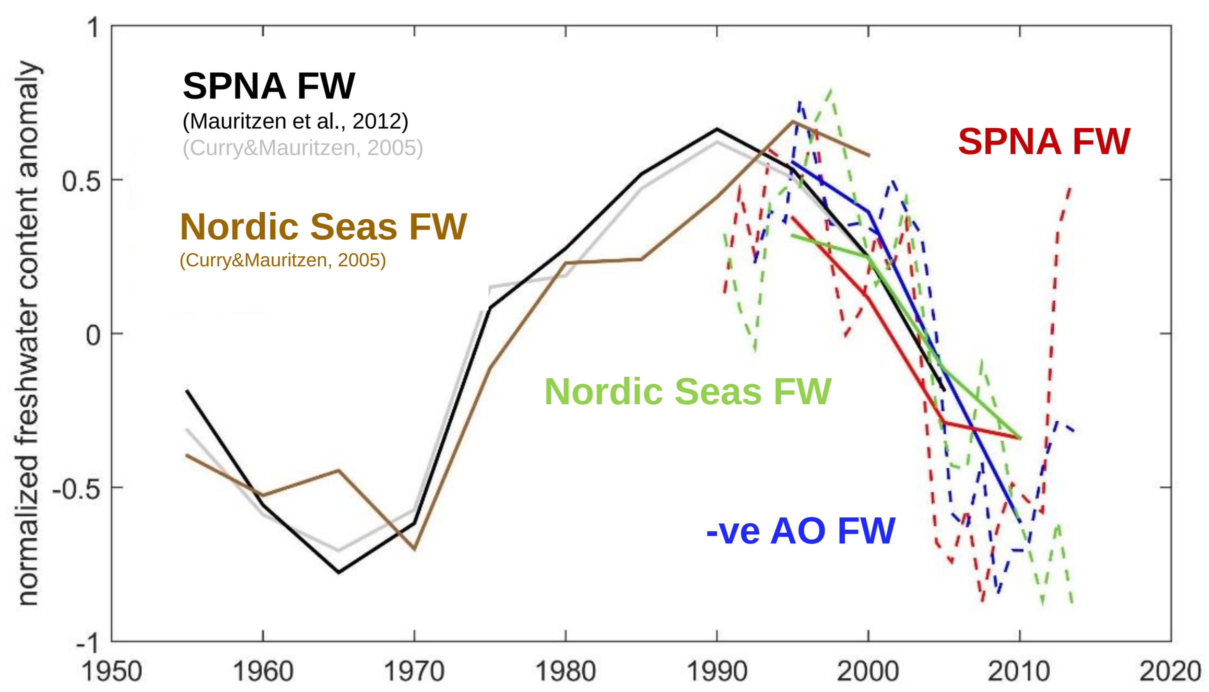


Figure 3: Opposing multi-decadal salinity variations in the Arctic and the subpolar Atlantic: Arctic freshwater content (FWC) from own analysis of observations (green) and own coupled ice-ocean simulation (NAOSIM, red). The salt deficit in the subpolar North Atlantic (Mauritzen et al.; 2012 NatGeo, blue, pentadal means). All data normalized.

Figure 4: Comparison of the Subpolar North Atlantic (SPNA, red), Nordic Seas (green) and inversed Arctic Ocean (AO, blue) freshwater contents to previously published time series (black, gray, and brown). Solid lines display pentadal means and dashed lines annual means. All time series have been normalized by twice their standard deviation (Horn et al., subm.).



Erste Ergebnisse RACE II

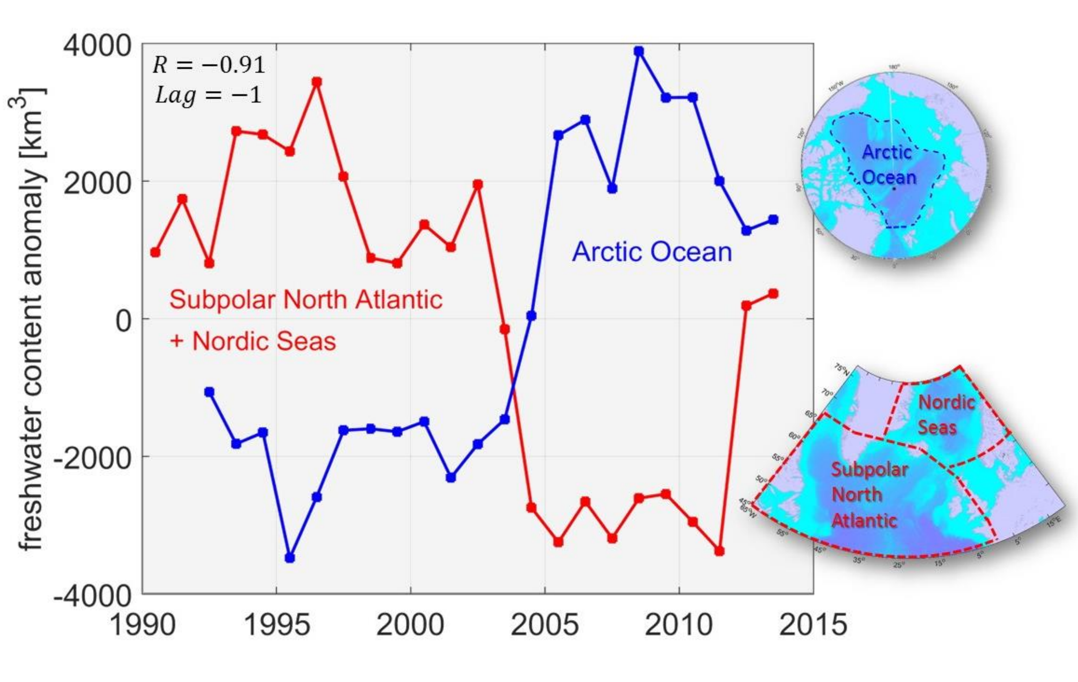


Figure 8: Significant anti-correlation (95 % significance) of the Subpolar North Atlantic and Nordic Seas liquid freshwater content anomalies and the Arctic Ocean total freshwater content anomalies with a 1-year lag of the Arctic Ocean freshwater content (Horn et al., subm.).

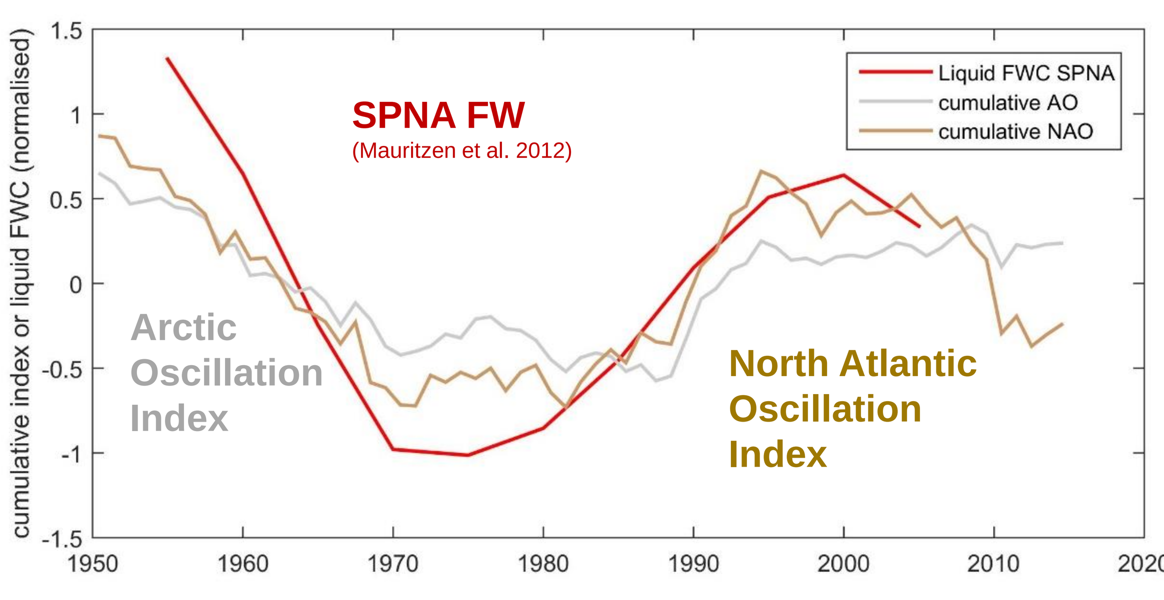


Figure 9: Significant correlation (95 % significance) of the SPNA liquid freshwater content (Mauritzen et al. ,2012), the cumulative Arctic Oscillation Index, and the cumulative North Atlantic Oscillation Index. All time series have been normalized by twice their standard deviation, detrended, and demeaned (Horn et al., subm.).

The total (solid+liquid) freshwater content of the Arctic Ocean and the liquid freshwater content of the subpolar North Atlantic and the Nordic Seas show oppsing multidecadal variabilty between 1992 and 2013. Furthermore the SPNA freshwater changes are correlated with changes in atmospheric oscillation patterns.

We suggest that the origin of freshwater variability in the North Atlantic is the freshwater accumulation in or release from the Arctic Ocean.

Aims RACE II

In this subproject the relation between freshwater circulation and accumulation in the Arctic Ocean and the interaction with the North Atlantic is investigated.

The scientific work is supposed to answer the following questions:

- What is the relation between freshwater variabilties in the Arctic Ocean, the Nordic Seas, and the North Atlantic?
- Which atmospheric processes have the biggest influence on the covariabilty of the freshwater content in this regions?
- How does the North Atlantic react on changed freshwater exports from the Arctic Ocean, especially according to the horizontal circulation and the deep water convection?

Therefore we will use a combination of observational and reanalysis data as well as model output and will perform model experiments.

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