Atlantic Inflow to the North Sea Modulated by the Subpolar Gyre: A Potential Oceanic Influence on North Sea Marine Ecosystems?

Vimal Koul[1,2] (vimal.koul@uni-hamburg.de), Johanna Baehr[1] and Corinna Schrum[1,3]

[1]Institute of Oceanography, CEN, Universität Hamburg, Germany
[2]International Max Planck Research School on Earth System Modelling, Hamburg, Germany
[3]Helmholtz-Zentrum Geesthacht, Geesthacht, Germany

1. Motivation and Methods

The oceanic inflow to the North Sea is known to be mainly wind driven. However, on interannual to decadal timescales, the properties of this inflow may be modulated by the subpolar gyre (SPG). We build on the work[1,2,3] carried out over past several years on the role of SPG in determining the physical and biogeochemical properties of eastern North Atlantic waters. Here we show that influence of the SPG extends to the North Sea.

We analyze historical simulation (1850-2005) from the coupled Max Planck Institute Earth System Model (MPI-ESM) in its low resolution setup. The ocean component, MPIOM, has 40 vertical levels with 13 levels in the first 220 meters. We carry out empirical orthogonal function analysis on modelled sea surface elevation to derive the canonical SPG index[4].

2. The SPG of the North Atlantic

- The SPG is a relatively cold and fresh cyclonic oceanic gyre with strong currents marking its periphery and showing variability on longer timescales (**fig1**).
- The canonical SPG index captures the observed relation between the gyre state and saline inflow towards the Nordic seas (**fig 2**).

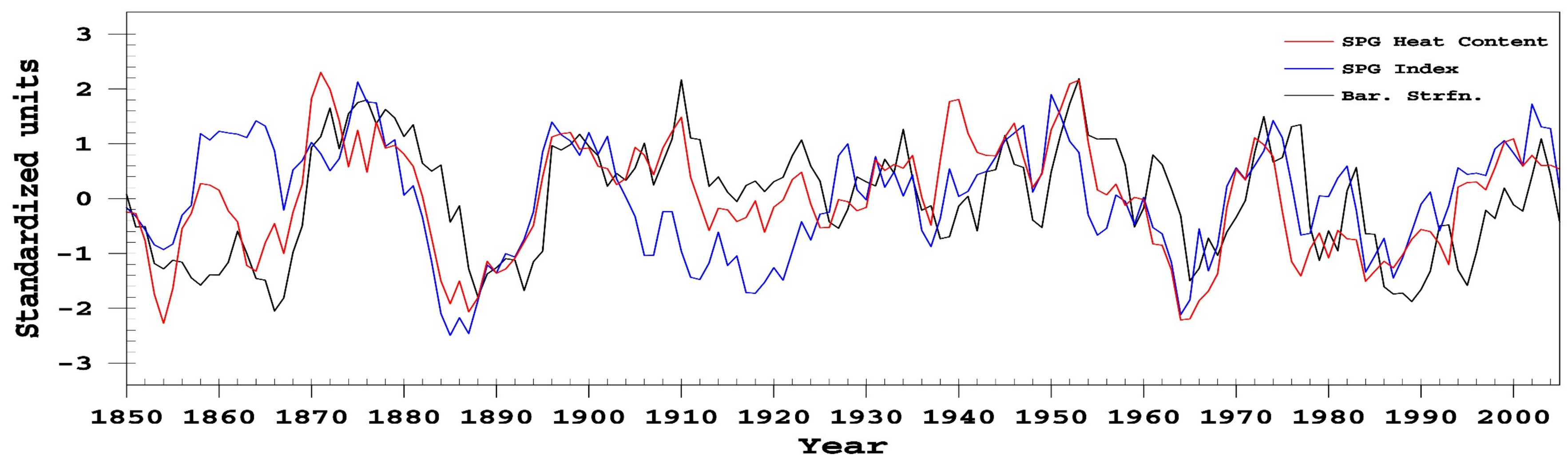

Figure 1. Standardized time-series of the subpolar gyre (SPG) heat content [J] of top 20 model levels (~740 m), the SPG index defined as the first principal component of the sea surface elevation [m] and the barotropic streamfunction [Sv] averaged over 23:54°W, 52:62°N.

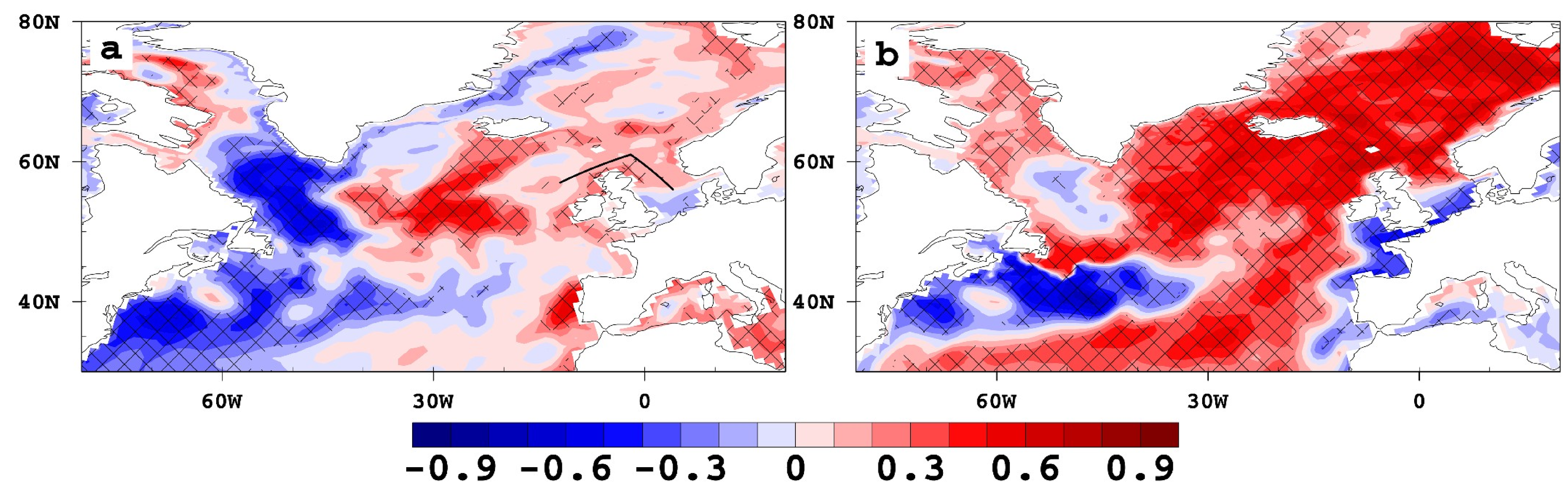

Figure 2. Correlation of **a.** barotropic streamfunction and **b.** SPG index with the top 485 m salinity. Positive correlations indicate increase in salinity with a weakening gyre. Statistically significant correlations at 0.05 significance level computed using bootstrapping procedure are hatched. The black line in **a** shows the section on which fig 3 is based.

3. Northward penetration of subtropical waters and the influence of the gyre state

- The oceanic inflow to the North Sea acquires its properties south of the Rockall Trough and is modified along its path through the Faroe Shetland Channel (FSC) (**fig 3**).
- Pulses of high salinity propagate into the northern parts of the North Sea and are diluted as they move towards the shallow southern part.
- This suggests a coherent variability in these three regions.

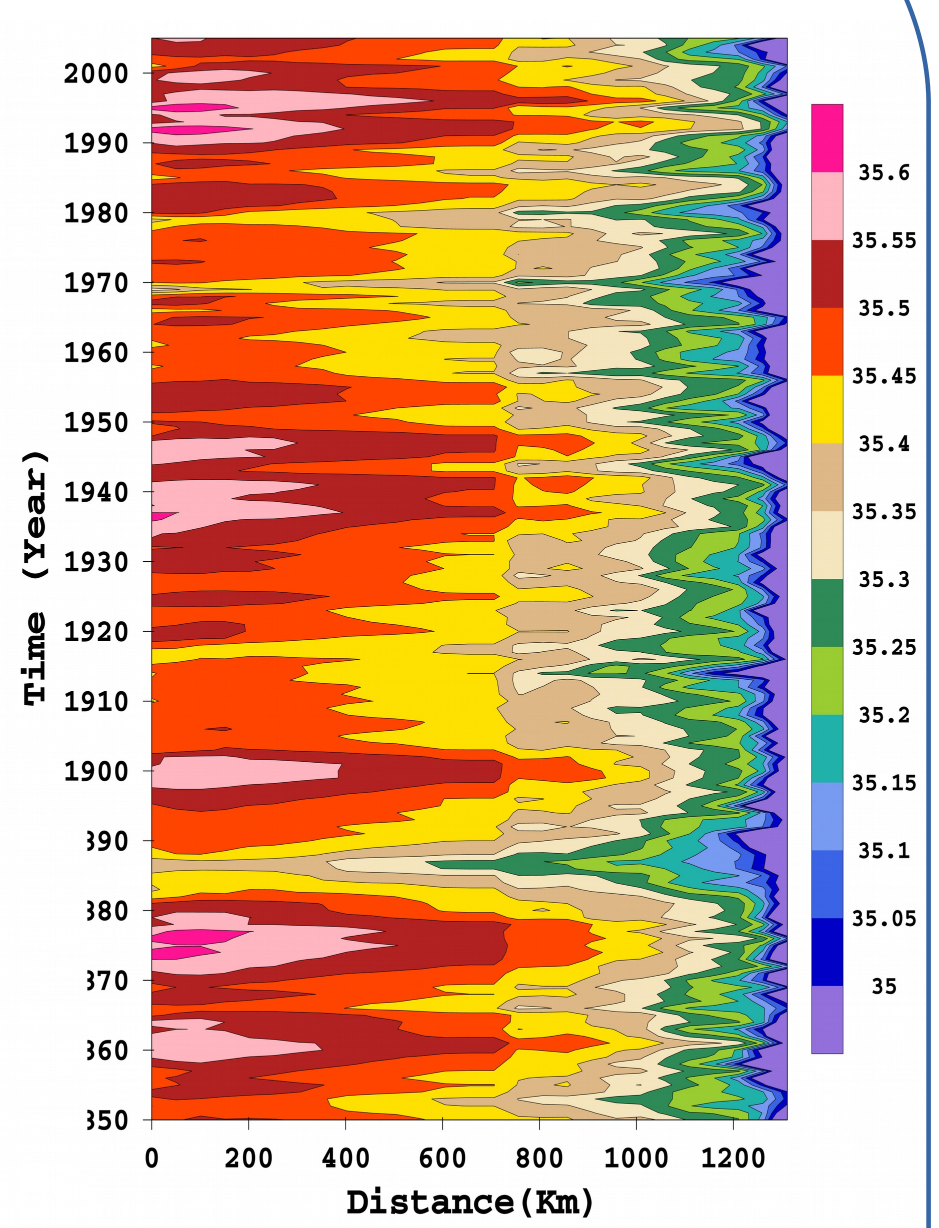

Figure 3. Hovmoller diagram for top 485 m salinity along a section (black line in fig 2a) from Rockall Trough (left, 0 km) to the North Sea (right, ~1300 Km) via the FSC (center, ~700 km). Points on the section shallower that 485 m have values averaged to bottom.

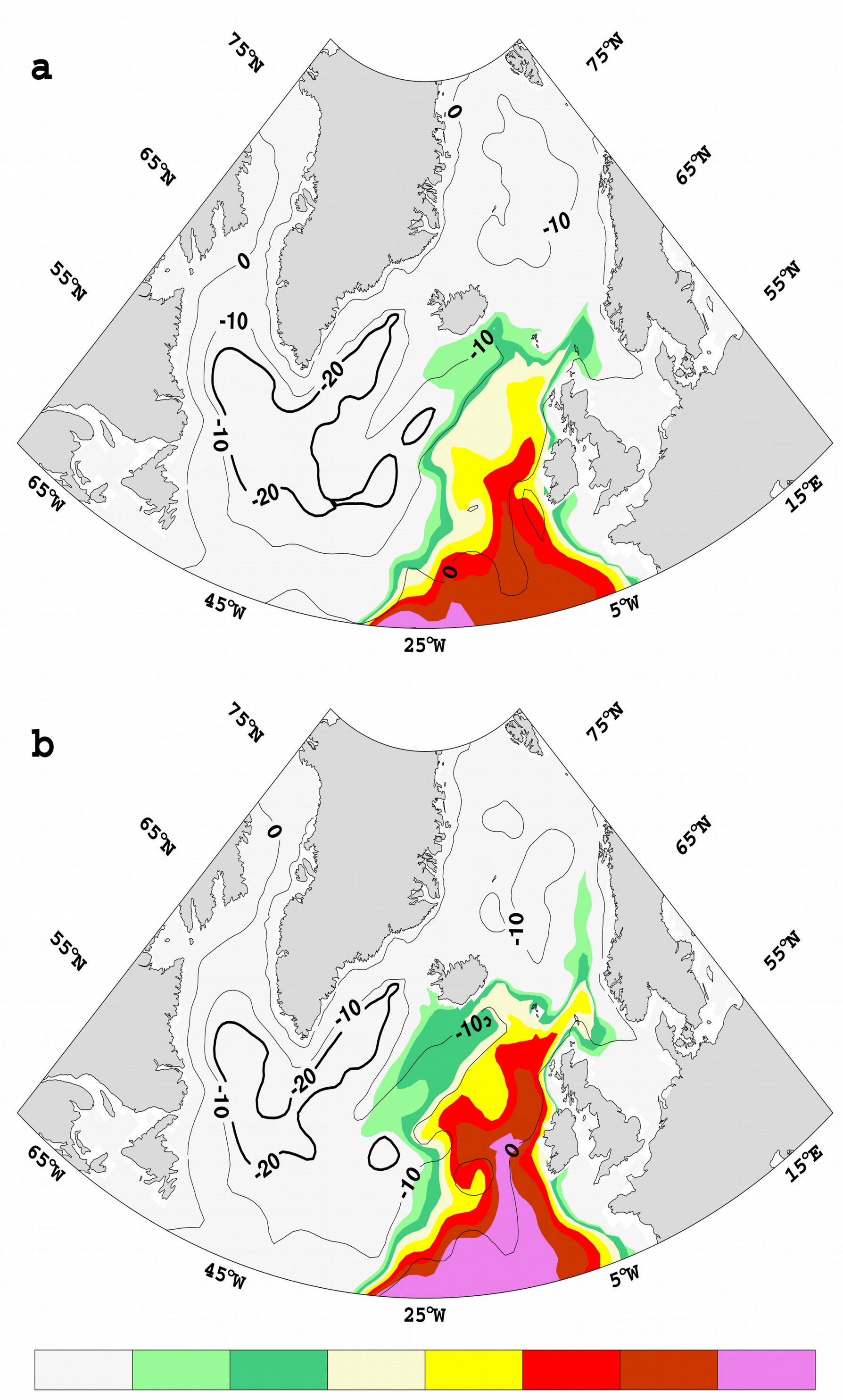

Figure 4. Composites of the top 485 m salinity (color) and Bar. Stfn. (contours) in the North Atlantic. Composites, **a.** strong SPG and **b.** weak SPG, are based on ±1 standard deviation of the SPG index.

- A strong gyre (**fig 4a**) has an east-west orientation. This zonally inflated gyre brings relatively fresh waters from the western SPG towards the eastern SPG, and therefore the northward extent of the subtropical waters is restricted.
- When the SPG is weak (**fig 4b**), the subpolar front (salinity gradient in the Iceland basin) moves westwards. The canonical SPG index captures this variability in the strength and shape of the gyre.
- The high salinity waters of subtropical origin have some contribution from the Mediterranean Overflow Water.

4. Volumetric T-S analysis of key inflow regions

- In the Rockall Trough region, thermohaline changes occur corresponding to the state of the SPG (**fig 5a**). In the FSC and northern North Sea, the salinity signal is preserved (**fig 5b,c**) while the temperature signal is lost to the atmosphere.
- The volume transport of saline Atlantic inflow to FSC (**fig 5d**) and North Sea (**fig 5e**) is significantly correlated with the SPG index (**r=0.65,** lag 0 and **r=0.44,** lag 2 respectively). The total inflow to North Sea (black line, **fig 5e**) is mainly wind driven.

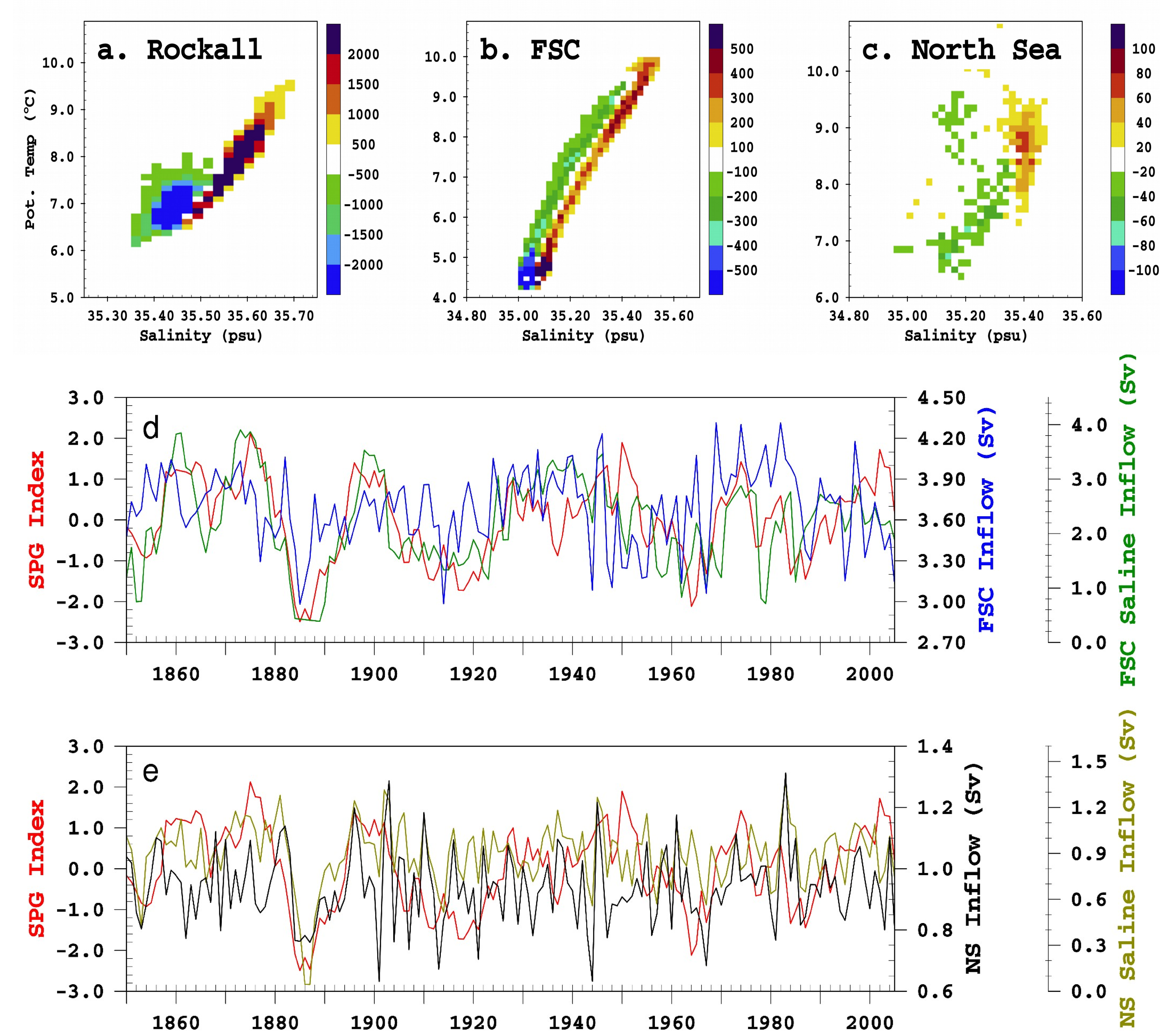

Figure 5. a-c. Composite difference of top 1000 m water volume [km³] for weak minus strong SPG. For the FSC and northern North Sea depth is till bottom. **d.** timeseries of SPG Index (red), volume transport of Atlantic inflow into the FSC (blue) and volume transport of extracted saline Atlantic inflow (salinity >35.40 psu and density <1027.6 Kg m⁻³) into the FSC (green) and **e.** timeseries of SPG Index (red), volume transport of Atlantic inflow into the North Sea (black) and volume transport of saline Atlantic inflow (salinity >35.30 psu) into the North Sea (yellowgreen).

5. Conclusions and Outlook

1. Overall, we find that volume transport of the saline inflow to the North Sea is influenced by the subpolar gyre, a weak gyre leading to a saline regime. Local water mass transformation processes do not constrain the gyre influence.

2. Across the Iceland-Scotland Ridge, the salinity part of the SPG signal is preserved while the temperature part is lost to the atmosphere.

3. In the next step, we will assess to which degree the North Sea marine ecosystem variability is influenced by the SPG dynamics.

References
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Max-Planck-Institut für Meteorologie
Universität Hamburg
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International Max Planck Research School on Earth System Modelling