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Dynamical constraints on the choice of the North Atlantic subpolar gyre index

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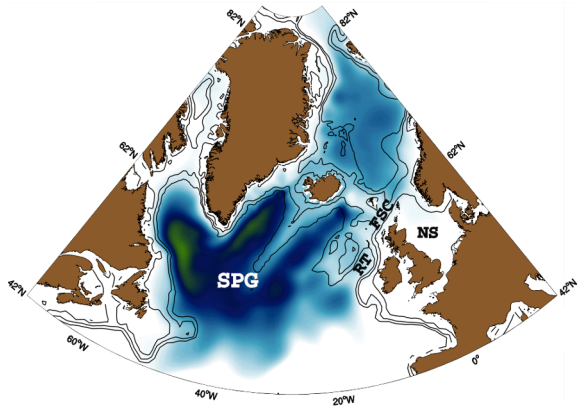
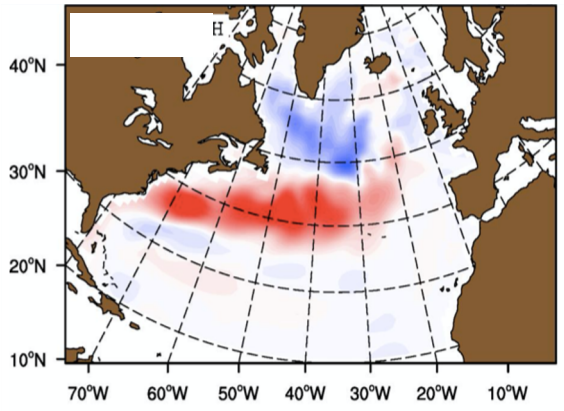
One Gyre Many Definitions

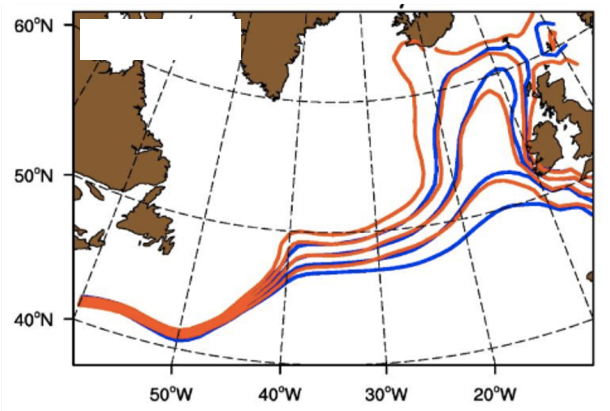
Barotropic streamfunction



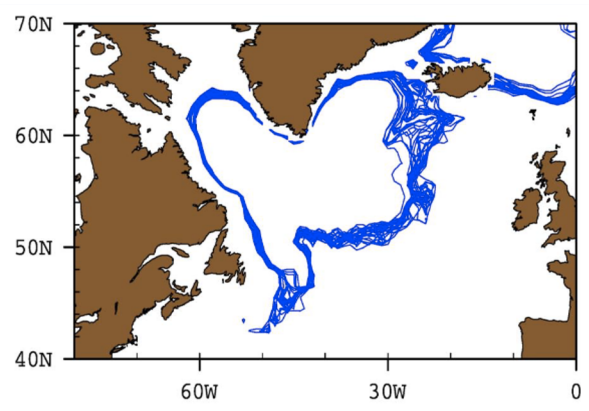
Leading EOF SSH



Isohalines



Largest closed contours SSH



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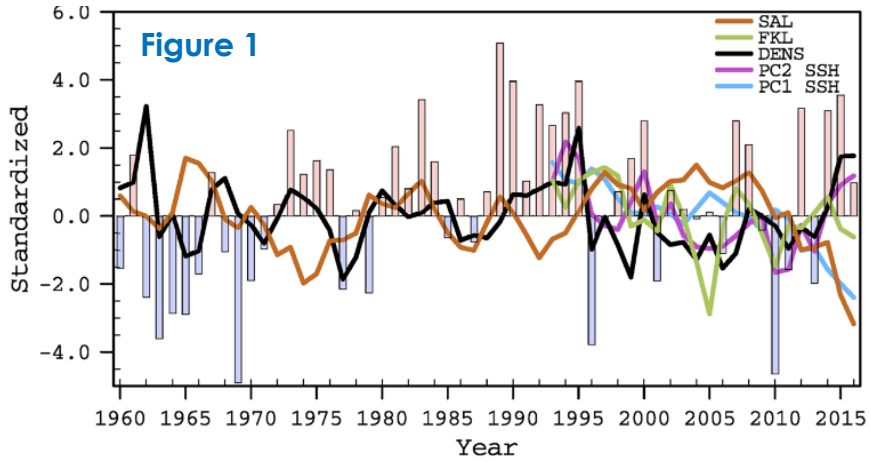
One Gyre Many Indices



Indices*

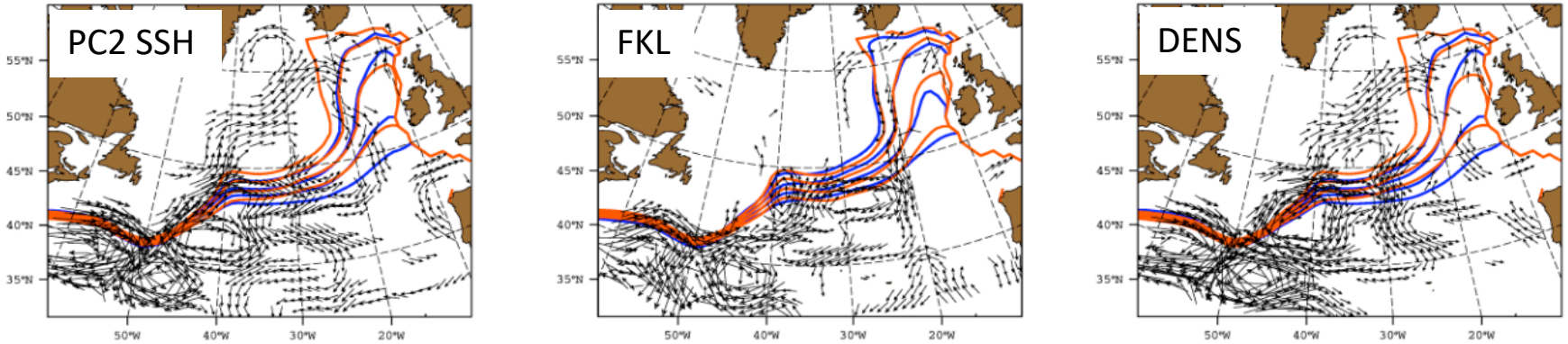
PC1 SSH: Principal component of first mode of observed sea surface height (SSH) variability.
PC2 SSH: Principal component of second mode of SSH variability.
DENS: Index based on subsurface density in the central SPG.
FKL: Index based on largest closed contours of SSH in the subpolar North Atlantic.

Why have multiple indices of subpolar gyre (SPG) strength been defined? Due to scarcity of direct observations of SPG circulation, various indices of SPG strength have been proposed, as shown in Figure1.

However, as new observations accumulated, it became apparent that some indices do not represent the dynamics of the SPG, as is the case with PC1 SSH, which shows a monotonous trend. With this, the long standing hypothesis, that the SPG circulation impacts eastern subpolar North Atlanic salinity, was questioned.

Differences in observed relationship of SPG indices with salinity and currents

Figure 2

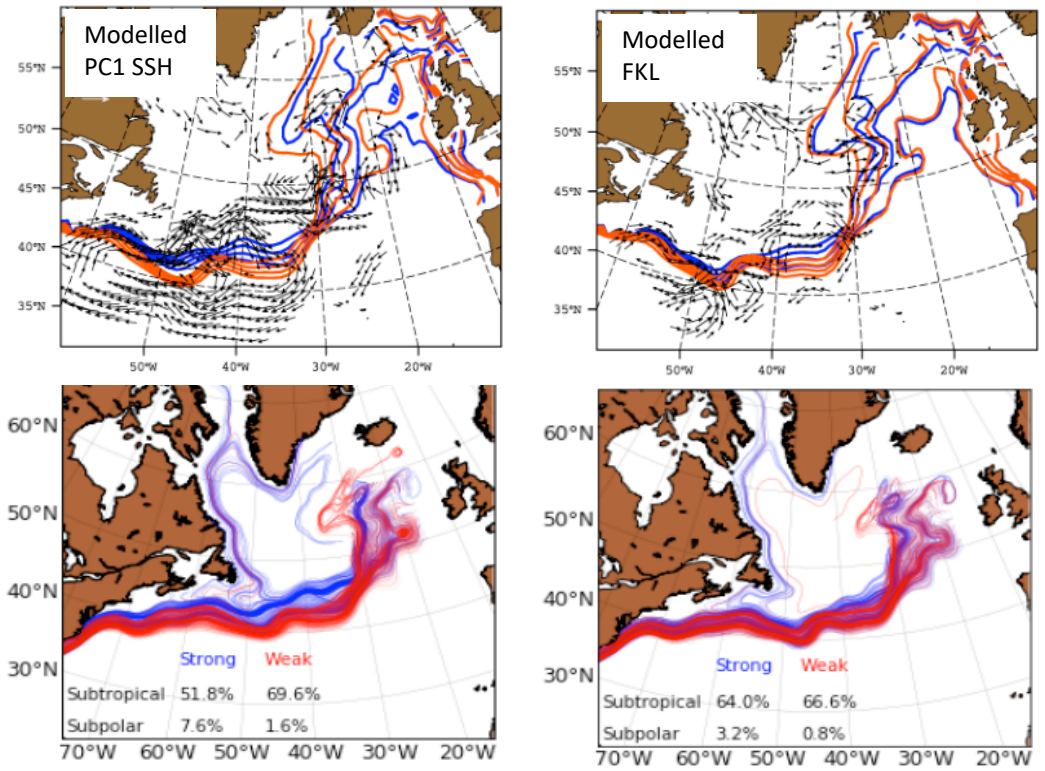


Does the SPG circulation impact salinity in the eastern subpolar North Atlantic (ENA)? Yes, two out of three indices suggest that variability in SPG circulation impacts salinity in the ENA. To illustrate this, composite difference (strong-weak) of annual mean geostrophic currents and salinity (35.2 to 35.5 psu isohalines with 0.1 psu spacing) for strong (blue) and weak (red) years of SPG strength are shown in Figure 2. The index based on largest closed contours of SSH disagrees with the other two indices, and does not show the strengthening of baroclinic velocities, which are related to isohaline shifts.

* **Data, model, methods and definition of SPG indices:** Koul, V., Tesdal, J., Bersch, M. *et al.* Unraveling the choice of the north Atlantic subpolar gyre index. *Sci Rep* 10, 1005 (2020). https://doi.org/10.1038/s41598-020-57790-5

Dynamical basis of isohaline shifts

Figure 3



How does circulation variabiliy in the Newfoundland basin impact salinity in the eastern subpolar North Atlanitc (ENA)? This is the key question and we explore it through model based Lagrangian trajectory experiments*.

The modelled differences in isohaline shifts in the ENA between the EOF based index (PC1 SSH) and the largest closed contour based index (FKL) are the result of their difference in advective pathways (Figure 3).

The modelled PC1 SSH (related to observed PC2 SSH)* index shows westward shift of Lagrangian trajectors in the ENA and northward shift in the Newfoundland basin. These shifts modulate the proportions of subpolar and subtropical waters reaching the ENA and thus impact salinity.

The closed contour definition does not capture such shift in Lagrangian trajectories in the model, thus leading to the absence of any impact on salinity in the ENA.

SPG-salinity relationship and the choice of the SPG index

Does the SPG circulation impact salinity in the ENA? Yes, both observations and model experiments show that SPG circulation impacts salinity in the ENA.

Which is the best suited index of SPG strength? The indices based on subsurface density (DENS) and principal component of the second mode of SSH variability in the subpolar North Atlantic (PC2 SSH) are the best suited observation based indices. In general, those indices which represent the circulation variability in the Newfoundland basin and conform to the strong-SPG-low-salinity hypothesis in the ENA are best suited proxies of SPG strength.

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