Supplement

1.1 Additional Tables

Table S1 Monthly Mean 2 dimensional files that were not archived, and how they were replaced: "Daily Means" the daily mean files were archived, and have been averaged into monthly means.

Ensemble Member	Date	Grid	Replacement averaged from
r001i1p00605	205107	T	Daily Means
r001i1p00605	205008	U	Daily Means
r001i1p00605	208403	V	Daily Means
r001i1p00834	205102	T	Daily Means
r001i1p00834	205103	T	Daily Means
r001i1p01113	208409	V	Daily Means
r001i1p01935	205110	T	Daily Means
r001i1p02123	205010	U	Daily Means
r001i1p02123	208311	V	Daily Means
r001i1p02242	205105	U	**Adjacent Years**
r001i1p02242	208311	U	Daily Means
r001i1p02335	205009	T	Daily Means
r001i1p02868	205111	T	**Adjacent Years**
r001i1p02868	205112	T	Daily Means
r001i1p02868	205108	U	Daily Means
r001i1p02868	205006	V	Daily Means

Table S2 Regional Mean monthly mean files not archived

Ensemble Member	Date	Replacement averaged from
r001i1p00605	205008	Daily Means
r001i1p00834	205109	Daily Means
r001i1p01935	202905	Daily Means
r001i1p01935	202906	Daily Means
r001i1p02123	205010	Daily Means
r001i1p02491	205008	Daily Means
r001i1p02832	205006	**Adjacent Years**

Table S3 MLD for summer and autumn. Note the grid boxes where the PEA < 20 J/m^3 have been masked out prior to calculation of the regional statistics.

MLD	Shelf	Southern North Sea	Central North Sea	Northern North Sea	English Channel	Irish Sea	Celtic Sea
JJA	-3.33 m (±2.17 m)	-2.78 m (±1.65 m)	-2.17 m (±1.55 m)	-2.01 m (±2.01 m)	-4.13 m (±2.67 m)	-6.03 m (±3.57 m)	-3.00 m (±1.40 m)
SON	-12.30 m (±6.69 m)	-0.11 m (±0.86 m)	-7.19 m (±3.82 m)	-8.23 m (±6.26 m)	0.31 m (±0.24 m)	-9.39 m (±8.65 m)	-9.55 m (±4.50 m)

Table S4 Projected regional mean Potential Energy Anomaly (PEA) changes between 2000-2019 and 2079-2098. 10 J/m³ is considered the threshold for stratification. See Table 5 for details.

PEA							
	Shelf	Southern North Sea	Central North Sea	Northern North Sea	English Channel	Irish Sea	Celtic Sea
ANN	17.41 J/m^3 (±13.40 J/m^3)	0.57 J/m^3 (±0.63 J/m^3)	10.02 J/m^3 (±4.49 J/m^3)	14.87 J/m^3 (±13.50 J/m^3)	1.75 J/m^3 (±0.81 J/m^3)	3.89 J/m^3 (±2.18 J/m^3)	36.25 J/m^3 (±25.67 J/m^3)
DJF	8.52 J/m^3 (±9.99 J/m^3)	-0.17 J/m^3 (±0.42 J/m^3)	0.02 J/m^3 (±0.44 J/m^3)	4.25 J/m^3 (±9.01 J/m^3)	-0.03 J/m^3 (±0.18 J/m^3)	-0.08 J/m^3 (±0.98 J/m^3)	27.87 J/m^3 (±23.69 J/m^3)
MAM	4.06 J/m^3 (±8.53 J/m^3)	0.22 J/m^3 (±0.97 J/m^3)	1.69 J/m^3 (±2.56 J/m^3)	3.49 J/m^3 (±8.66 J/m^3)	0.40 J/m^3 (±0.48 J/m^3)	1.33 J/m^3 (±1.96 J/m^3)	10.53 J/m^3 (±17.87 J/m^3)
JJA	24.03 J/m^3 (±17.14 J/m^3)	2.03 J/m^3 (±1.55 J/m^3)	21.57 J/m^3 (±8.78 J/m^3)	22.71 J/m^3 (±18.74 J/m^3)	4.03 J/m^3 (±1.58 J/m^3)	10.11 J/m^3 (±4.56 J/m^3)	41.12 J/m^3 (±28.00 J/m^3)
SON	32.84 J/m^3 (±21.40 J/m^3)	0.22 J/m^3 (±0.50 J/m^3)	16.77 J/m^3 (±8.91 J/m^3)	28.98 J/m^3 (±23.80 J/m^3)	2.60 J/m^3 (±1.44 J/m^3)	4.21 J/m^3 (±3.02 J/m^3)	64.99 J/m^3 (±37.43 J/m^3)

Table S5 Projected regional mean Potential Energy Anomaly (temperature component, PEAT) changes between 2000-2019 and 2079-2098. 10 J/m³ is considered the threshold for stratification. See Table 5 for details.

PEAT	Shelf	Southern North Sea	Central North Sea	Northern North Sea	English Channel	Irish Sea	Celtic Sea
ANN	9.81 J/m^3 (±5.80 J/m^3)	0.44 J/m^3 (±0.25 J/m^3)	10.44 J/m^3 (±3.67 J/m^3)	15.80 J/m^3 (±5.89 J/m^3)	1.87 J/m^3 (±0.71 J/m^3)	3.37 J/m^3 (±1.45 J/m^3)	14.88 J/m^3 (±9.48 J/m^3)
DJF	-0.36 J/m^3 (±4.01 J/m^3)	0.00 J/m^3 (±0.05 J/m^3)	0.20 J/m^3 (±0.25 J/m^3)	2.28 J/m^3 (±3.05 J/m^3)	-0.00 J/m^3 (±0.05 J/m^3)	0.08 J/m^3 (±0.30 J/m^3)	1.30 J/m^3 (±7.15 J/m^3)
MAM	-0.85 J/m^3 (±5.26 J/m^3)	0.17 J/m^3 (±0.15 J/m^3)	2.06 J/m^3 (±1.62 J/m^3)	2.21 J/m^3 (±3.65 J/m^3)	0.40 J/m^3 (±0.31 J/m^3)	1.02 J/m^3 (±0.74 J/m^3)	-3.71 J/m^3 (±10.18 J/m^3)
JJA	17.36 J/m^3 (±8.34 J/m^3)	1.47 J/m^3 (±0.80 J/m^3)	21.84 J/m^3 (±6.95 J/m^3)	25.97 J/m^3 (±8.84 J/m^3)	4.28 J/m^3 (±1.42 J/m^3)	8.97 J/m^3 (±3.49 J/m^3)	22.45 J/m^3 (±11.74 J/m^3)
SON	23.06 J/m^3 (±10.25 J/m^3)	0.13 J/m^3 (±0.17 J/m^3)	17.63 J/m^3 (±7.64 J/m^3)	32.65 J/m^3 (±13.47 J/m^3)	2.82 J/m^3 (±1.41 J/m^3)	3.39 J/m^3 (±2.17 J/m^3)	39.45 J/m^3 (±14.86 J/m^3)

Table S6 Projected regional mean Potential Energy Anomaly (salinity component, PEAS) changes between 2000-2019 and 2079-2098. 10 J/m³ is considered the threshold for stratification. See Table 5 for details.

PEAS	Shelf	Southern North Sea	Central North Sea	Northern North Sea	English Channel	Irish Sea	Celtic Sea
ANN	7.60 J/m³ (±13.53 J/m³)	0.13 J/m³ (±0.44 J/m³)	-0.42 J/m³ (±1.86 J/m³)	-0.92 J/m³ (±10.67 J/m³)	-0.12 J/m³ (±0.19 J/m³)	0.52 J/m³ (±1.29 J/m³)	21.37 J/m³ (±28.61 J/m³)
DJF	8.87 J/m³ (±12.61 J/m³)	-0.17 J/m³ (±0.46 J/m³)	-0.18 J/m³ (±0.41 J/m³)	1.97 J/m³ (±8.82 J/m³)	-0.03 J/m³ (±0.18 J/m³)	-0.15 J/m³ (±1.20 J/m³)	26.57 J/m³ (±28.34 J/m³)
MAM	4.91 J/m³ (±11.80 J/m³)	0.05 J/m³ (±0.86 J/m³)	-0.37 J/m³ (±1.48 J/m³)	1.29 J/m³ (±9.67 J/m³)	0.00 J/m³ (±0.26 J/m³)	0.31 J/m³ (±1.49 J/m³)	14.24 J/m³ (±25.19 J/m³)
JJA	6.68 J/m³ (±15.98 J/m³)	0.56 J/m³ (±0.88 J/m³)	-0.27 J/m³ (±3.97 J/m³)	-3.26 J/m³ (±14.69 J/m³)	-0.25 J/m³ (±0.34 J/m³)	1.13 J/m³ (±1.89 J/m³)	18.67 J/m³ (±29.97 J/m³)
SON	9.78 J/m³ (±16.19 J/m³)	0.09 J/m³ (±0.42 J/m³)	-0.86 J/m³ (±3.17 J/m³)	-3.67 J/m³ (±14.30 J/m³)	-0.22 J/m³ (±0.19 J/m³)	0.81 J/m³ (±1.85 J/m³)	25.54 J/m³ (±34.15 J/m³)

Table S7 Projected regional mean DFS changes between 2000-2019 and 2079-2098. See Table 5 for details.

DFS	Shelf	Southern North Sea	Central North Sea	Northern North Sea	English Channel	Irish Sea	Celtic Sea
ANN	-0.06 psu (±0.15 psu)	-0.01 psu (±0.03 psu)	0.01 psu (±0.05 psu)	0.02 psu (±0.15 psu)	0.00 psu (±0.01 psu)	-0.01 psu (±0.03 psu)	-0.16 psu (±0.25 psu)
DJF	-0.07 psu (±0.13 psu)	0.02 psu (±0.03 psu)	0.01 psu (±0.01 psu)	-0.00 psu (±0.10 psu)	0.00 psu (±0.01 psu)	0.01 psu (±0.02 psu)	-0.22 psu (±0.24 psu)
MAM	-0.04 psu (±0.13 psu)	-0.00 psu (±0.05 psu)	0.01 psu (±0.04 psu)	0.00 psu (±0.14 psu)	-0.00 psu (±0.02 psu)	-0.01 psu (±0.03 psu)	-0.12 psu (±0.22 psu)
JJA	-0.05 psu (±0.21 psu)	-0.04 psu (±0.05 psu)	0.00 psu (±0.11 psu)	0.06 psu (±0.28 psu)	0.01 psu (±0.01 psu)	-0.02 psu (±0.05 psu)	-0.12 psu (±0.28 psu)
SON	-0.08 psu (±0.18 psu)	-0.01 psu (±0.03 psu)	0.02 psu (±0.07 psu)	0.04 psu (±0.19 psu)	0.01 psu (±0.01 psu)	-0.02 psu (±0.03 psu)	-0.20 psu (±0.32 psu)

Table S8 Projected regional mean NBS changes between 2000-2019 and 2079-2098. See Table 5 for details.

NBS	Shelf	Southern North Sea	Central North Sea	Northern North Sea	English Channel	Irish Sea	Celtic Sea
ANN	-0.95 psu (±0.82 psu)	-0.93 psu (±1.00 psu)	-0.98 psu (±0.92 psu)	-1.08 psu (±0.96 psu)	-0.82 psu (±0.80 psu)	-0.97 psu (±0.76 psu)	-0.80 psu (±0.58 psu)
DJF	-0.93 psu (±0.82 psu)	-0.92 psu (±1.01 psu)	-0.96 psu (±0.91 psu)	-1.05 psu (±0.95 psu)	-0.80 psu (±0.78 psu)	-0.97 psu (±0.78 psu)	-0.76 psu (±0.58 psu)
MAM	-0.98 psu (±0.83 psu)	-0.94 psu (±1.01 psu)	-1.00 psu (±0.92 psu)	-1.09 psu (±0.95 psu)	-0.83 psu (±0.78 psu)	-1.01 psu (±0.78 psu)	-0.85 psu (±0.61 psu)
JJA	-0.95 psu (±0.82 psu)	-0.92 psu (±1.01 psu)	-0.97 psu (±0.92 psu)	-1.08 psu (±0.95 psu)	-0.82 psu (±0.81 psu)	-0.98 psu (±0.77 psu)	-0.82 psu (±0.59 psu)
SON	-0.93 psu (±0.82 psu)	-0.93 psu (±1.00 psu)	-0.97 psu (±0.92 psu)	-1.09 psu (±0.97 psu)	-0.81 psu (±0.82 psu)	-0.90 psu (±0.75 psu)	-0.78 psu (±0.57 psu)

Table S9 Change in AMOC between 2000-2019 and 2079-2098.

Ensemble member	Early century (2000-2019) AMOC.	Late century (2079-2098) AMOC.	Change in AMOC between early century (2000-2019) and late century (2079-2098)
r001i1p00000	13.876	6.647	-7.229
r001i1p00605	16.888	7.965	-8.923
r001i1p00834	18.039	7.933	-10.106
r001i1p01113	13.147	6.708	-6.439
r001i1p01554	15.008	6.541	-8.466
r001i1p01649	16.892	8.825	-8.067
r001i1p01843	17.646	8.165	-9.481
r001i1p01935	17.909	10.578	-7.331
r001i1p02123	17.814	8.235	-9.579
r001i1p02242	17.259	8.666	-8.593
r001i1p02491	16.752	7.145	-9.607
r001i1p02868	13.445	6.644	-6.800

1.2 Additional Figures
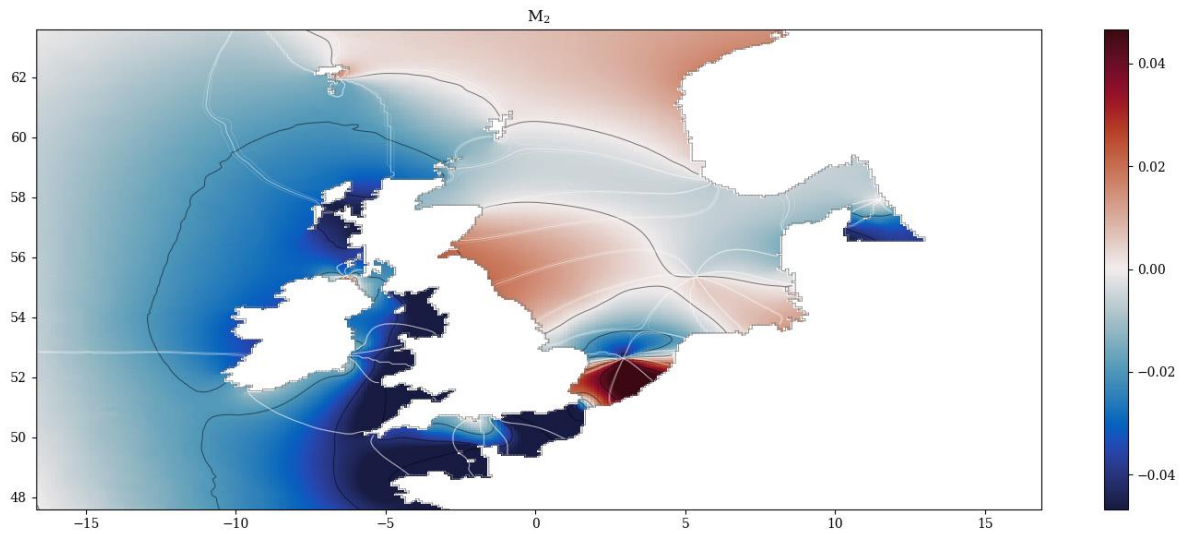
Figure S1 The impact of the Tide Generating Potential on the M_2 co-tidal chart. The difference between the tidal harmonic analysis of the simulation with the Tide Generating Potential and the unperturbed member of the PPE, the equivalent simulation with the Tide Generating Potential off. The amplitude (m) is shown with colour map (and black contours which match the tick labels of the colourbar). The phase every $45°$ is shown as fine white contours, for the two simulations, and the average phase of the two simulations is a bolder white line
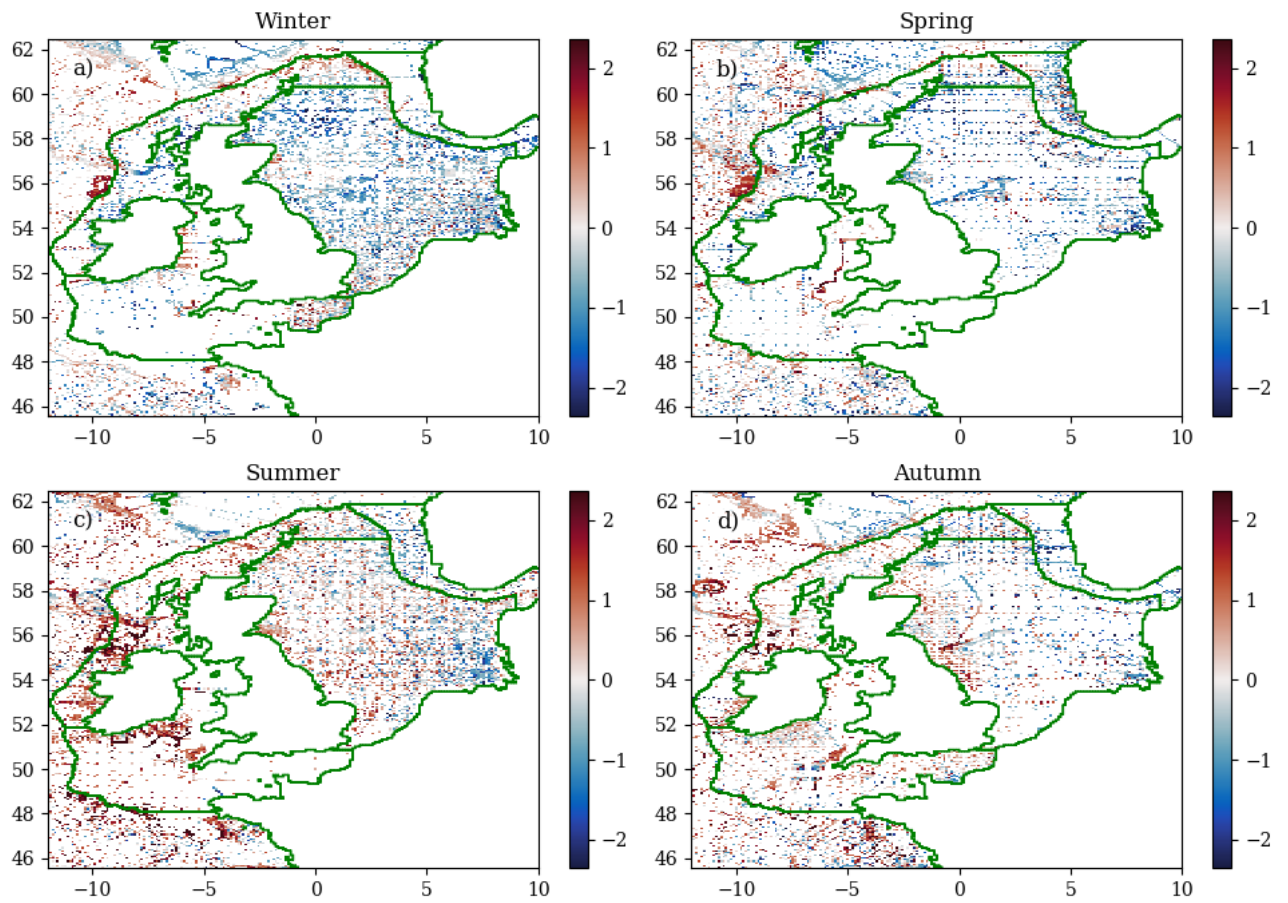
Figure S2 Model-EN4 biases normalised by the ensemble standard deviation for the four season (a-d) – effectively the number of ensemble standard deviations the observations are from the ensemble mean. See text for details.
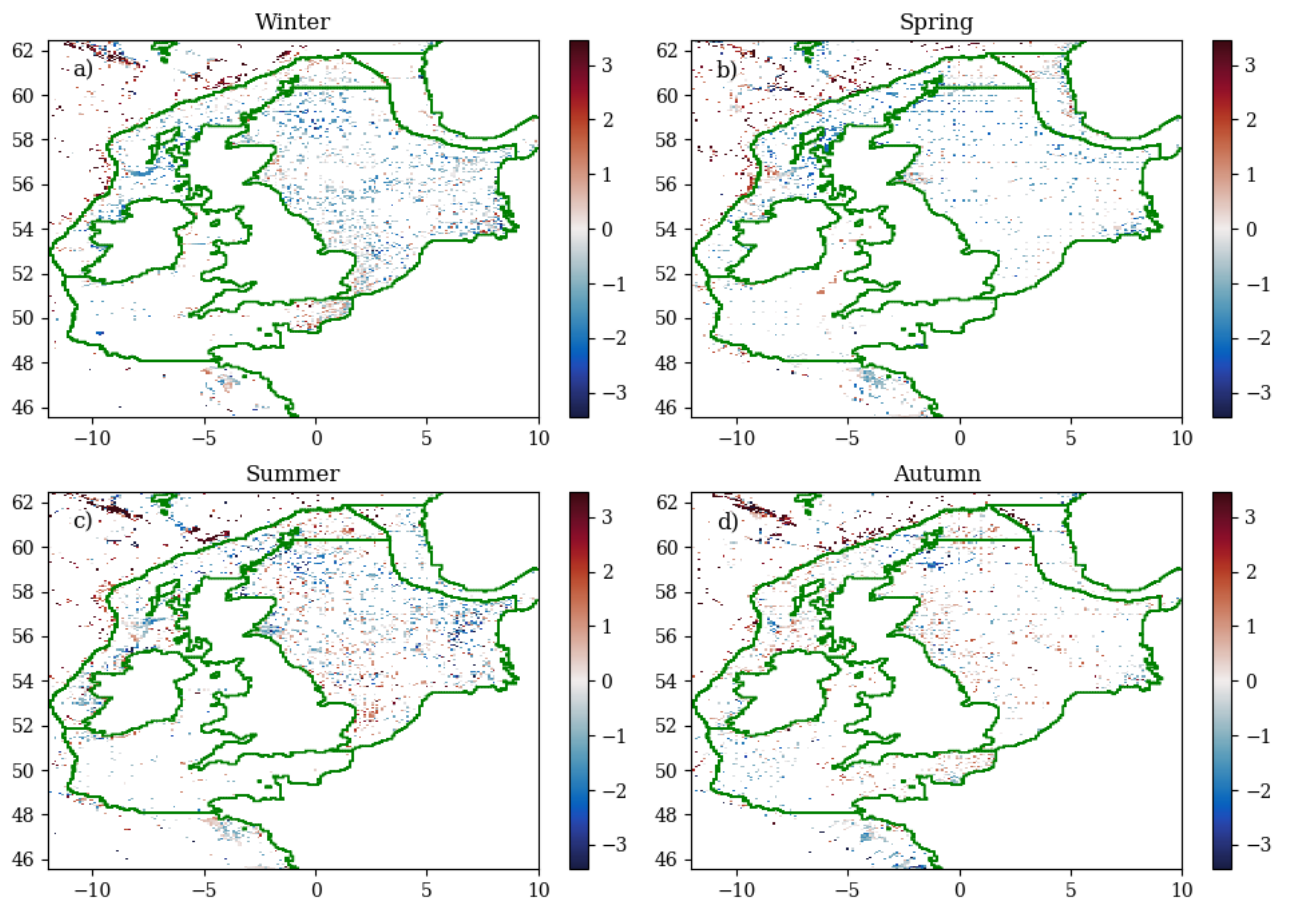
Figure S3 as Figure S2 but for NBT
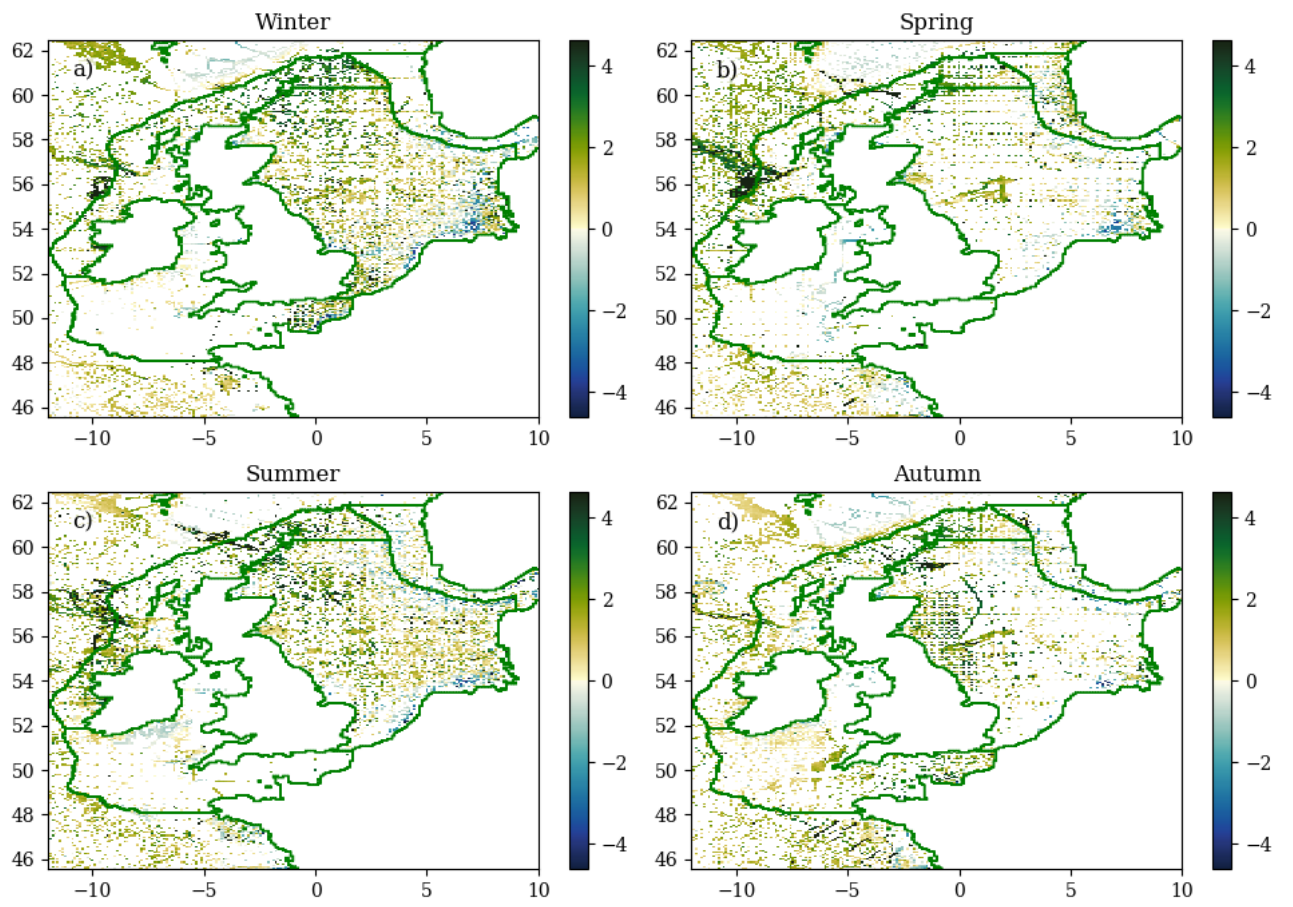
Figure S4 as Figure S2 but for SSS.
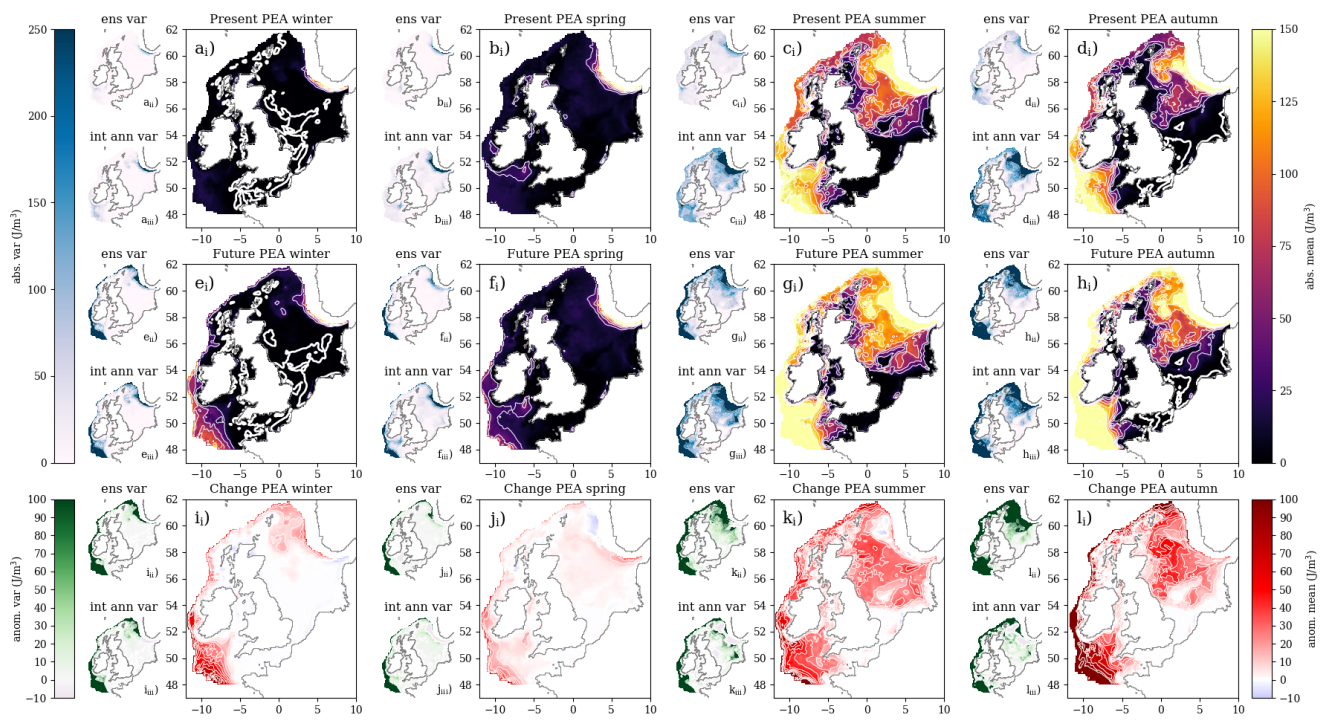
Figure S5 as Figure 6 but for Potential Energy Anomaly (PEA), a measure of stratification, where >10 J m⁻³ is considered stratified).
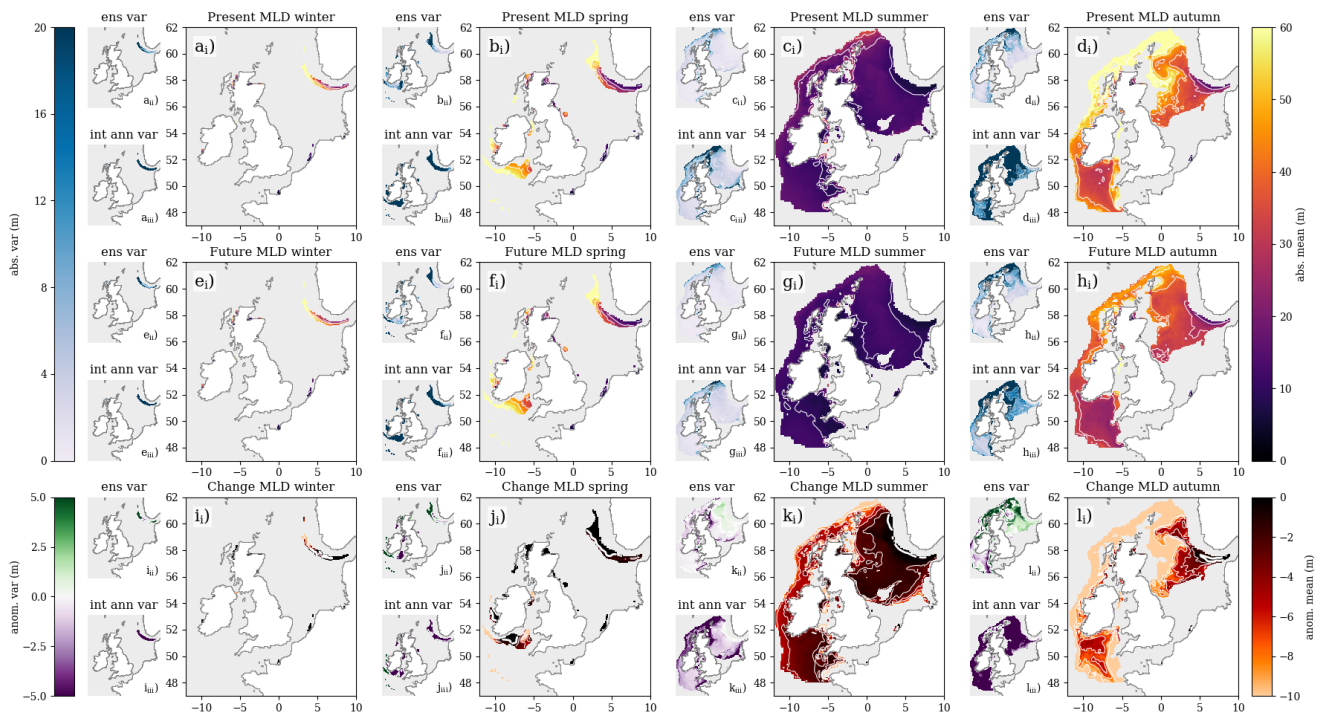
Figure S6 as Figure 6, but for the Mixed Layer Depth (m).
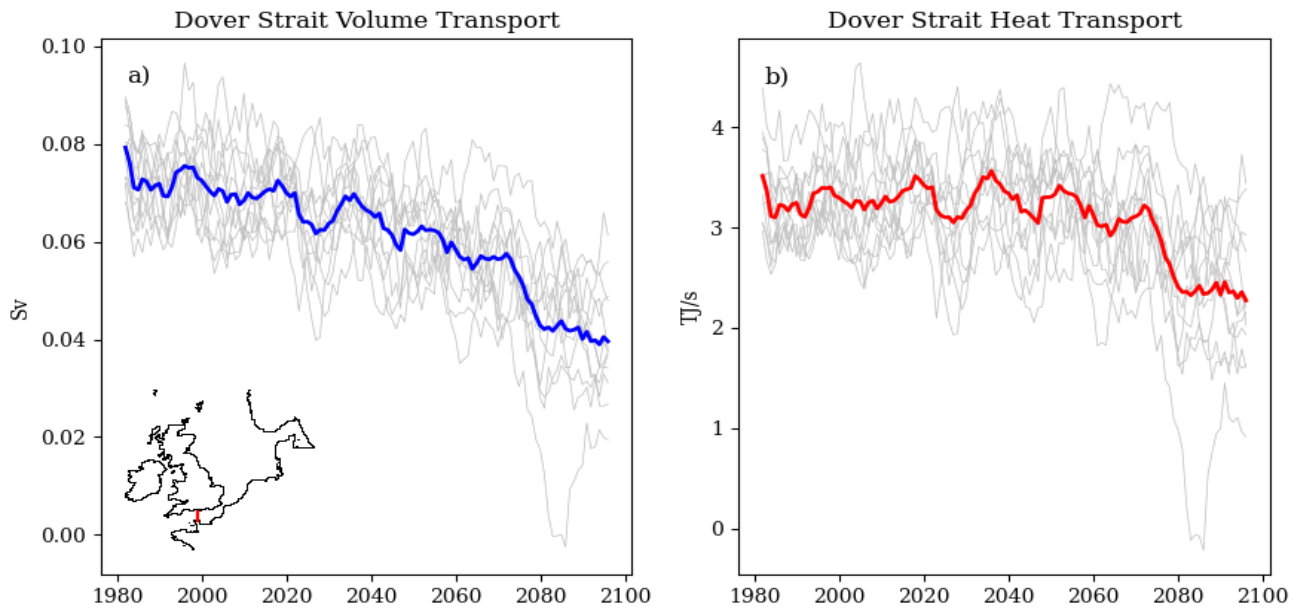
Figure S7 a) Volume and b) heat transport (west to east) through the Dover Strait, for the ensemble members of the PPE (grey) and the Ensmeble Mean (coloured).
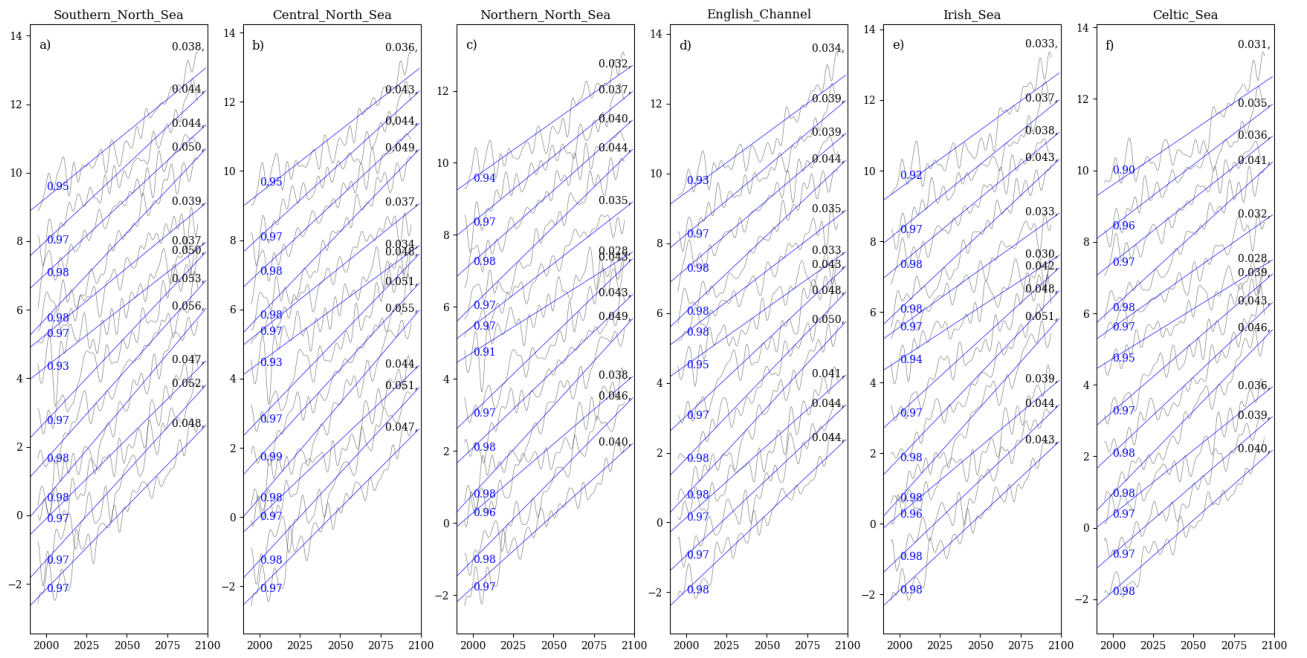
Figure S8 Linear fits for (de-seasonalised) SST trends for each ensemble member (each line is offset) for selected inner shelf region (a-f – see region mask in Figure 10). On the left of each line is the correlation of the fit (blue), and the right is the gradient (black).
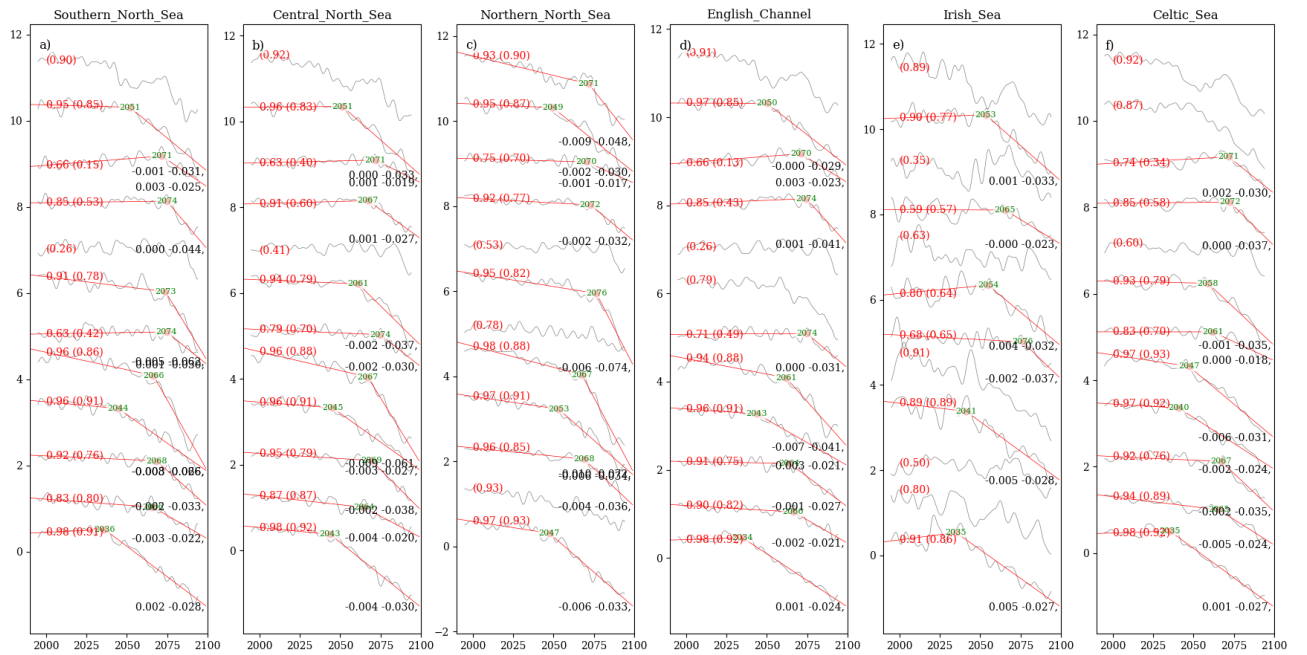
Figure S9 Based on Figure S8 for (de-seasonalised) SSS, but rather than a single linear fit, two intersecting lines are fitted with a curve fitting program. Where the correlation is improved (compared to a single line), it is plotted in red. The correlation is given in red (and for the single linear fit in brackets). The slope of the first and second line is given in black. The year where the slope changes is given in green.
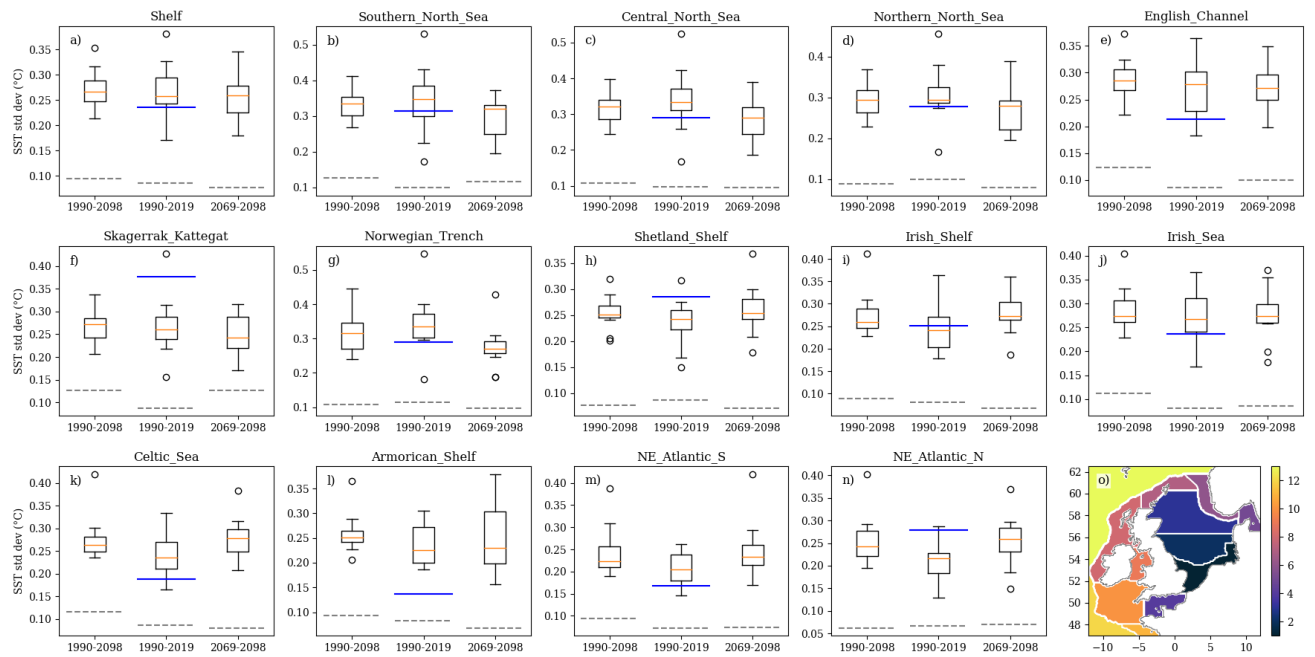
Figure S10 SST (de-seasonalised and detrended) interannual variability. Low frequency (<5 yr) interannual variability for 1990-2098, 1990-2019 and 2069-2098. Each ensemble member annual mean time series is filtered with a 5-year low pass filter. The standard deviation is then calculated for the appropriate time-period, giving a distribution of 12 interannual variability estimates for the NWSPPE. These distributions are then plotted as box and whisker plots. The same method is applied to the NWSPPE ensemble mean, and the RAN (only for the 1990-2019 period), which are plotted as dotted grey and blue lines respectively. a-n) the NWS regions, and o) the NWS region mask.
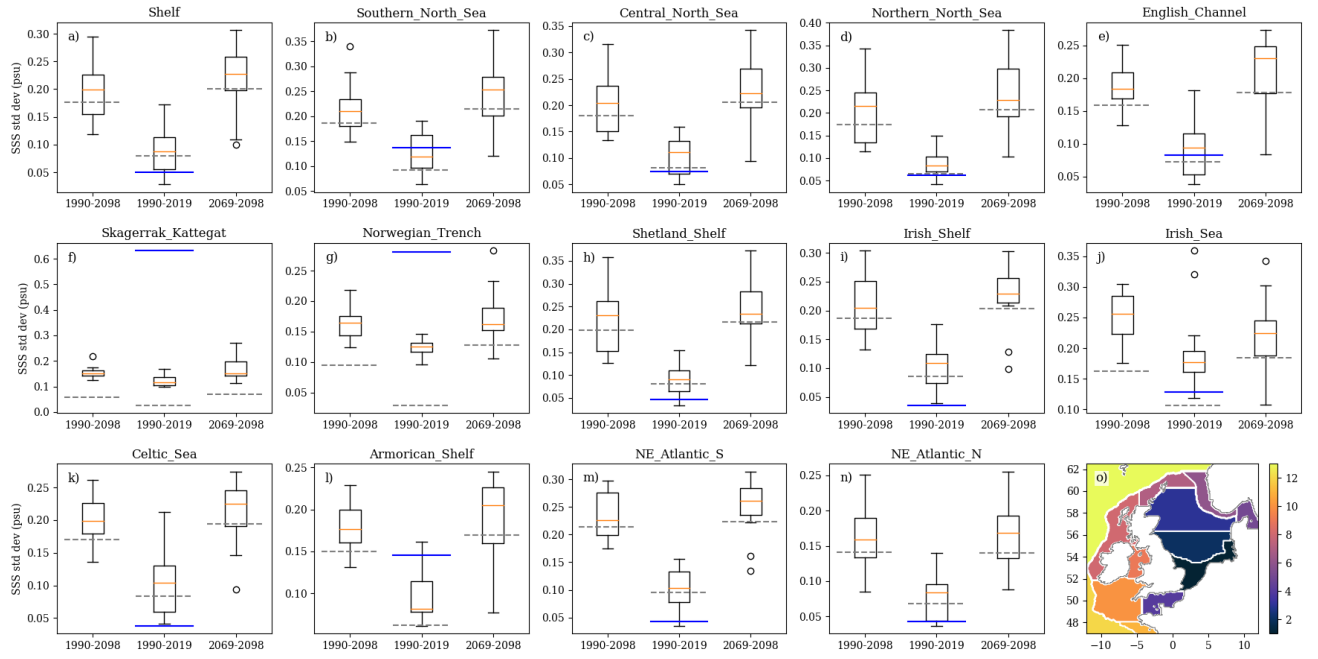
Figure S11 SSS Low frequency variability, see Figure S10 for details.
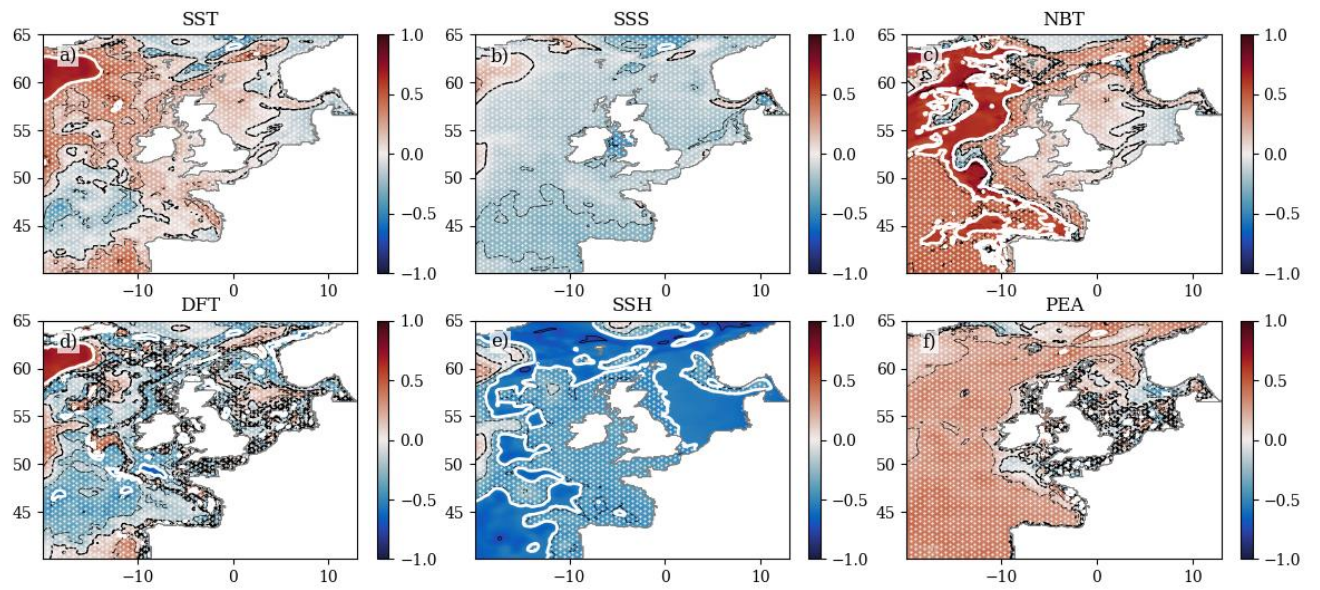
Figure S12 Correlation between NWS winter change, and AMOC (at 26°N) change, both the difference between the 2069-2098 and 1990-2019 mean. a) Winter (DJF) SST change (2069-2098 mean minus 1990-2019 mean) for each of the 12 NWSPPE ensemble members is correlated against the (annual mean) AMOC slow down (between the same periods) on a point-by-point basis. This is repeated for b) SSS; c) NBT; d) DFT; e) SSH and f) PEA. The (annual mean) AMOC slowdown is given in Table S9.
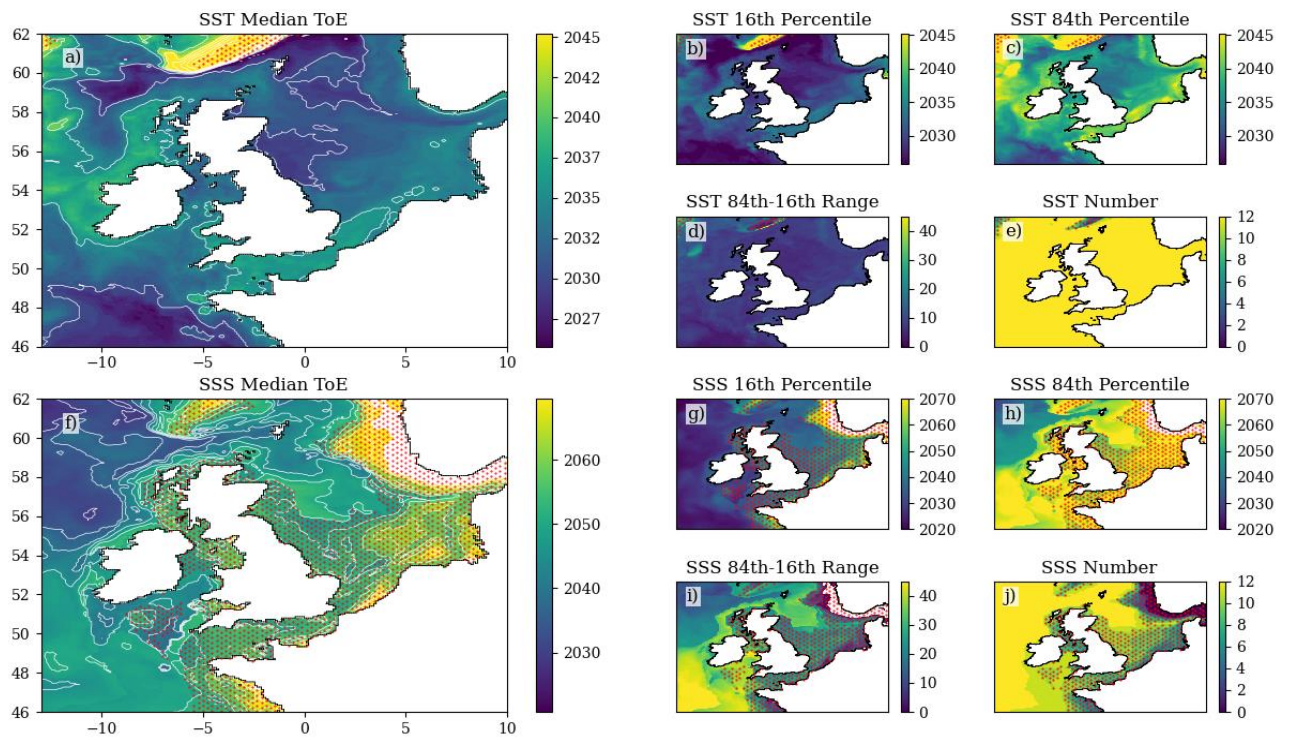
Figure S13 Estimates of the Time of Emergence for SST (a-e) and SSS (f-j) following the Lyu et al., (2014) method. ToE is calculated for each ensemble member of the NWSPPE, and the median range is given in a) and f) with the 16th (b, g) and 84th (c, h) percentile value, and their (16th-84th percentile) range (e, j). The number of ensemble members where the climate signal emerges is given in e) and j). Stippling shows where less than 84% of the ensemble (10 out of 12 members) show emergence.