

Figure S1. Individual model mPWP-PI difference in sea surface salinity.

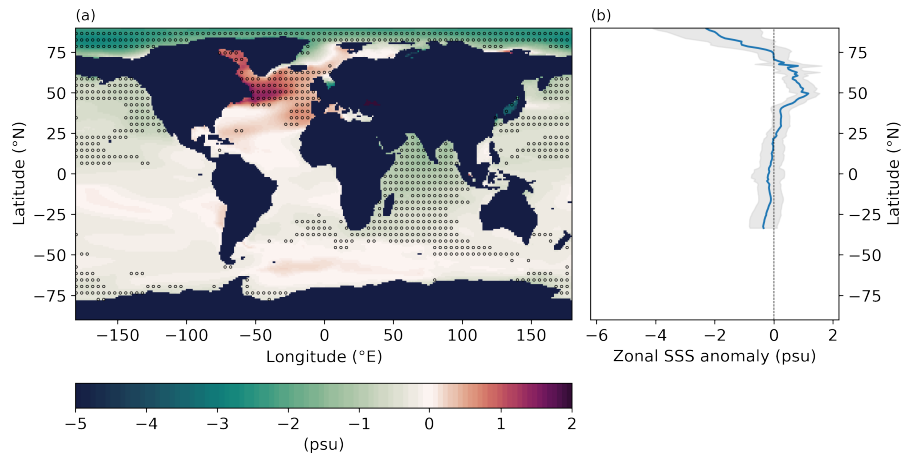


Figure S2. (a) Multi-model mean mPWP-PI difference in top 100 m average salinity. Stippling indicates that 12 or more models agree on the sign of the difference. (b) Atlantic zonal mean salinity difference. The shading indicates one standard deviation from the MMM by individual models, excluding HadGEM3.

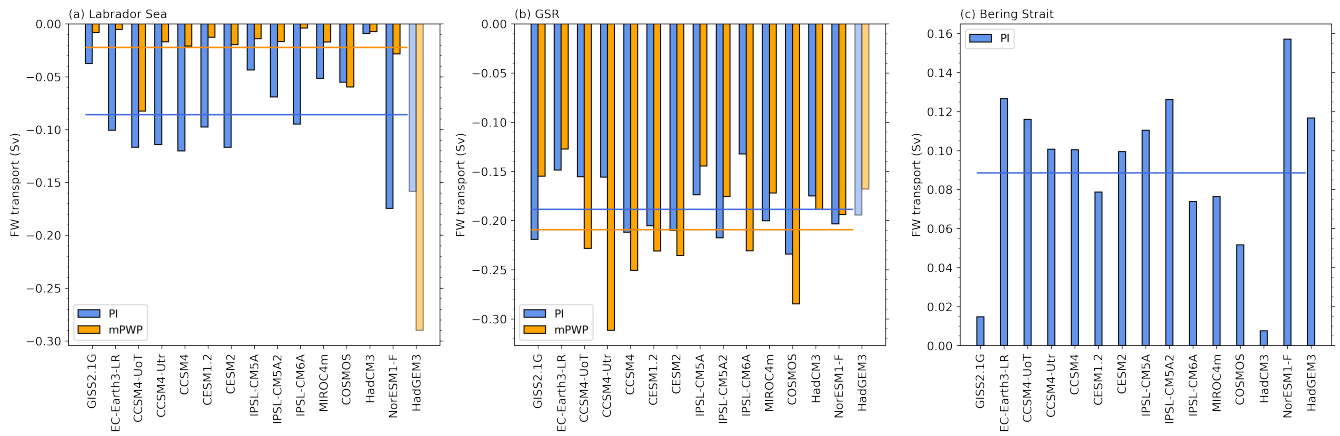


Figure S3. Mean freshwater transport (Sv) in pre-industrial and mid-Pliocene at 62°N (a) into the Labrador Sea and (b) across the GSR. (c) Mean freshwater transport (Sv) through the Bering Strait in the pre-industrial. Horizontal lines indicate the MMM transports in the pre-industrial and mid-Pliocene.

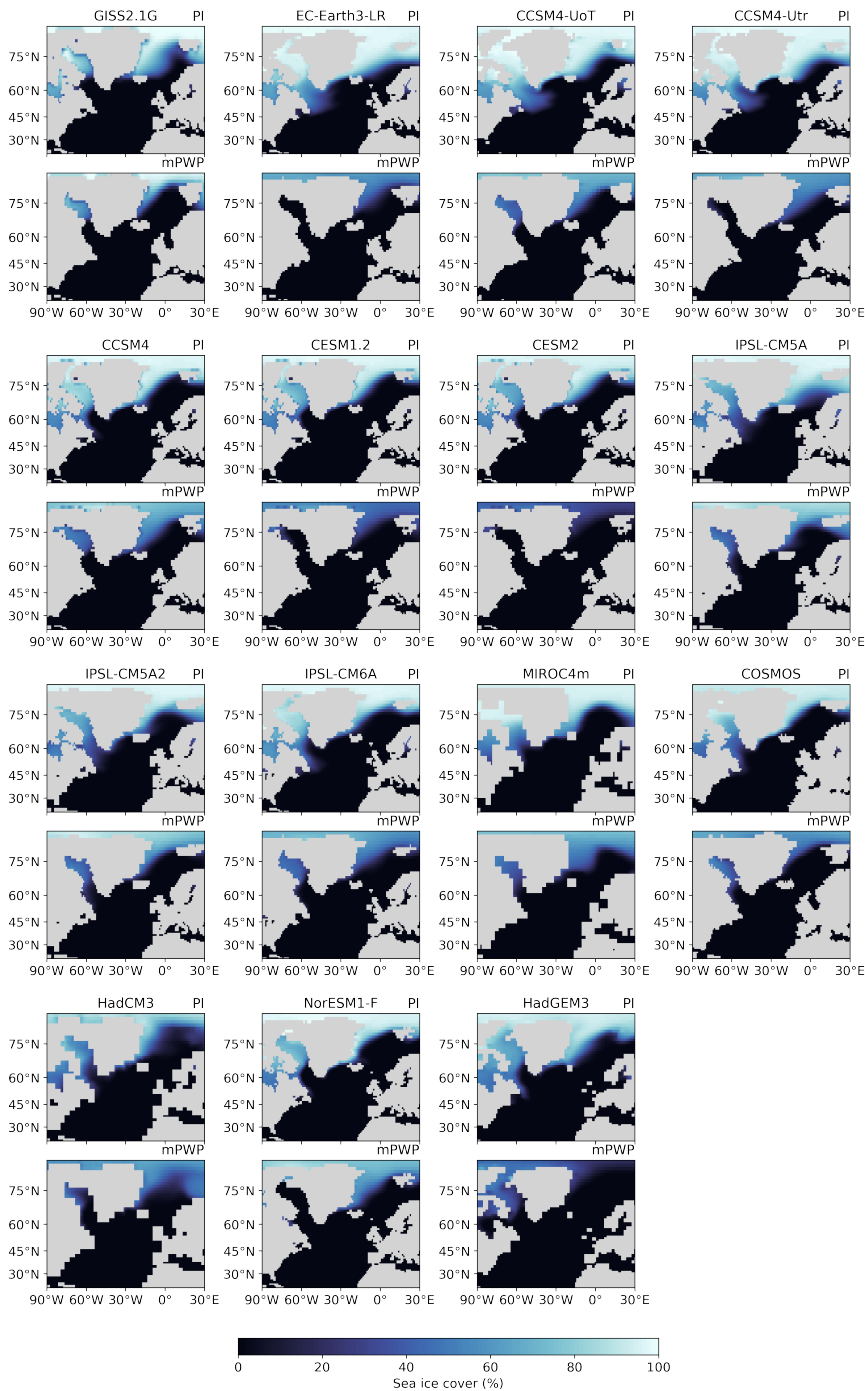


Figure S4. Individual model annual mean sea-ice coverage (%), interpolated to a regular $1 \times 1^\circ$ grid. The top panel for each model shows the results for the pre-industrial and the bottom panel for the mid-Pliocene. The land-sea masks as shown are not necessarily identical to those of the models due to interpolation.

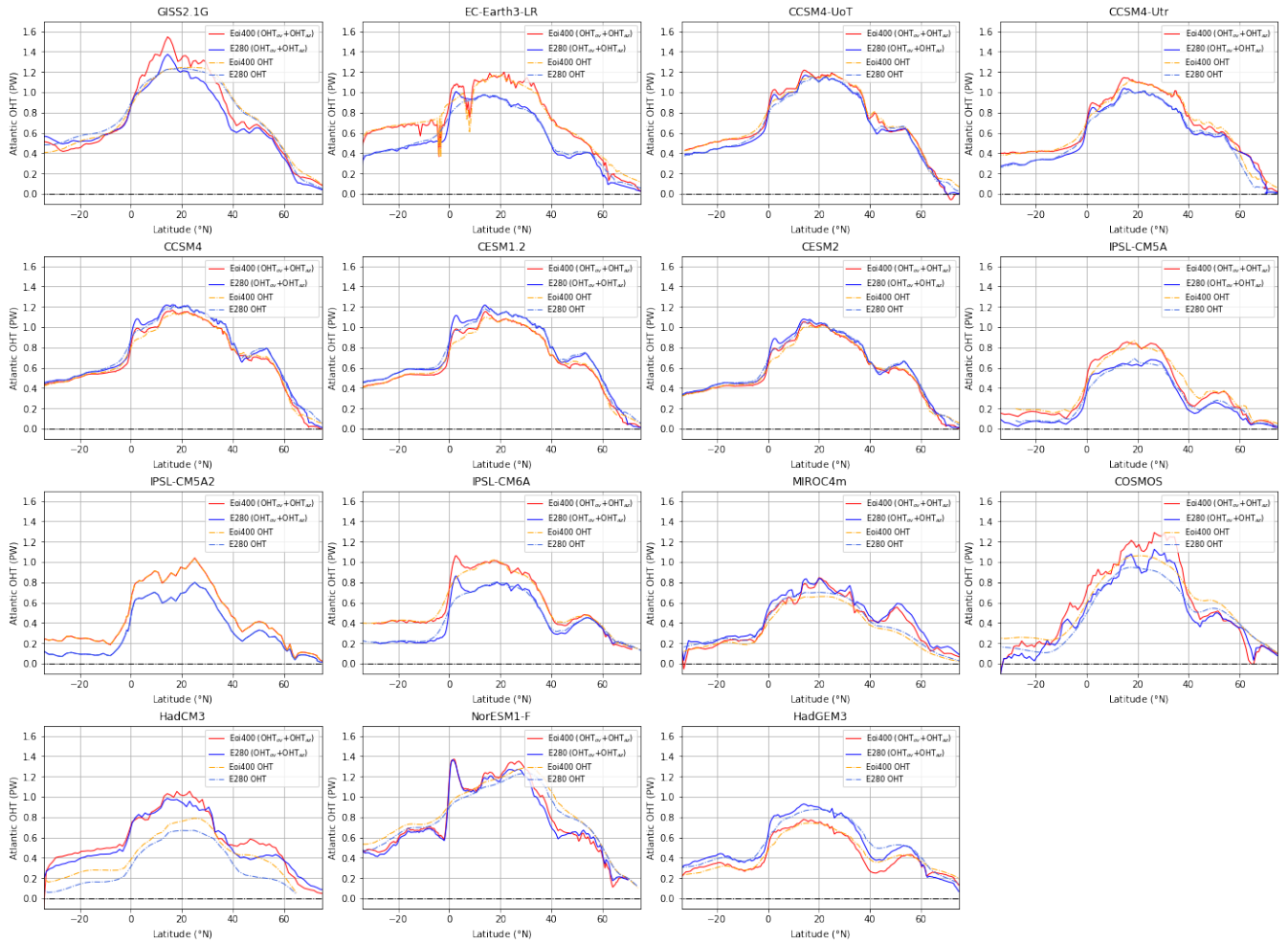


Figure S5. Comparison of total Atlantic OHT with the sum of the overturning and gyre Atlantic OHT components ($OHT_{ov}+OHT_{az}$) for all models. Solid lines represent the sum of the overturning and gyre Atlantic OHT component and dashed lines represent the total Atlantic OHT.

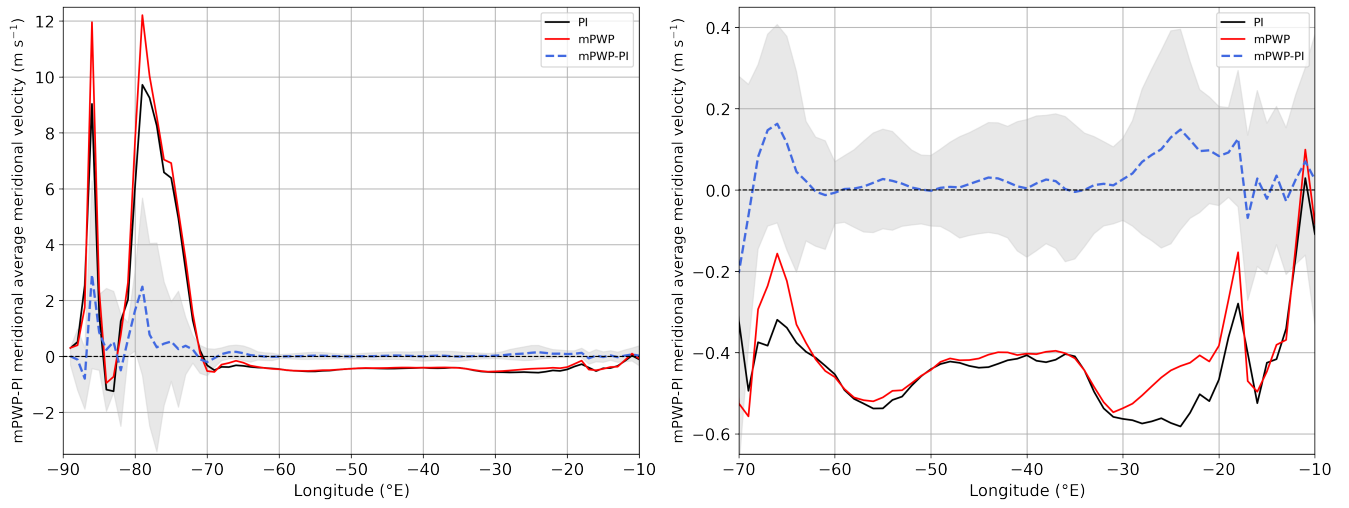


Figure S6. (a) MMM top 500 m Atlantic ocean meridional velocity, averaged over 20–40°N, in the PI and mPWP, as well as the mPWP-PI anomaly. Grey shading indicates one standard deviation from the MMM anomaly by individual models. (b) Same as (a) but with adapted scaling to show differences in the 10–70°W longitude band.

Table S1. SST proxy data and MMM at North Atlantic sites. FD19-U₃₇^{k'} refers to the Foley and Dowsett (2019) data, M20-U₃₇^{k'} and M20-Mg/Ca to the McClymont et al. (2020) data. SST proxy mPWP-PI anomalies are computed with pre-industrial ERSST5 data (Huang et al., 2017).

| Site | Proxy/MMM | mPWP (°C) | mPWP-PI (°C) | MMM - proxy mPWP (°C) | MMM - proxy mPWP-PI (°C) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|----------|------------------------------------|-----------|--------------|--------------------------|-----------------------------|----------|------------------------------------|------|-----|------|------|------------------------------------|------|-----|------|------|-----------------------------------|------|-----|------|------|-----------------------------------|------|-----|------|-----|-----------|------|-----|------|------|-----|------|-----|--|--|-----|------------------------------------|------|-----|------|------|------------------------------------|------|-----|----|-----|-----------------------------------|------|-----|------|-----|-----------|------|------|-----|-----|-----|------|-----|--|--|-----|------------------------------------|------|-----|------|------|-----------------------------------|------|-----|------|------|-----|------|-----|--|--|-----|------------------------------------|------|-----|------|------|-----------------------------------|------|-----|------|------|-----|-----|-----|--|--|-----|-----------------------------------|-----|-----|-----|-----|-----|-----|
| 603 | M20-Mg/Ca | 20.4 | -1.8 | 4.7 | 3.9 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | MMM | 25.1 | 2.1 | | | 607/1313 | FD19-U ₃₇ ^{k'} | 21.2 | 3.4 | -1.4 | -0.4 | FD19-U ₃₇ ^{k'} | 20.9 | 3.1 | -1.1 | -0.1 | M20-U ₃₇ ^{k'} | 20.9 | 3.1 | -1.1 | -0.1 | M20-U ₃₇ ^{k'} | 20.3 | 2.6 | -0.5 | 0.4 | M20-Mg/Ca | 22.2 | 4.5 | -2.4 | -1.5 | MMM | 19.8 | 3.0 | | | 609 | FD19-U ₃₇ ^{k'} | 18.5 | 5.1 | -3.3 | -1.2 | FD19-U ₃₇ ^{k'} | 17.2 | 3.8 | -2 | 0.1 | M20-U ₃₇ ^{k'} | 17.1 | 3.7 | -1.9 | 0.2 | M20-Mg/Ca | 11.7 | -1.7 | 3.5 | 5.6 | MMM | 15.2 | 3.9 | | | 982 | FD19-U ₃₇ ^{k'} | 17.2 | 6.5 | -2.9 | -2.2 | M20-U ₃₇ ^{k'} | 16.6 | 5.9 | -2.3 | -1.6 | MMM | 14.3 | 4.3 | | | 642 | FD19-U ₃₇ ^{k'} | 13.8 | 7.0 | -4.2 | -2.9 | M20-U ₃₇ ^{k'} | 13.2 | 6.4 | -3.6 | -2.3 | MMM | 9.6 | 4.1 | | | 907 | M20-U ₃₇ ^{k'} | 3.2 | 1.7 | 1.1 | 2.3 | MMM | 4.3 |
| 607/1313 | FD19-U ₃₇ ^{k'} | 21.2 | 3.4 | -1.4 | -0.4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | FD19-U ₃₇ ^{k'} | 20.9 | 3.1 | -1.1 | -0.1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | M20-U ₃₇ ^{k'} | 20.9 | 3.1 | -1.1 | -0.1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | M20-U ₃₇ ^{k'} | 20.3 | 2.6 | -0.5 | 0.4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | M20-Mg/Ca | 22.2 | 4.5 | -2.4 | -1.5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | MMM | 19.8 | 3.0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 609 | FD19-U ₃₇ ^{k'} | 18.5 | 5.1 | -3.3 | -1.2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | FD19-U ₃₇ ^{k'} | 17.2 | 3.8 | -2 | 0.1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | M20-U ₃₇ ^{k'} | 17.1 | 3.7 | -1.9 | 0.2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | M20-Mg/Ca | 11.7 | -1.7 | 3.5 | 5.6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | MMM | 15.2 | 3.9 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 982 | FD19-U ₃₇ ^{k'} | 17.2 | 6.5 | -2.9 | -2.2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | M20-U ₃₇ ^{k'} | 16.6 | 5.9 | -2.3 | -1.6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | MMM | 14.3 | 4.3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 642 | FD19-U ₃₇ ^{k'} | 13.8 | 7.0 | -4.2 | -2.9 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | M20-U ₃₇ ^{k'} | 13.2 | 6.4 | -3.6 | -2.3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | MMM | 9.6 | 4.1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 907 | M20-U ₃₇ ^{k'} | 3.2 | 1.7 | 1.1 | 2.3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | MMM | 4.3 | 4.0 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

Table S2. AMOC-SST correlation map (Figure 3) data. The area of positive correlation is shown as the percentage of significant positively correlated grid cells with respect to the total number of extratropical North Atlantic (30°N-80°N) grid cells. The mean and maximum correlation are respectively the mean and the maximum of all significant positively correlated grid cells in the extratropical North Atlantic.

| Model | Area (%) | | Mean | | Maximum | |
|--------------|------------------|--------------------|------------------|--------------------|------------------|--------------------|
| | E ²⁸⁰ | Eoi ⁴⁰⁰ | E ²⁸⁰ | Eoi ⁴⁰⁰ | E ²⁸⁰ | Eoi ⁴⁰⁰ |
| GISS-E2.1G | 28 | 61 | 0.35 | 0.38 | 0.69 | 0.60 |
| EC-Earth3-LR | 1 | 65 | 0.25 | 0.32 | 0.36 | 0.54 |
| CCSM4-UoT | 30 | 31 | 0.34 | 0.36 | 0.54 | 0.62 |
| CCSM4-Utr | 11 | 52 | 0.28 | 0.40 | 0.40 | 0.72 |
| CCSM4 | 19 | 27 | 0.31 | 0.27 | 0.46 | 0.43 |
| CESM1.2 | 17 | 24 | 0.31 | 0.31 | 0.50 | 0.48 |
| CESM2 | 40 | 2 | 0.35 | 0.22 | 0.55 | 0.26 |
| IPSL-CM6A | 32 | 23 | 0.36 | 0.35 | 0.54 | 0.56 |
| MIROC4m | 9 | 26 | 0.27 | 0.33 | 0.47 | 0.55 |
| COSMOS | 12 | 58 | 0.25 | 0.39 | 0.38 | 0.65 |
| HadCM3 | 20 | 52 | 0.29 | 0.36 | 0.49 | 0.61 |
| NorESM1-F | 20 | 20 | 0.27 | 0.29 | 0.37 | 0.45 |
| HadGEM3 | 29 | 12 | 0.26 | 0.29 | 0.36 | 0.50 |
| MMM* | 20 | 37 | 0.30 | 0.33 | 0.48 | 0.54 |

*HadGEM3 is excluded from the MMM.