Supplementary Information for

Pan-Atlantic decadal climate oscillation linked to ocean circulation

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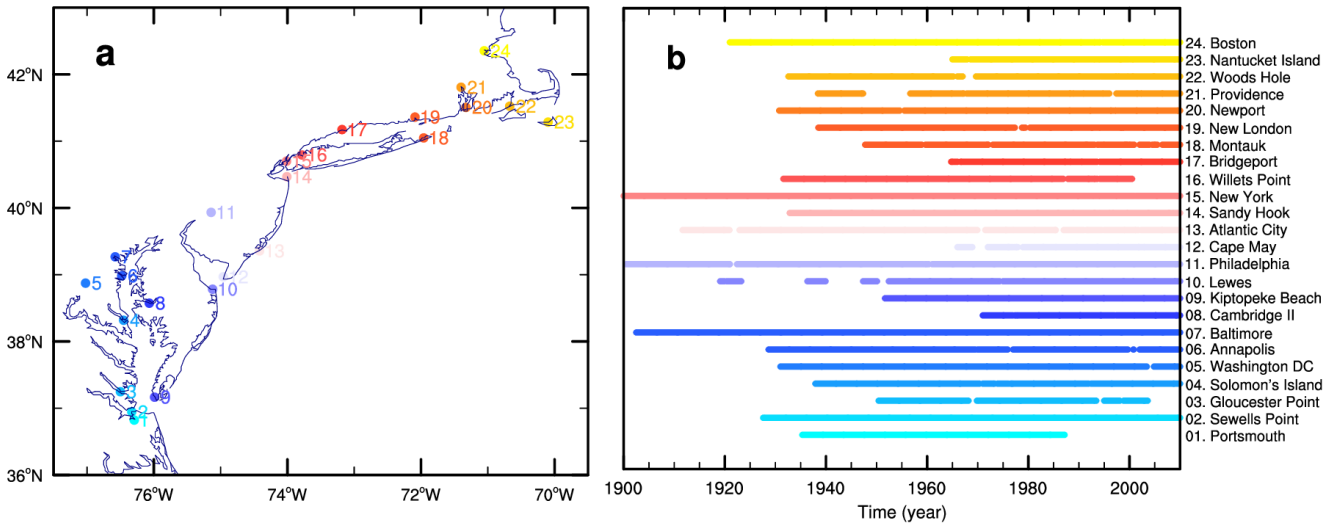
Supplementary Table 1. Standard deviation (σ) of the RAPID-MOCHA and sea-level and correlation between the two indices using seasonal, monthly, and annual data. The unit of AMOC is Sv (1 Sv = 10^6 m^3 s^{-1}).

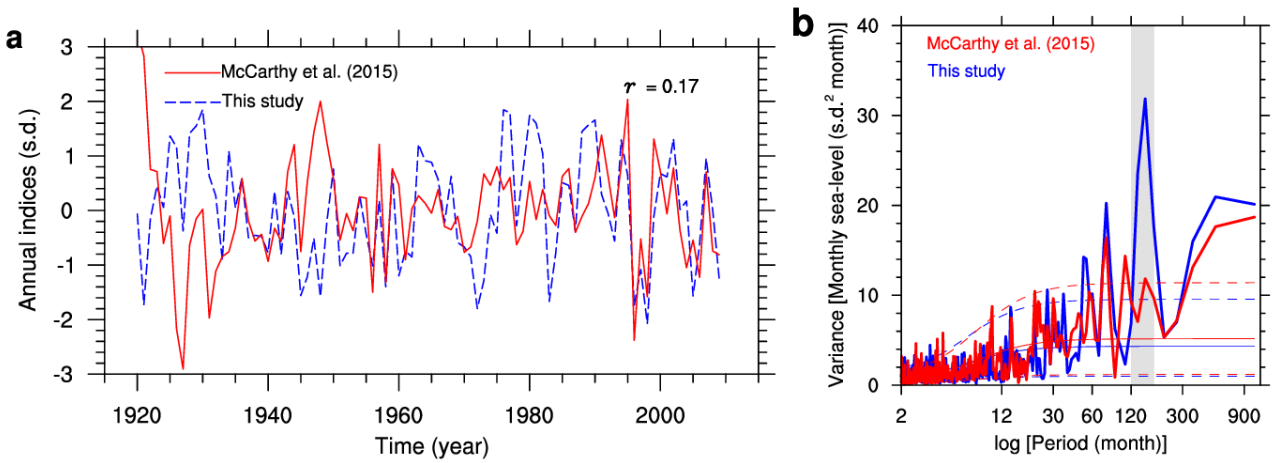
	σ[AMOC(Sv)]	σ[Sea-level(mm)]	Correlation(*p*-value)
Monthly	2.87	49	0.50(1.48×10^{-9})
Annual	1.34	27	0.32(0.3142)
December-February	3.41	47	0.72(0.0011)
March-May	1.24	48	0.49(0.0469)
June-August	1.72	24	0.28(0.2942)
September-November	2.10	31	0.39(0.1248)

Supplementary Table 2. Lag 0 pattern correlation (*r*) between the maps constructed using the 1900-2009 and 1950-2009 periods.

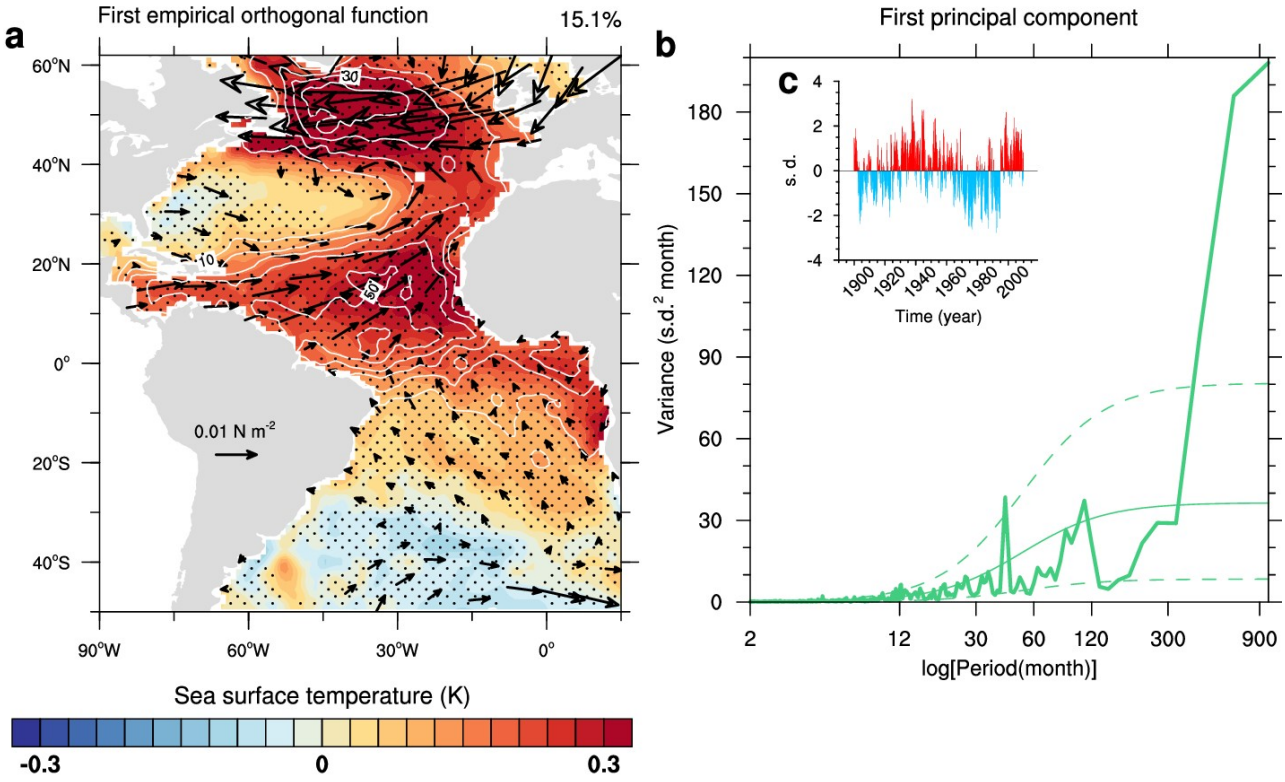
Variable	**Time-mean**	**Reference plot**	***r***
Sea surface temperature	Monthly	Fig. 2a	0.98
Zonal wind stress	Monthly	Fig. 2a	0.97
Meridional wind stress	Monthly	Fig. 2a	0.96
Sea surface height	Monthly	Fig. 3a	0.89
Sea surface temperature	Annual	Fig. 4d	0.96
Zonal wind stress	Annual	Fig. 4d	0.92
Meridional wind stress	Annual	Fig. 4d	0.94
Sea surface height	Annual	Fig. 4j	0.86
Sea level pressure	December-February	Fig. 4r	0.82



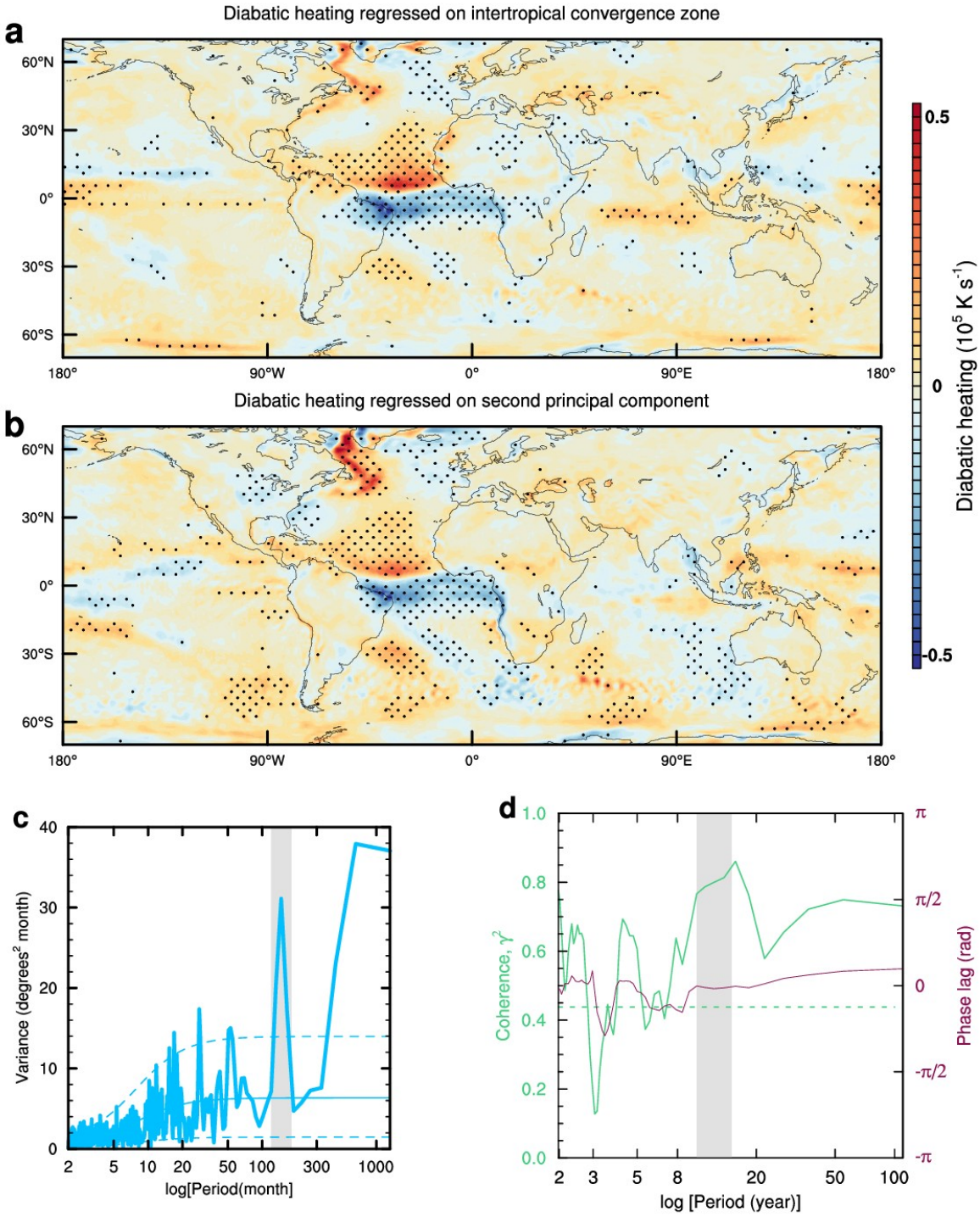
Supplementary Figure 1. Locations and temporal coverage of the tide gauges used to construct the sea-level index. a Location and **b** temporal coverage.



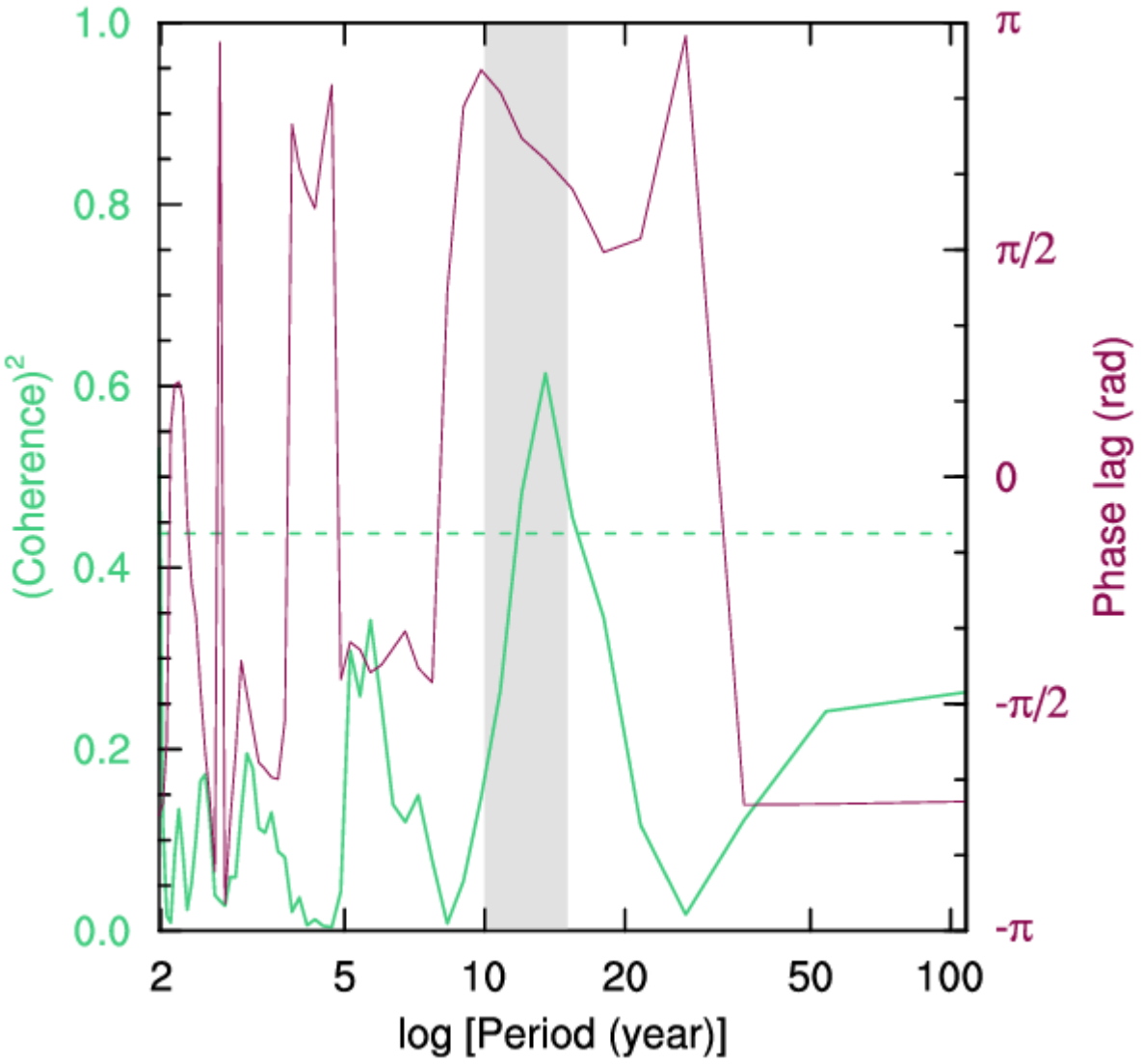
Supplementary Figure 2. Comparison of the sea-level and sea-level difference indices, 1920-2009. a Normalized annual sea-level difference south and north of Cape Hatteras[1] (solid, red curve) and the northern sites representing the index discussed in the present study (dashed, blue curve). The correlation between the two indices 1900-2009 (r=0.17)is shown in the top-right corner. **b** Spectra of the monthly sea-level difference index (thick, solid), its first-order autoregressive fit (solid, thin) and 95% confidence bounds (thin, dashed) for the studies indicated in the top-left corner**.** The vertical bar shows the 10–15 year period band.



Supplementary Figure 3. First leading empirical orthogonal function mode of the monthly SST anomalies in the Atlantic Ocean, 1900-2009. a The SST anomalies are regressed onto the normalized first principal component (PC1) time series. The stipples in **a** denote statistical significance at 95% confidence level. **c** Time evolution of the PC1 and **b** its spectrum (thick, solid curve); the associated first-order autoregressive curve (thin, solid curve) and the 95% confidence bounds (thin, dashed curves).



Supplementary Figure 4. Relating the ITCZ, diabatic heating and SST variability. a,b Monthly diabatic heating anomalies regressed on the normalized **a** inter-tropical convergence zone (ITCZ) and **b** second principal component (PC2) time series. The stipples in denote statistical significance at 95% confidence level. **c** Monthly ITCZ spectrum (thick, solid curve); associated first-order autoregressive curve (thin, solid curve) and the 95% confidence bounds (thin, dashed curves). **d** Coherence (left axis) and phase lag (right axis) between annual ITCZ and PC2. The dashed horizontal line denotes 95% confidence level for spectral coherence. The ITCZ leads at positive lags whereas PC2 leads at negative lags. The vertical bar in both panels shows the 10–15 year period band.



Supplementary Figure 5. Relating phase changes in ocean circulation to turbulent heat fluxes. Coherence (left axis) and phase lag (right axis) between the October-December turbulent heat fluxes[2] averaged over the subpolar North Atlantic (40-50°N,20-60°W) and December-February sea-level index. The heat fluxes leads (follows) sea-level index at positive (negative) lags. The vertical bar shows the 10–15 year period band. The dashed horizontal line denotes 95% confidence level for spectral coherence.

Supplementary References

1. McCarthy, G. D., Haigh, I. D., Hirschi, J. J.-M. J. M., Grist, J. P. & Smeed, D. A. Ocean impact on decadal Atlantic climate variability revealed by sea-level observations. *Nature* **521,** 508–510 (2015).
2. Gulev, S., Latif, M., Keenlyside, N. *et al.* North Atlantic Ocean control on surface heat flux on multidecadal timescales. *Nature* **499**, 464–467 (2013).