Supporting Information for "Atlantic Multidecadal Variability in a model with an improved North Atlantic Current"

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This document contains additional information on data pre-processing and analysis, the slab ocean model setup, and additional figures referred to in the main text.

Methods

All pre-processing of the time series was done with the Climate Data Operators (CDO, https://code.zmaw.de/projects/cdo), i.e., annually averaging, subtracting long term means, detrending (subtracting a linear trend), and also low pass filtering. All further analyses, including regressions, were computed with python and plotted with pyplot or pyNGL.

Slab ocean model: The setup is similar to that proposed by *Bretherton and Battisti* [2000], see also *O'Reilly et al.* [2016]. A slab ocean of 50m depth and only a single grid box in the vertical is forced with a prescribed heat flux Q, in our case the turbulent (i.e. sensible and latent) heat flux anomalies from the corrected model, and is damped with a damping time scale $(c_p H \rho)/\lambda$ of 1 year to mimic radiative relaxation to space. The surface ocean temperature T_o follows the equation:

$$c_p \cdot H \cdot \rho \cdot \frac{dT_o}{dT} = Q - \lambda T_o \qquad (1)$$

where $H = 50$m is the depth of the slab ocean, $c_p = 4000$ J kg^{-1} K^{-1} is the specific heat at constant pressure for sea water, and $\rho = 1024$ kg m^{-3} is an average density of sea water.

References

Bretherton, C. S., and D. S. Battisti (2000), An interpretation of the results from atmospheric general circulation models forced by the time history of the observed sea surface temperature distribution, *Geophys. Res. Lett.*, *27*(6), 767–770, doi: 10.1029/1999GL010910.

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Levitus, S., T. Boyer, M. Conkright, T. O'Brien, J. Antonov, C. Stephens, L. Stathoplos, D. Johnson, and R. Gelfeld (1998), *NOAA Atlas NESDIS 18, World Ocean Database 1998: VOLUME 1: INTRODUCTION*, U.S. Gov. Printing Office, Washington, D.C.

O'Reilly, C. H., M. Huber, T. Woollings, and L. Zanna (2016), The signature of low-frequency oceanic forcing in the Atlantic Multidecadal Oscillation, *Geophys. Res. Lett.*, p. 2016GL067925, doi:10.1002/2016GL067925.
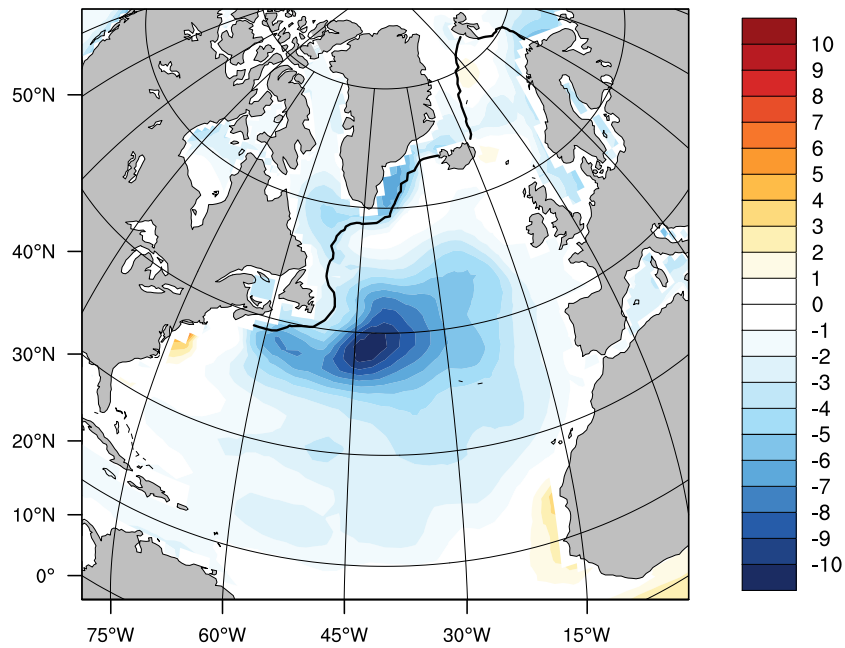
References

Figure 1.   Sea surface temperature bias in the uncorrected model (CTRL) (°C), computed

from model years 300–999 and referenced to *Levitus et al.* [1998]. The black line denotes the

contour for the March mean 15% sea ice extent, also for the model years 300–999.
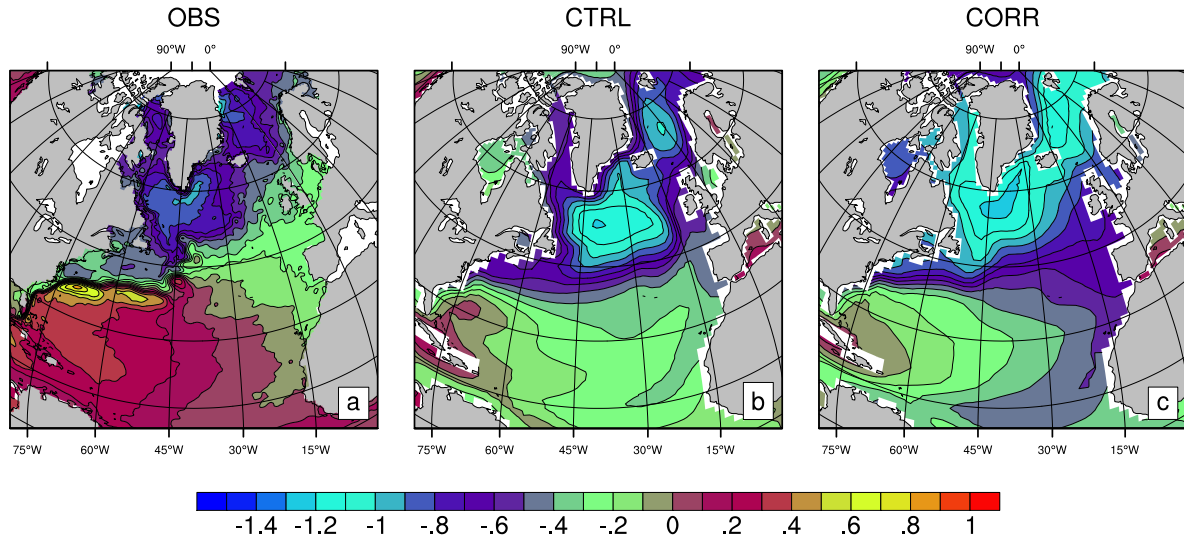
Figure 2. Mean sea surface height (m) a) as observed (AVISO, 1993-2008), b) of the uncorrected model (CTRL), and c) of the corrected model (CORR). The global mean sea level has been removed from all panels. Note the presence of the northwest corner region east of Newfoundland in the corrected model, a feature missing from the uncorrected model in which the North Atlantic Current takes a path that is too zonal. Modified after *Drews et al.* [2015]
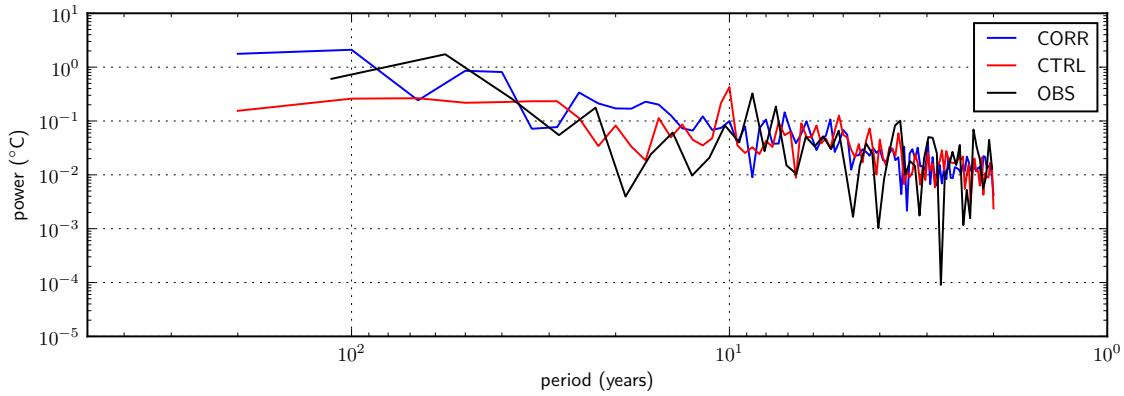
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Figure 3.   Power spectra for the AMV in observations (HadISST, 1900-2012) and both model versions (model years 300–899). For the model versions, the time series were divided into three chunks of 200 years each, making 600 years in total, and the spectra shown are the average of the spectra over the three chunks. Note the reduced energy levels on multidecadal time scales in CTRL compared to CORR.
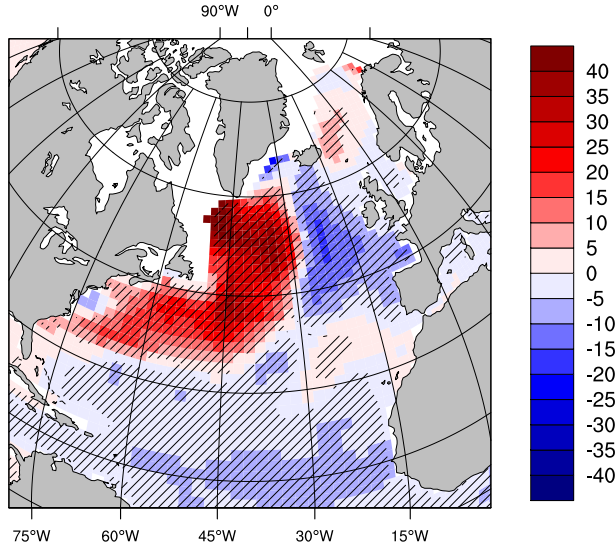
Figure 4.   Regression of the annual mean total net surface heat flux (positive upward) (in

$\text{Wm}^{-2}\text{K}^{-1}$) against the AMV index from the corrected model CORR. All time series are 5 year

low pass filtered. Areas with more than 15% mean sea ice cover in March are masked. Hatching

denotes that the corresponding correlation coefficients are significantly different from zero at the

95% or greater level according to the method of *Ebisuzaki* [1997]
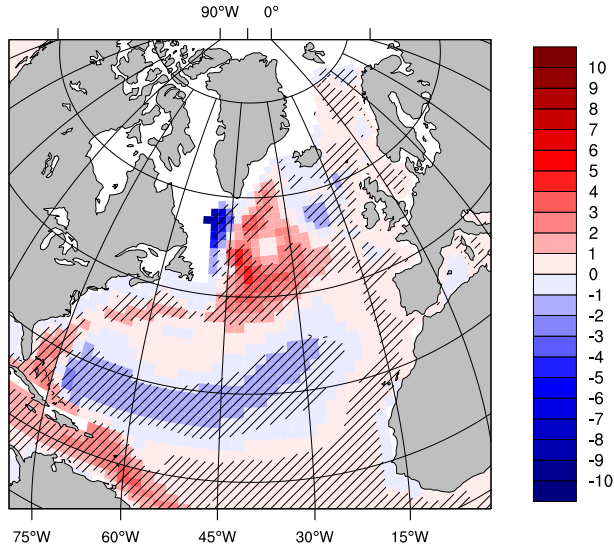
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Figure 5.   Regression of the annual mean barotropic streamfunction against the AMV index from the corrected model CORR (in Sv/°C). All time series are 5 year low pass filtered. Areas with more than 15% mean sea ice cover in March are masked. Hatching denotes that the corresponding correlation coefficients are significantly different from zero at the 95% or greater level according to the method of *Ebisuzaki* [1997].
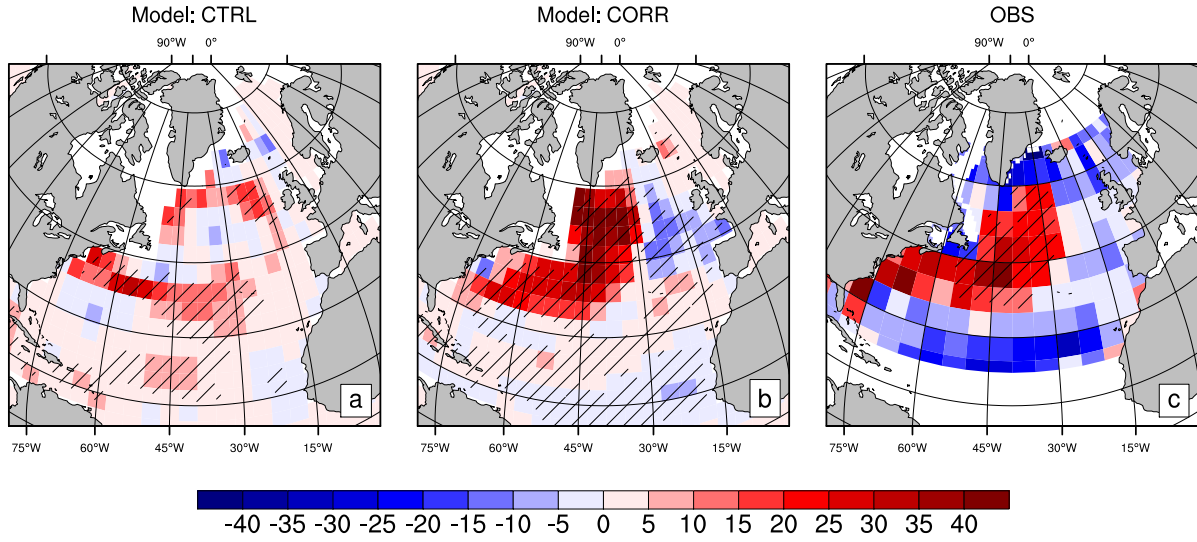
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Model: CTRL   Model: CORR   OBS

Figure 6.   Same as Figure 3 in the main text but using an 11 year running mean filter applied

to all time series.
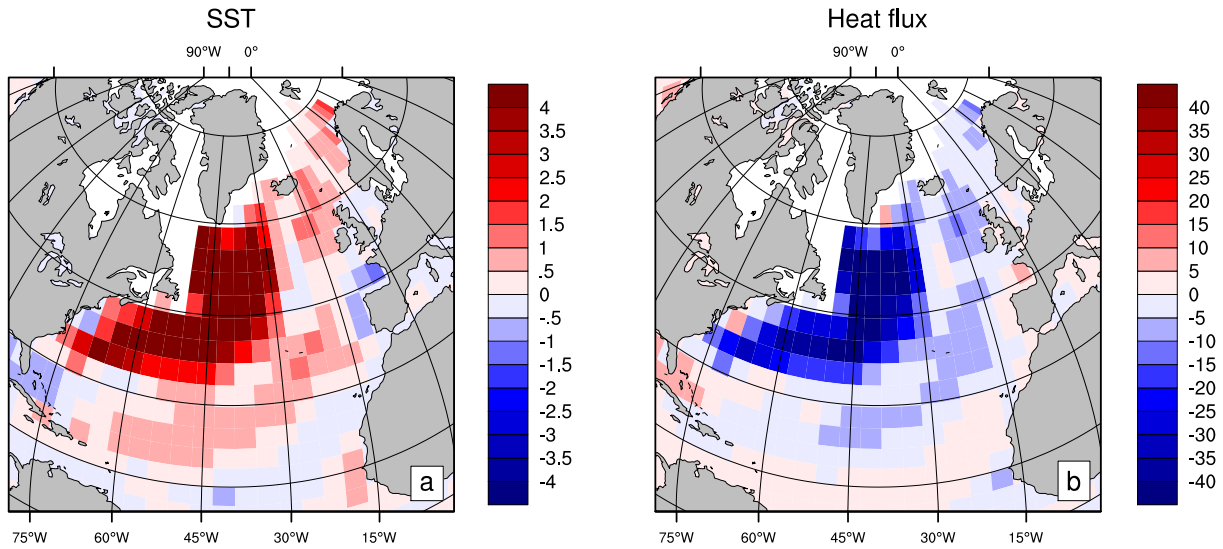
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SST   Heat flux

Figure 7.   Regression of (a) SST (in °C/°C), and (b) turbulent surface heat flux (positive

upward.) (in $Wm^{-2}K^{-1}$) on the AMV index in the slab ocean experiment. All time series are

300 years long and 5 year low pass filtered. Areas with more than 15% mean sea ice cover in
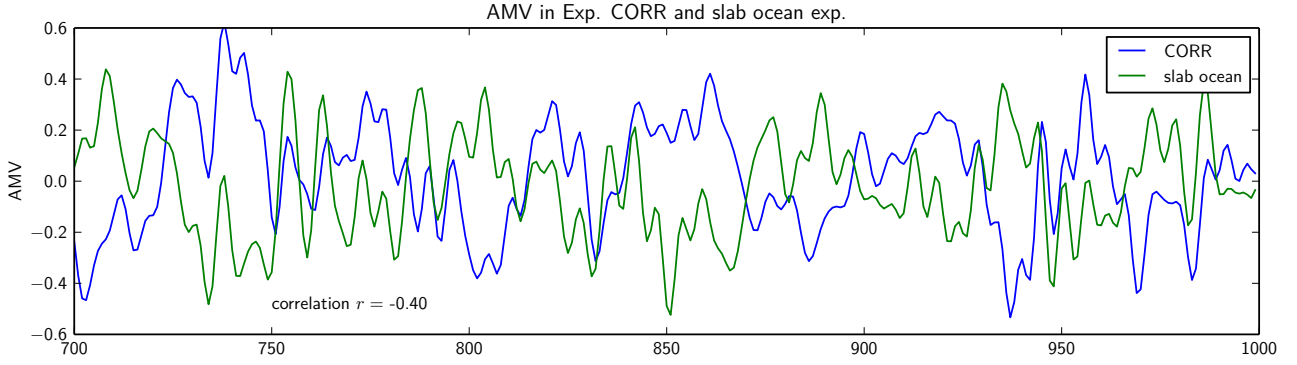
March are masked.

Figure 8. Time series of the AMV (5 year low pass filtered) from the corrected model (CORR) and the slab ocean model. Correlation $r = -0.40$
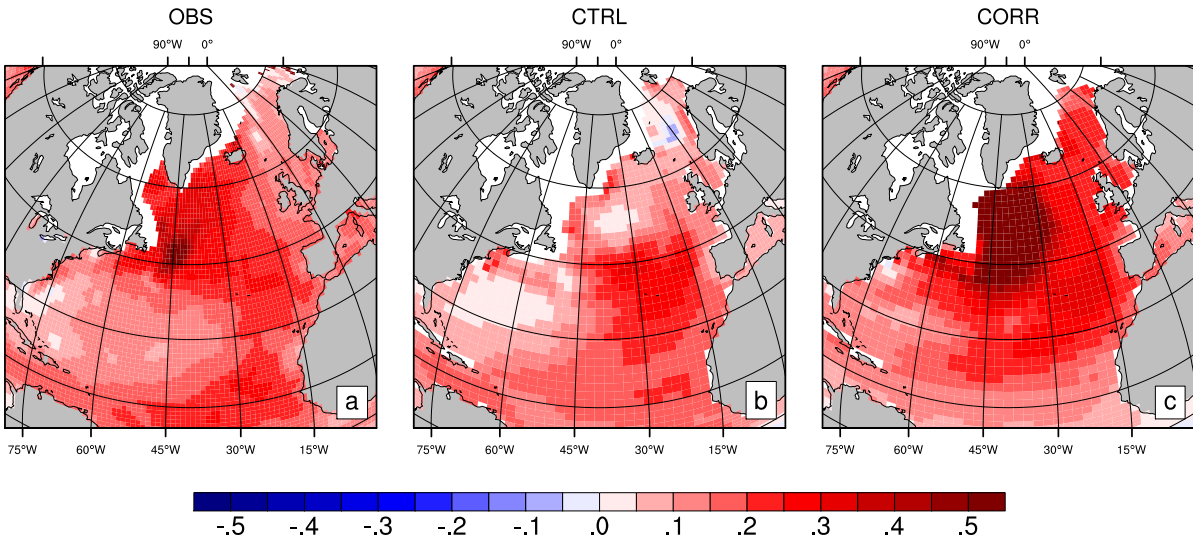

Figure 9. Same as Figure 2 in the main text but regressed on respective normalized AMV index.

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