Graphical Abstract

Simplifying the dynamics of the Atlantic meridional overturning circulation at 26°N

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Highlights

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Simplifying the dynamics of the Atlantic meridional overturning circulation at 26°N[⋆]

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ABSTRACT

A decline in Atlantic meridional overturning circulation (AMOC) strength has been observed between 2004 and 2008 by the RAPID array, this weakened state of the AMOC persisting until 2017. Climate model and paleo-oceanographic research suggests that the AMOC may have been declining for decades or even centuries before this, however direct observations are sparse prior to 2004, giving only 'snapshots' of the overturning circulation. Previous studies have used linear models based on upper layer temperature anomalies to extend earlier, but these ignore changes in the deep circulation that are beginning to emerge in the observations of AMOC decline.

We use a linear statistical model of AMOC variability based on RAPID data, and associated physically with changes in thickness of the persistent upper, intermediate and deep layers at 26°N. Boundary density anomalies at depths representing each layer are used to develop a multiple linear regression model which explains approximately 70% variance in the open ocean component. Using this regression model, we can estimate relative AMOC strength from a reduced number of observations, opening up the use of historical data that are insufficient for the usual AMOC estimation method.

1. Introduction

A simple linear regression representing the AMOC as a single-layer dynamic model showed that the western boundary temperature anomaly at 400 decibar (dbar) explained 53% of the variance in the transport anomaly of the thermocline (0-800 m) layer (Longworth et al., 2011).

2. Materials and methods

We repeated the simple linear regression from Longworth et al. (2011) using monthly mean temperatures from the RAPID western boundary moorings instead of CTD data. Despite the resulting regression having almost identical slope and intercept, we found that it explained only 10% of the variance of the thermocline layer transport, rather than 53% as Longworth et al. (2011) found. Concluding that representing a single layer did not sufficiently explain the AMOC dynamics at 26°N, we investigated representing two, three and four layers: first with boundary temperature and salinity anomalies; and then with boundary density anomalies.

- creation of model
- dynamic relationship
- justification of using a linear regression model?
- testing of model
- cross-validation?
- testing against RAPID

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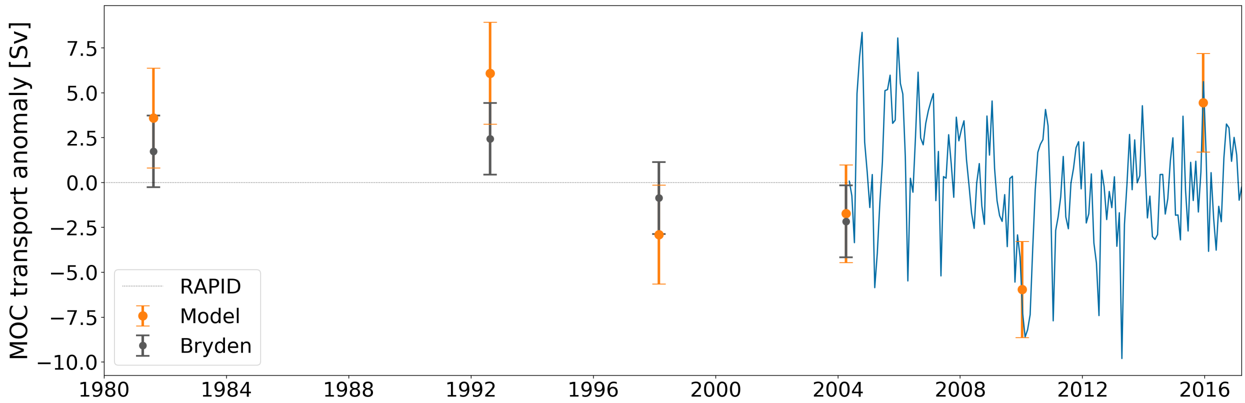

Figure 1: AMOC transport anomaly estimated from the statistical model using density anomalies from transatlantic hydrographic sections, compared to estimates from Bryden et al. (2005) and RAPID. The uncertainties shown for the model-derived values are the model's prediction intervals; the B05 uncertainty is 2 Sv.

- evaluating uncertainty - Monte Carlo method/bootstrapping
- prediction intervals
- model assumptions - autocorrelation of residuals, non-stationarity of variables
- types of model - OLS, GLSAR, ARIMA, SARIMAX?

The model was created using data from the RAPID project from ?? Apr 2004 to ?? ?? 2017. To create dynamic height profiles to calculate geostrophic transport across the basin, several moorings on both western and eastern boundaries are combined to make single full height profiles of temperature and salinity, interpolated over a 20 dbar grid. The full method is detailed in McCarthy et al. (2015). Data from a subsequent RAPID cruise was used to test the model against RAPID's own MOC estimate.

The historical hydrographic data came from multiple sources: the Western Boundary Time Series (WBTS); the underlying profiles used to create the Met Office EN4 reanalysis; the World Ocean Database (WOD); TODO.

- issues with using reanalysis data, i.e., no real deep (4100 dbar) data

3. Results

Initially applying the model to density anomaly data derived from transatlantic hydrographic sections shows the estimated AMOC transport anomalies to be generally larger than those estimated by Bryden et al. (2005) (Figure 1). The statistical model and Bry05 estimates are within the approximately 2 Sv uncertainty with the exception of the 1992 results. The estimates post-2004 also agree very well with the RAPID AMOC transport anomaly, capturing the large downturn in 2009-2010.

Applying the same model to density anomaly data derived from the EN4 underlying profiles shows

– transatlantic section data
– en4 data
– other hydrographic data
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4. Discussion

5. Conclusion

6. Acknowledgements

7. Funding

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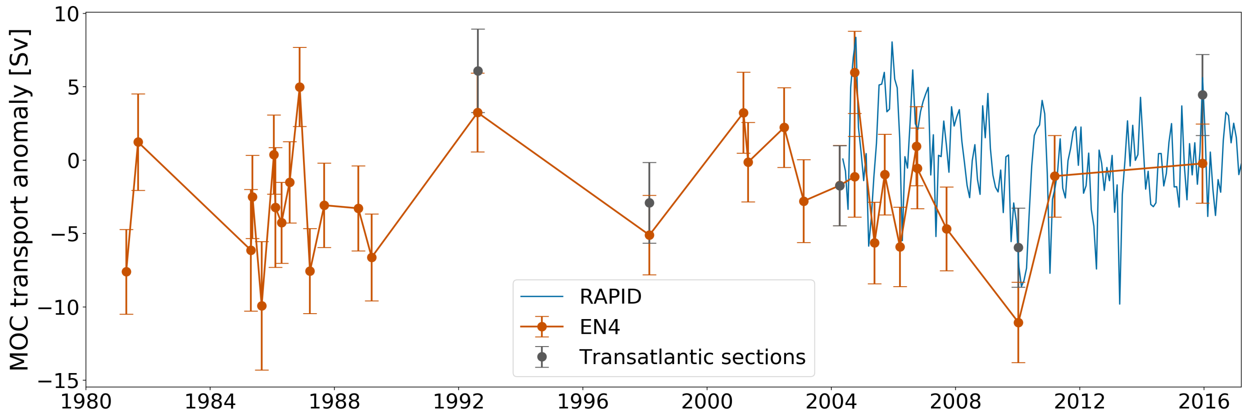

Figure 2: AMOC transport anomaly estimated from the statistical model using density anomalies from EN4 underlying profiles, compared to estimates from the transatlantic hydrographic sections (see Figure 1) and RAPID

Figure 3: AMOC transport anomaly estimated from the statistical model using density anomalies derived from World Ocean Database data, compared to estimates from the transatlantic hydrographic sections (see Figure 1) and RAPID

Table 1
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A. My Appendix

Appendix sections are coded under `\appendix`.

`\printcredits` command is used after appendix sections to list author credit taxonomy contribution roles tagged using `\credit` in frontmatter.

CRediT authorship contribution statement

R.Marsh: Data curation, Writing - Original draft preparation.

Figure 4: The evanescent light - $1S$ quadrupole coupling ($g_{1,l}$) scaled to the bulk exciton-photon coupling ($g_{1,2}$). The size parameter kr_0 is denoted as x and the is placed directly on the cuprous oxide sample ($\delta r = 0$, See also Table 1).

References

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