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Can the boundary profiles at 26° N be used to extract buoyancy-forced Atlantic Meridional Overturning Circulation signals?

Irene Polo et al.

Correspondence to: Irene Polo (ipolo@ucm.es) and Jon Robson (j.i.robson@reading.ac.uk)

1 Mean N2, AMOC and density profiles

We present the mean fields for the Brunt-Väisälä (N2) for the western and eastern boundaries (Fig. S1) for the three NEMO1 forced experiments together with the GC2 simulation and the RAPID data.

Figure S2 compares the AMOC timeseries for the CTRL, BUOY and WIND forced experiments. Figure S2b compares the seasonality of the AMOC standard deviation for the 3 experiments. Similar AMOC variability is present when linear trend is removed.

Boundary density profiles are plotted as Hovmöller diagrams (time versus density anomalies) for the three NEMO1 forced experiments (Fig. S3). The linearity of the density anomalies in the simulations is represented comparing CTRL and SUM (BUOY+WIND).

Figure S4 illustrates the mean currents in the CTRL at deep levels.

2 Wind forced coherent signal in CTRL experiment at upper levels

We look here at the spatial density anomalies averaged over 900-1300m regressed onto the PC1-WB for the CTRL (suggested by the maximum in the EOF profiles in Fig. 4). Density anomalies begin in the Labrador Sea, leading PC1-WB by 30months (Fig. S5). A pattern of equatorial Kelvin and Rossby- as in Johnson and Marshall (2002) - is also visible up to lag 0, suggesting a coherent wind-driven signal in the CTRL experiment (Fig. S5).

In CTRL (Fig. S5) the equatorial density signal appears 10 months earlier than in BUOY (not shown) and therefore seems to occur before the propagating WB signal could reach the equator. The explanation lies with large-scale northerly winds in the western Atlantic at ~15N which correlate with PC1-WB from lags -30 months, and which strengthen into a clear +NAO-like signature at lag 0 (Fig. S6b). The Ekman divergence would generate upwelling density anomalies around 60W along the South American coast (Fig. S6c-d), triggering Kelvin waves that then initiate the earlier equatorial density signals in CTRL. Wind signals are also important along the African coast (between 0-15N Fig. S6c-d). These wind-forced signals at low latitudes explain the main differences between CTRL and BUOY at upper levels. We conclude that the buoyancy forced signals do reach the EB at upper levels at 26N but that wind forced signals generated near the equator in the CTRL experiment, can misleadingly suggest that they do. This explains the shorter EB phase lags identified for the joint boundary EOFs in section 3 and correlations in Fig. 5.

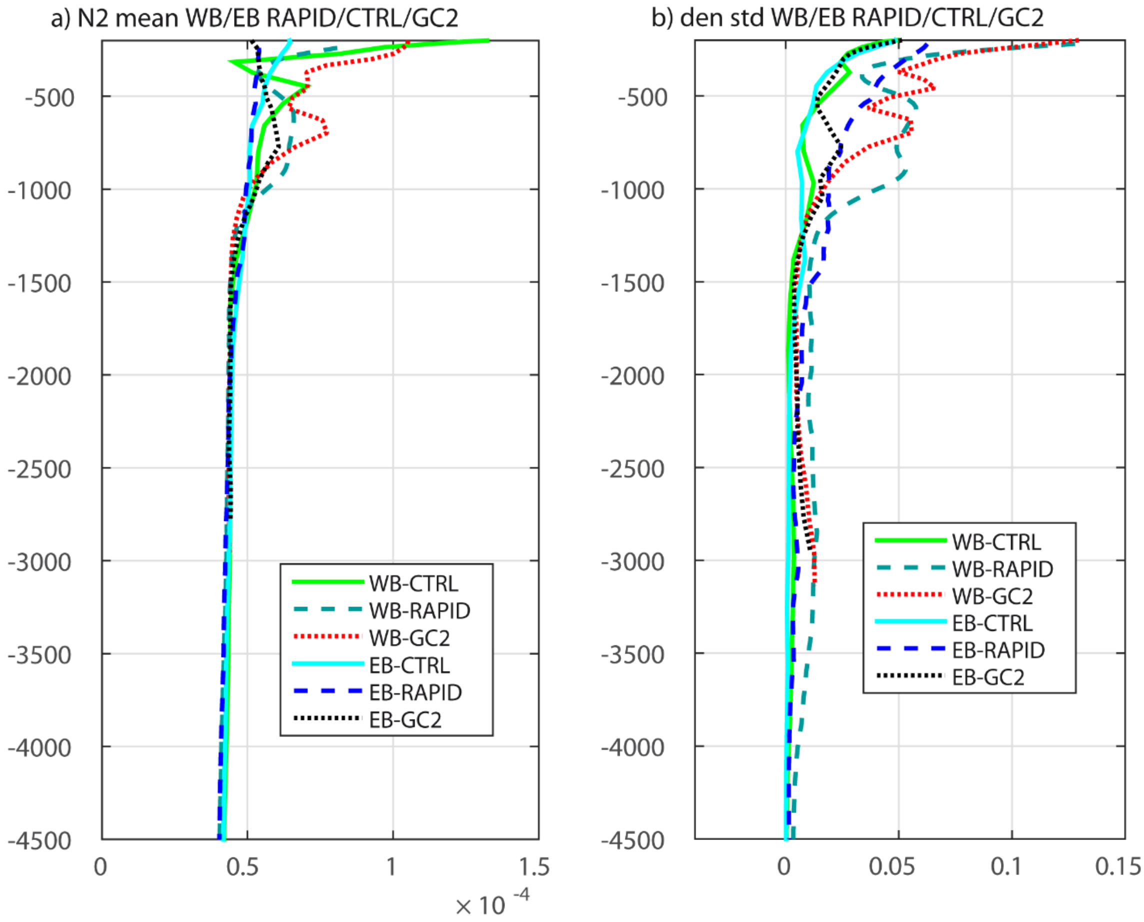

Figure S1. Density vertical gradients for NEMO1, GC2 and RAPID. a) Brunt-Väisälä frequency (N^2) of the WB and EB simulated by the CTRL experiment, GC2 simulation and RAPID observations. The mean has been computed for the common period 2004-2009. b) Same as a) but for the standard deviation of the density profiles (kg/m3).

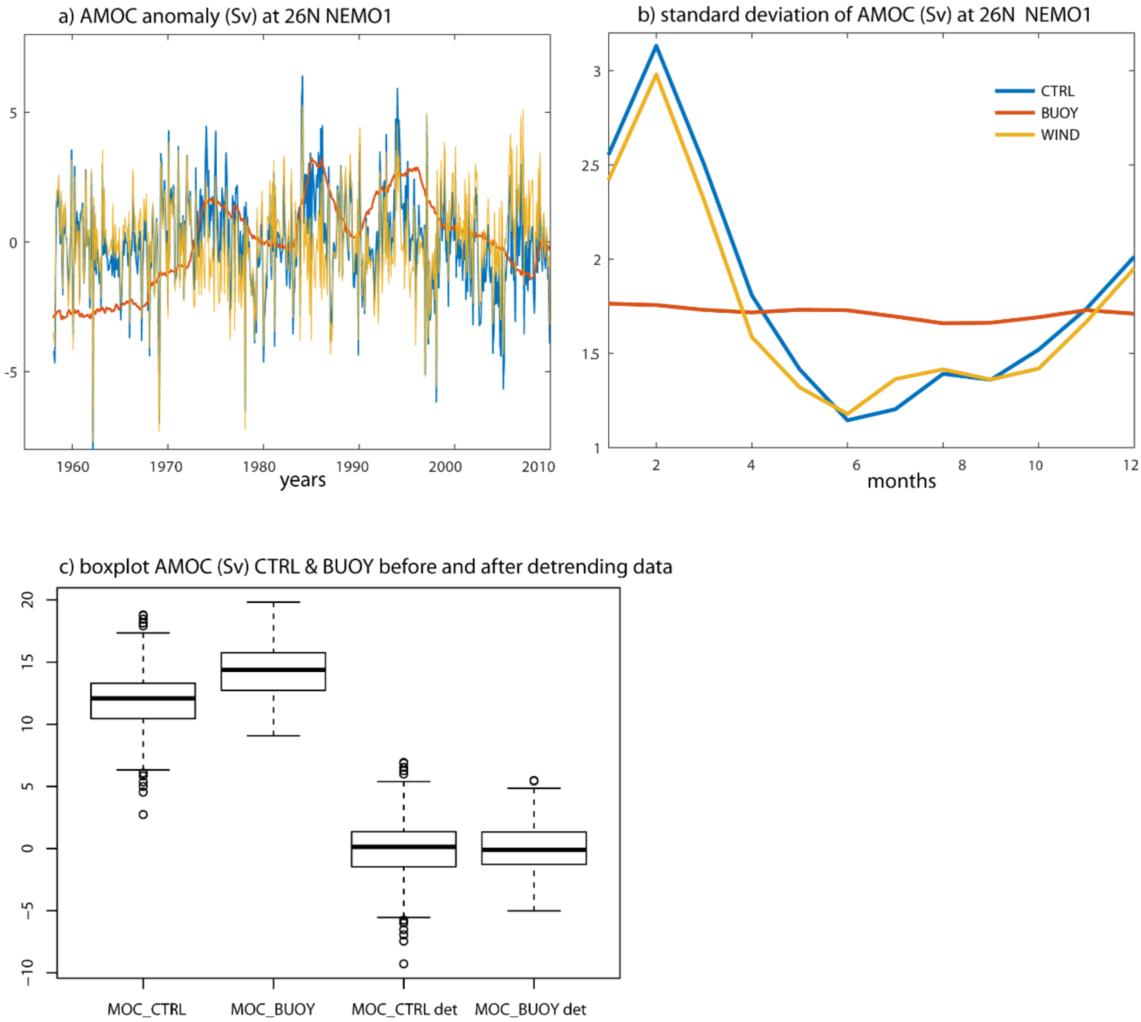

Figure S2. AMOC in the NEMO experiments. a) Timeseries of the AMOC at 26N and 1160m (Sv) after removing the seasonal cycle for each experiment. b) standard deviation of the AMOC (Sv) after removing the linear trend for each month and each experiment. c) Box-plot for the AMOC for the CTRL and BUOY experiments, before and after removing the linear trend, showing similar variability after detrending data.

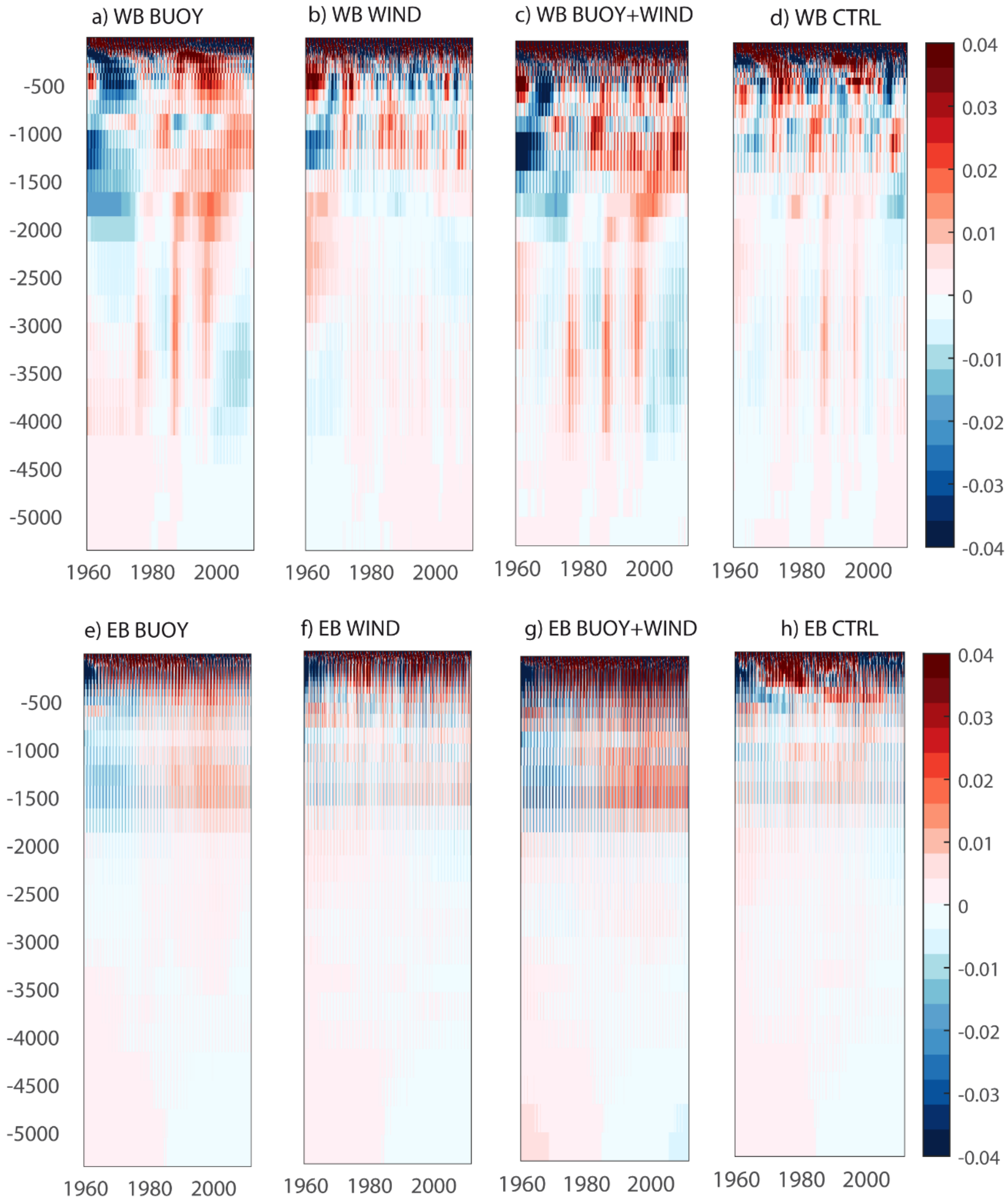

Figure S3: Hovmöller of vertical density profiles. a) Time versus anomalous density for the WB profiles for the BUOY experiment at 26N (kg/m3). b) Same as a) but for the WIND, c) Same as a) but for the sum of WIND+BUOY=SUM. d) Same as a) but for the CTRL. e)-h) Same as a)-d) but for the EB.

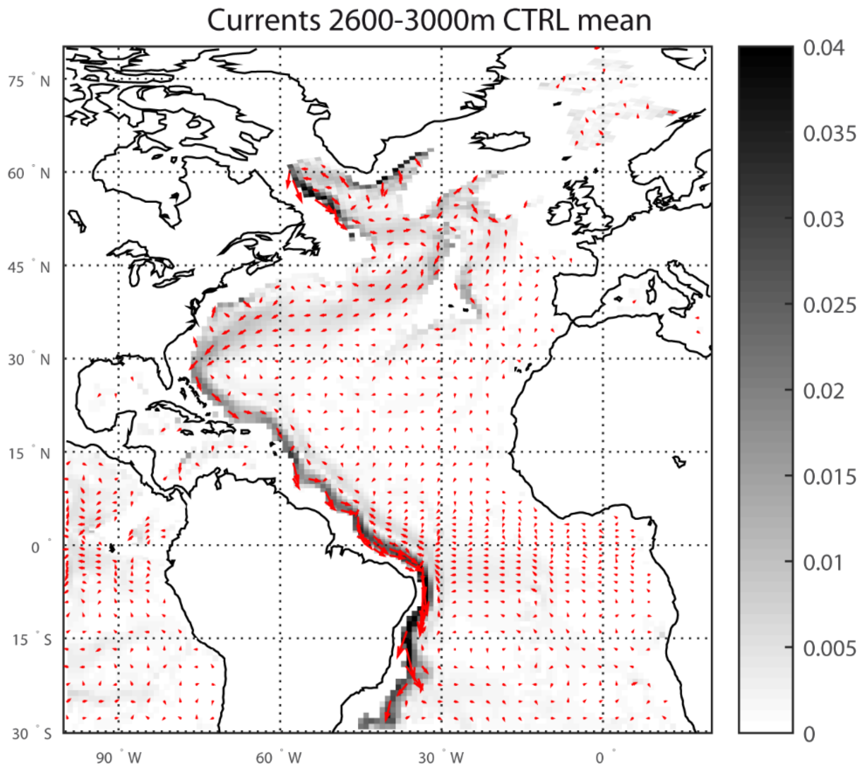

Figure S4. Currents in NEMO1 CTRL experiment. a) current (vectors) and speed (grey scale in m/s) at 2700-3000m depth for the CTRL experiment.

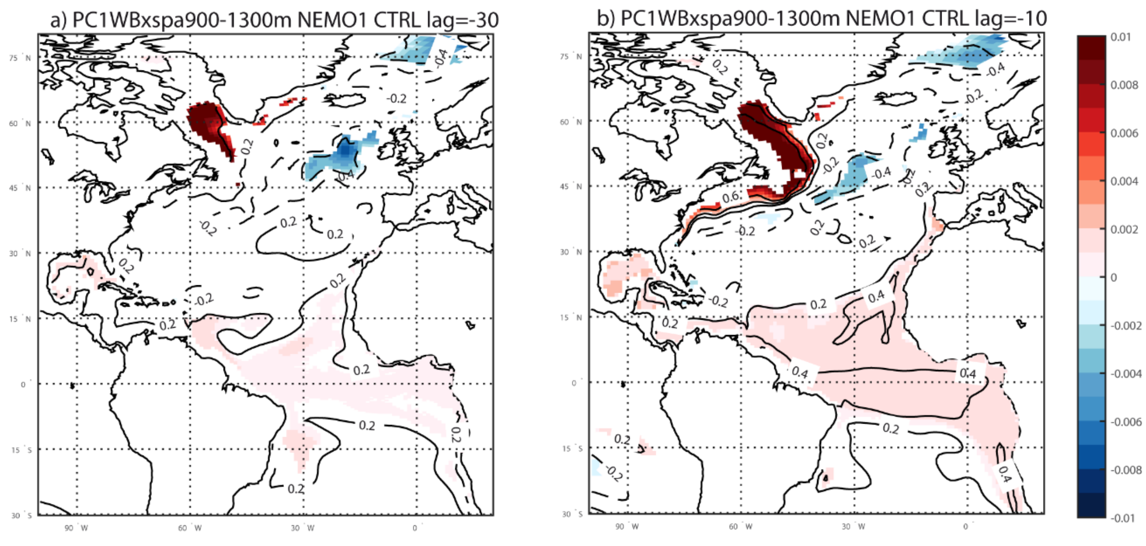

Figure S5. The relation between PC1-WB and density anomalies at upper levels in the CTRL. a) Density anomalies (kg/m3) averaged over 900-1300m depth, 30 months in advance, projected onto PC1-WB for the CTRL experiment. Black lines correspond to the correlation every 0.2. Only significant areas are plotted with a Student's t-test with 95% confidence level, considering only effective degrees of freedom. b) Same as a) but for lags -10months.

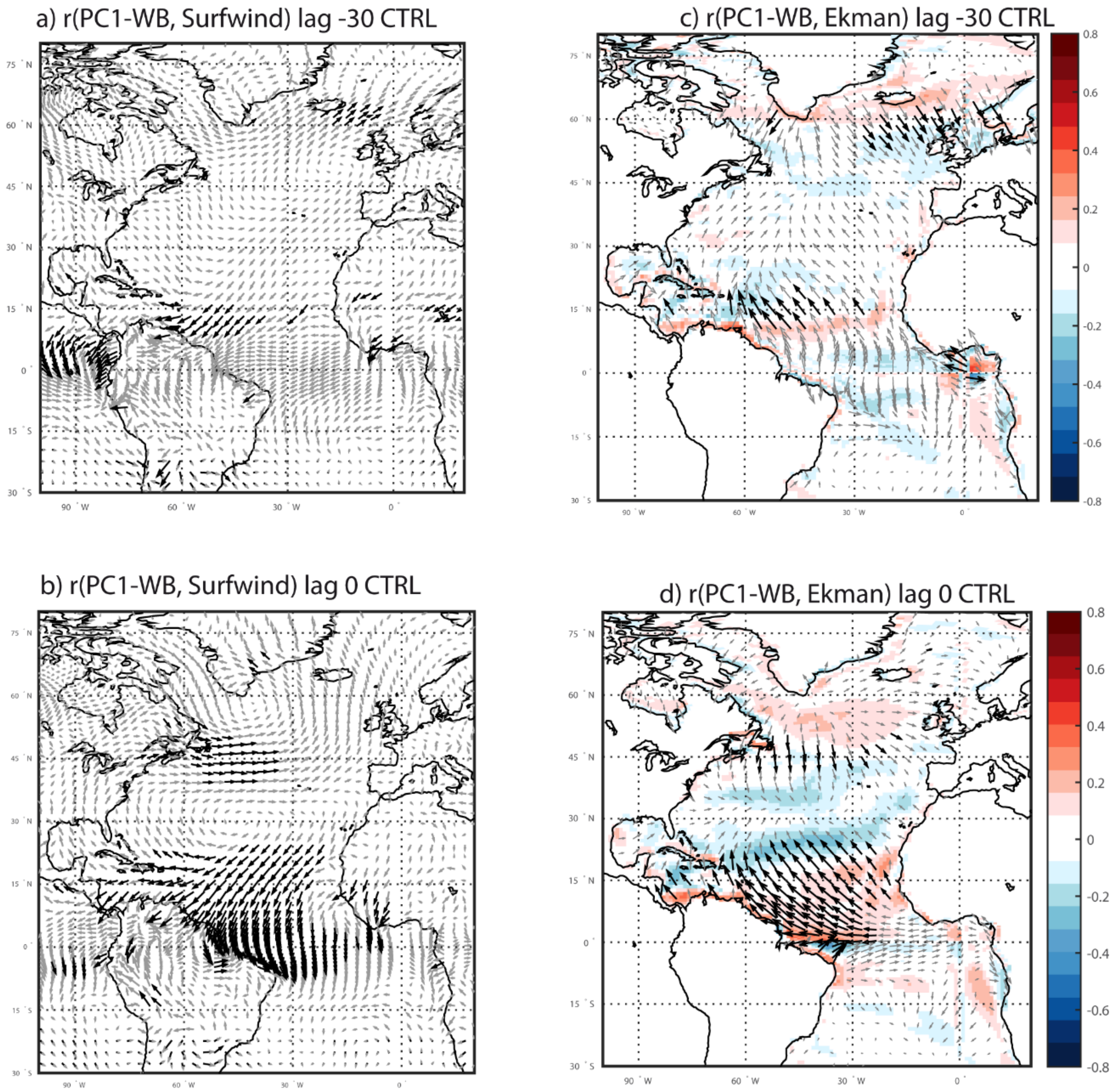

Figure S6. Correlation between PC1-WB and surface winds in the CTRL experiment. a) Correlation between PC1-WB and the surface winds for lag -30 months for the CTRL experiment. b) Same as a) but for lag 0. c) Correlation between PC1-WB and Ekman transport components (vectors) and the Ekman divergence (shaded) for lag -30 months. d) Same as c) but for lag 0. Only significant areas are plotted with a Student's t-test with 95% confidence level, considering only effective degrees of freedom. Similarly, surface wind vector and Ekman vector are shown in bold black when it is significant.