Observations for Climate: The Contribution of the XBT Network to Climate Studies

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Summary

The international community maintains a global XBT network of 51 transects utilizing approximately 50 ships of opportunity. One primary objective of this network is to provide oceanographic data needed to initialize the operational climate forecasts. Data from XBT transects have been used extensively in ocean analysis to estimate and monitor the variability of ocean heat storage, western boundary currents, global heat and freshwater transport. In particular, two zonal XBT transects (AX18 and AX7) in the Atlantic Ocean have been used to estimate the strength of the meridional overturning circulation (MOC) and the meridional heat transport (MHT). Results derived from XBT measurements have been used to evaluate model performance in simulating MOC processes.

XBT observations can be used with data from other observational platforms, such as blended satellite altimetry observations and Argo profiling floats, to investigate the year-to-year variability of the MOC and MHT along 35°S since 1993 and to assess the contribution of the barotropic and baroclinic components to these transports. The barotropic and baroclinic components of sea height can be extracted from co-located altimetric and hydrographic data.

Combination of XBT and satellite measurements has been used to investigate air-sea interaction in the tropical Atlantic and to examine the variability of the Gulf Stream path.

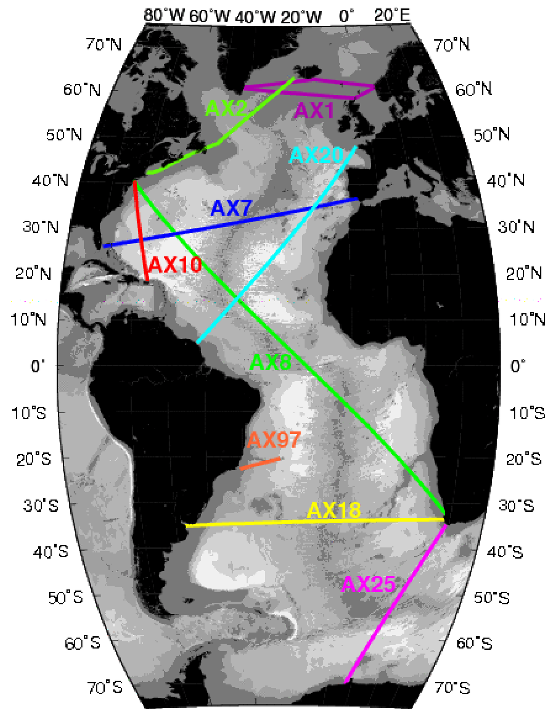

Figure 1: location of high-density XBT transects in the Atlantic maintained by NOAA/AOML. Details of each XBT transect can be found at http://www.aoml.noaa.gov/phod/hdenxbt/index.php

South Atlantic MOC from XBT Measurements

The AX18 transect was started in 2002 in the South Atlantic at ~35°S between Cape Town, South Africa and Buenos Aires, Argentina. It has been carried out four time per year. One of the main objectives of this transect is to monitor the upper limb of the MOC as it enters the Atlantic, providing the first critical ‘time series’ observations in this region. Studies using AX18 measurements during 2002-2007 give a time-mean MOC of 17.9±2.2 Sv. About 88% of the mean MOC is contributed by the geostrophic transport. However, both the geostrophic and Ekman transports are important in explaining the MOC variability. The contributions of geostrophic and Ekman transports to the MOC show annual cycles, but they are out of phase, resulting in weak seasonal variability in the MOC. The MHT variability is significantly correlated with the MOC, where a 1Sv increase in the MOC would yield a 0.05±0.01 PW increase in the MHT. Partition of transport into the western and eastern boundaries and suggests that, to quantify changes in the MOC and MHT, it is critical to monitor all three regions. Separation of the MHT into the overturning and horizontal heat fluxes indicates that the bulk of the NHT is associated with the overturning component.

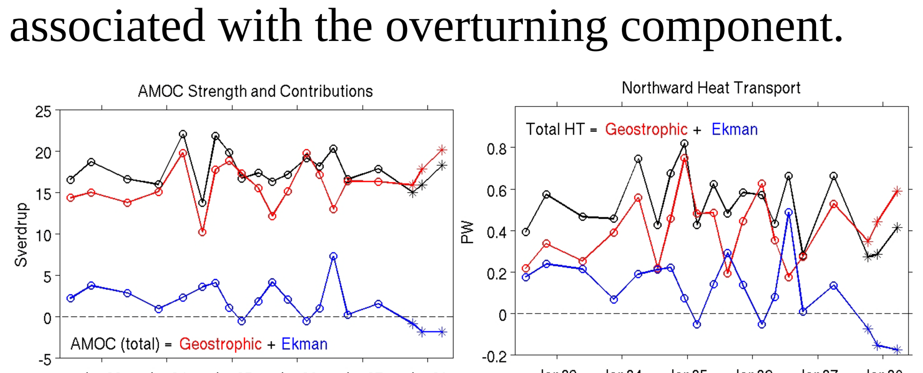

Fig.2. The strength of the MOC (left) and the MHT (right) from AX18 and contributions from geostrophic and Ekman components.

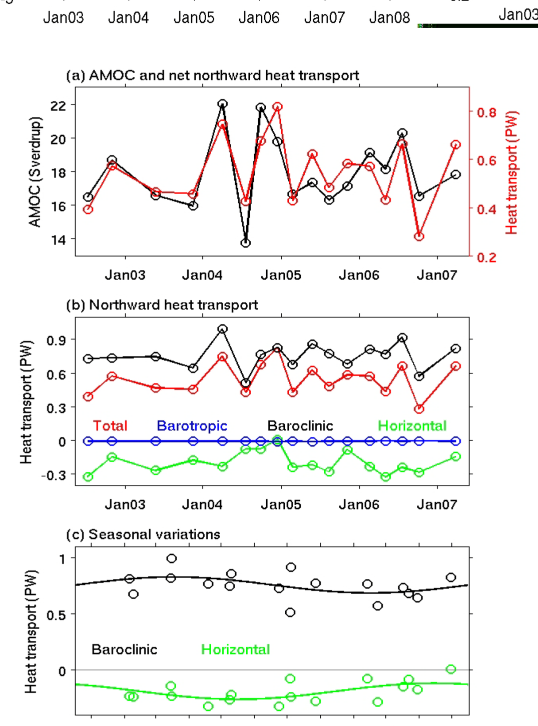

Fig.3. Time series of (a) the MHT (red, right axis) and the MOC (black, left axis), and (b) the MHT (red) and contributions from the barotropic (blue), overturning (black), and horizontal (green) components. (c) Scatter plots of the overturning (black) and horizontal (green) heat fluxes versus month.

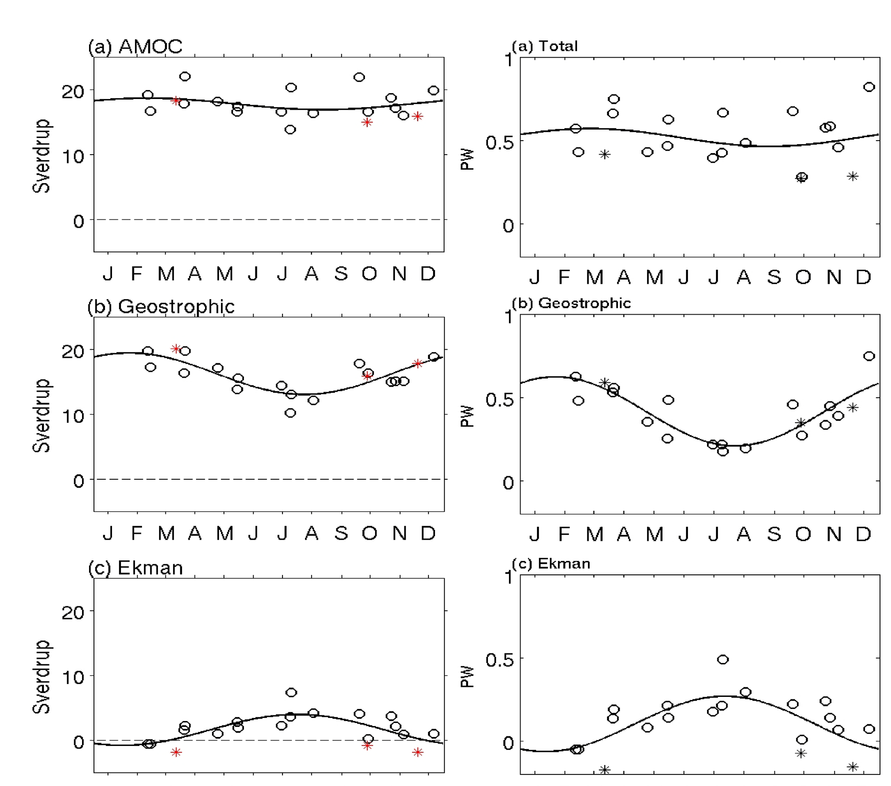

Fig.4 Left panels: scatter plots of the (a) MOC, and its (b) geostrophic and (c) Ekman contributions versus month. Right panels: scatter plots of the (a) MHT and its (b) geostrophic and (c) Ekman contributions versus month.

Model Evaluation Based on Results from AX18

The MOC and MHT obtained from two GFDL coupled models, with and without data assimilation, are examined and compared with results from AX18 transect in the South Atlantic. The performance of the GFDL coupled data assimilation (CDA) model is quite different between the two periods, 1979-2002 and 2003-2007, due to the assimilation of Argo data in later period. The MOC structure from GFDL CDA during 1979-2002 are similar to those from GFDL CM2.1 simulation, both give weak boundary currents and strong interior overturning transport compared to observations. However, after assimilating T/S profiles from Argo floats, the performance of the GFDL CDA in simulating the MOC/MHT is greatly improved: the transports of boundary currents are twice as strong as those during pre-Argo period, and the overturning flow in the interior region is reduced. The improvement of the boundary currents, despite the lack of Argo data at the boundaries, is probably due to better T/S representation at the interior side of the boundaries. The lack of Argo data at the boundaries may be responsible for the weak MOC in GFDL CDA during 2003-2007, suggesting that measurements from other platforms are needed at the boundaries to further improve MOC processes in data-assimilating models.

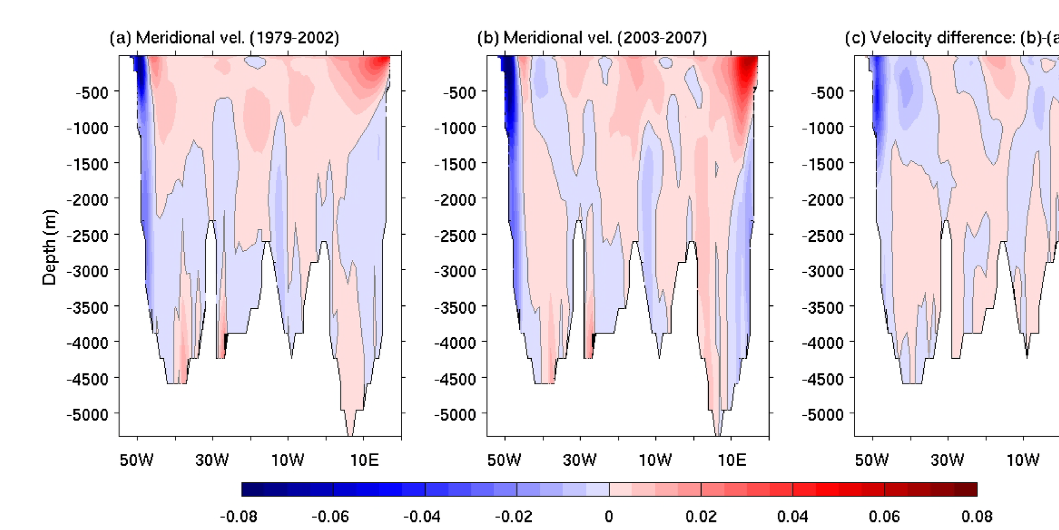

Fig.5. Meridional velocity from GFDL CDA averaged (a) during 1979-2002 (pre-Argo period), (b) during 2003-2007 (Argo period), and the differences in averaged meridional velocity for the two periods, 2003-2007 and 1979-2002. Unit is $m\ s^{-1}$.

		GFDL CM2.1 1979-2000	GFDL CDA 1979-2002	GFDL CDA 2003-2007	AX18 2002-2008
MOC (Sv)					
Total		19.2 ± 3.2	18.9 ± 3.6	13.3 ± 4.2	17.9 ± 2.2
Geostrophic and Ekman	Ekman	2.5 ± 3.1	0.4 ± 2.3	0.5 ± 2.7	2.2 ± 2.0
	Geostrophic	16.7 ± 1.1	18.5 ± 2.2	12.8 ± 3.4	15.7 ± 2.6
Regional contributions	West	-12.0 ± 2.8	-15.2 ± 6.9	-29.8 ± 6.7	-27.7 ± 5.3
	Interior	19.3 ± 2.9	20.2 ± 8.8	17.1 ± 6.2	16.5 ± 6.3
	East	11.9 ± 1.8	13.8 ± 5.3	26.0 ± 6.3	29.2 ± 5.2
MHT (PW)					
Total		0.50 ± 0.21	0.46 ± 0.21	0.31 ± 0.25	0.55 ± 0.14
Geostrophic and Ekman	Ekman	0.17 ± 0.21	0.02 ± 0.17	0.03 ± 0.20	0.15 ± 0.13
	Geostrophic	0.33 ± 0.05	0.44 ± 0.10	0.28 ± 0.17	0.40 ± 0.17
Regional contributions	West	-0.75 ± 0.16	-0.87 ± 0.34	-1.55 ± 0.30	-1.59 ± 0.33
	Interior	0.68 ± 0.18	0.65 ± 0.34	0.74 ± 0.33	0.80 ± 0.35
	East	0.57 ± 0.08	0.69 ± 0.20	1.12 ± 0.29	1.33 ± 0.27
Overturning and horizontal	Overturning	0.63 ± 0.19	0.58 ± 0.19	0.52 ± 0.24	0.75 ± 0.12
	Horizontal	-0.12 ± 0.03	-0.12 ± 0.05	-0.21 ± 0.06	-0.20 ± 0.10

Table 1. Summary of time-mean MOC and MHT and contributions from various processes at 34°S in the South Atlantic from GFDL CM2.1 and GFDL CDA models and AX18 measurements. The ground ‘truth’ and the closest values to the ground ‘truth’ are shaded.

Other Studies Using Combination of XBT and Satellite Measurements

The tropical Atlantic is an important region in the coupled climate system. Better understanding the variability of the tropical Atlantic and the coupling of the atmosphere and ocean is critical to improve our ability in predicting climate variability. Measurements from the AX8 transect are combined with satellite altimeter observations to determine transports of the North Equatorial Counter Current (NECC) and North Equatorial Undercurrent (NEUC). The temporal resolution of the estimated transports allow us to investigate dynamical mechanisms of variability of these currents with the sea-surface variables..

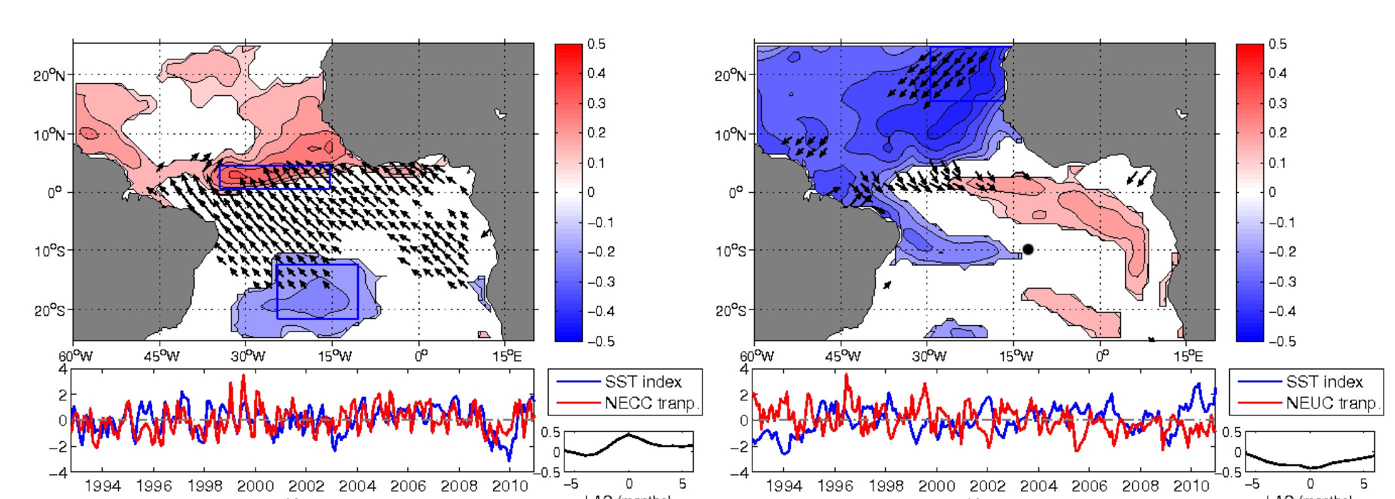

Fig.6. Upper panels: maps of correlation between monthly anomalies of the transport time series and SST and wind stress . Only the values that are statistically significant are plotted. Lower panels: time series and respective lagged correlations of the normalized transport anomalies (red) and the SSTA index defined by the average inside the blue boxes in the upper panels. Figure a) is for NECC and b) is for NEUC.

The Gulf Stream (GS) plays both important dynamic and thermodynamic roles in climate system. As the northward return flow of the upper limb of the MOC, the GS transports a vast amount heat from low latitudes to high latitudes. A recent study suggests that changes in the GS path are related to the MOC variability, indicating the former could be used as a proxy for measuring long-term changes in the MOC. Measurements from the AX10 transect have been used to locate the Gulf Stream path, which can then be compared to estimates of the Gulf Stream path from satellite altimeter.

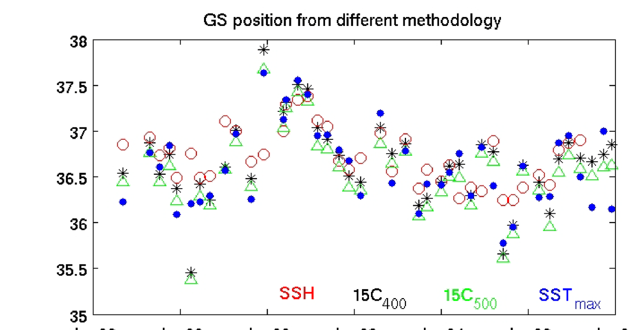

Fig.7. GS position from 15°C isotherm at 400 m and 500 m depth, and those from maximum SST and from the maximum surface velocity from satellite altimeter.