Upper Ocean Transports in the Atlantic Ocean

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INTRODUCTION

One of the most important transport mechanisms in the Atlantic ocean is the Meridional Overturning Circulation (MOC), which is driven by temperature, salinity and by the wind variations. The upper limb of the MOC carries warm South Atlantic water across the equator and into the North Atlantic subtropical gyre. Subtropical cells exchange water between subtropical and tropical regions and are a conduit for MOC water. Currents in the tropical region are complicated--swift zonal flows, equatorial upwelling, off-equatorial downwelling, energetic waves, and strong seasonal variations. Therefore the interhemispheric paths of the MOC are complicated and poorly known. South Atlantic water makes its way into the North Atlantic through at least two primary pathways; rings shed from the NBC as it retroflects into the interior and a seasonal rectification that temporarily stores water in the NECC/NEC ridge system and then releases it into northward Ekman transport. Moreover, southward interhemispheric transport of North Atlantic cannot be excluded.

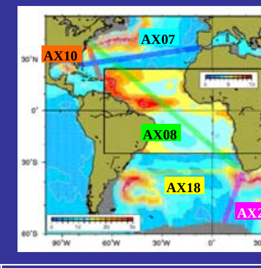
Schematics of the Meridional Overturning Circulation (MOC) (Adapted from W. Schmitz, Jr, 1996).

OBJECTIVES

This project provides real time high resolution XBTs spaced 30-50 km apart along five important lines in the Atlantic Ocean. Data obtained from the five high density XBT lines (AX25, AX18, AX08, AX10 and AX07) are being used to investigate:

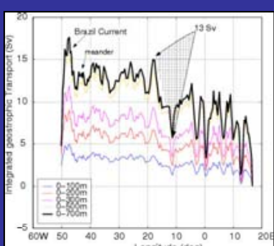
- **The interbasin exchange of water between the Indian and Atlantic Ocean,**
- **The mass transport by western boundary currents and their associated warm rings in the South Atlantic Ocean,**
- **The meridional heat transport across 30-35S,**
- **The mass transport of the zonal currents in the tropical Atlantic,**
- **The meridional heat transport across 30-35N,**
- **The variability of the Gulf Stream, and**
- **Long period variations of sea surface and subsurface temperatures along these lines.**

These lines also provide data to the community for analysis of the thermal structure of the subtropical gyre to investigate the seasonal to interannual variability in upper ocean thermal energy to monitor and understand the role that the ocean plays in climate fluctuations, and to improve the ability to predict important climatic signals such as the North Atlantic Oscillation.



RMS of sea height in the Atlantic Ocean derived from seven years of TOPEX/Poseidon altimetry data. Regions with the largest values of variability are associated with western boundary currents. The five XBT lines are superimposed to the map.

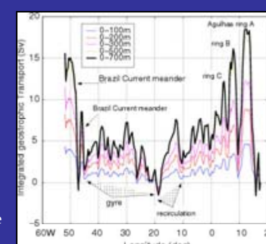
The South Atlantic



The integrated water mass transport from West to East is shown here for the first two sections of AX18. The contribution from 5 layers from the surface (0 m) to 100, 200, 300, 500, and 700 m relative to a zero flow at 800 m are presented here.

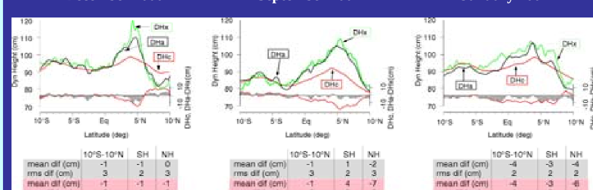
The July 2002 section indicates that there is approximately 13 Sv flowing north between 10°W and 20°W. West of 20°W there seems to be little transport towards the North (less than 3 Sv). The Brazil Current transport is approximately 12 Sv between 30°S-35°S. The almost coincident transport between the 0-500 and 0-700 m estimates indicate the existence of little shear in the flow between these two layers.

The November 2002 section shows that the meander of the Brazil Current carries approximately 15 Sv. This section crosses a second meander between 45°W and 48°W. Between 30° and 20°W there are 10 Sv of water transported to the North and between 20°W and 10°W there are 10 Sv flowing to the South, probably because of an artifact of the section going along the Subantarctic front boundary or because of recirculation. East of 0°E this section shows remarkably well the net transport of three Agulhas rings (named A,B and C in the figures). Their transport range between 5 to 15 Sv, having an effective net transport of 2 to 3 Sv each. As in the July section, the nearly coincident transport between the 0-500 and 0-700 estimates indicate the existence of little shear in the flow between these two layers.

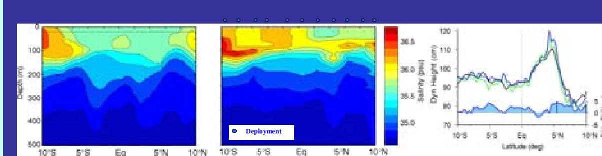


The Tropical Atlantic

December 2000 **September 2001** **January 2002**



Dynamic heights along the first three AX08 transects derived from XBTs using historical T-S relationships (DHx, green lines), from altimetry using climatological dynamic height (DHc, red lines). The differences between the XBT and the altimeter (in red shades) and climatological estimates are also indicated (in gray shades). The tables list the mean differences for the altimeter (gray) and climatological (red) estimates for the entire section and the Northern (NH) and southern (SH) hemispheres.



Salinity sections along AX08 during December 2000 using monthly T-S relationships (left) and profiling floats salinities (center). (right) Difference (blue line and shading below) between the dynamic height derived from the XBT section and salinity from monthly T-S relationship (green line) and from the XBT section and the salinity obtained from the profiling floats (blue line). This difference shows the overestimation of dynamic height when using historical T-S data. The altimeter-derived dynamic height is superimposed (black line)

	December 2000		September 2001		January 2002	
	Location	Sv	Location	Sv	Location	Sv
NEC	19.7-9.7°N	-23	19-13.1°N	-15	19.8-11.1°N	-22
NECC	7.2-4.9°N	25	9.7-5.6°N	22	9.3-7°N	16
nSEC	4.0-3.7°N	-20	5.6-3.2°N	-20	7-5.5°N	-14
NEUC	3.7-3.0°N	14		-	5.5-3.9°N	18
nSEC	3.0-1.7°N	-37		-	3.9-2.2°N	-30
eSEC	1.5-3.6°S	-36	1.7-4.3°S	-5	1.8-4.2°S	-13
SEUC	3.6S-5.2°S	17	4.3-5.4°S	11	4.2-4.7°S	14
cSEC	5.2-6.8°S	-13	5.4–6.9°S	-11	4.7-8.0°S	-6
SECC	10-12.9°S	6	6.7-9.5°S	11	8.0-9.3°S	7
sSEC	12.9-19.9°S	-7	9.5-15.3°S	10	9.3-20°S	-8

Table 1: Location and transports for each of the currents identified along AX08 during the first three realizations. The negative values indicate transports towards the west. All transports are integrals to 800 m of geostrophic velocities assuming a level of no motion at 800m, the deepest level of XBT temperature observations.

The North Atlantic

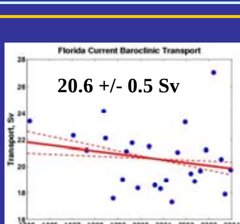


Figure 2: Baroclinic transports from 0-800m (v=0 at 800m) from AX7 XBT data within the Florida Straits. Linear trend with 95% confidence limits shown in red.

AX7 cuts through the subtropical gyre longitudinally. A typical cumulative transport picture is shown in Figure 1. The major features include the southward flowing subtropical gyre which typically increases linearly to the Mid-Atlantic Ridge (about 45W). The mean southward transport above 800 meters (with a zero reference level at 800 meters) is -29.9 +/- 1.0 Sv. Highest transport variability is seen to the west of the Mid-Atlantic Ridge. The XBT line enters the Northwest Providence channel near Abaco Island, Bahamas at 77W, close to shore along the Northern part of the channel. They then transit to the southern side of the Channel, before crossing the Florida Straits to enter Miami. As such, they cross the Antilles Current (between approx 71-77W), transit along the Northwest Providence Channel (79-77W) and the Florida Current (80-79W). Mean transports for these currents (relative to 800m or the ocean bottom) are 10.1 +/- 0.5 Sv, 0.6 +/- 0.5 Sv and 20.6 +/- 0.5 Sv respectively.

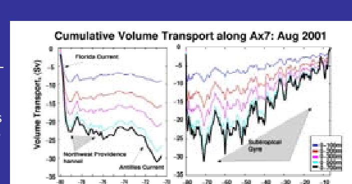


Figure 1: Cumulative transport relative to a level of no motion at 800m.

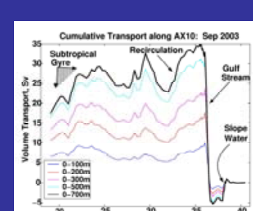


Figure 5: Cumulative transport relative to a level of no motion at 800m.

AX10: The cumulative transport along a typical section from AX10 is shown in Figure 5. Between New York and Puerto Rico, this section crosses the subtropical gyre meridionally. Currents include the Gulf Stream, the slope water and the large scale subtropical circulation. Repeat occupations along AX10 suggest a a mean baroclinic transport relative to 800 meters of 39.3 +/- 3.7 for the Gulf Stream. XBT transects suggest an increase of the baroclinic Gulf Stream transport of 8.7 +/- 2.2 Sv/decade (at the 95% confidence level, Figure 6). This trend is coincident with a smaller trend in the northern limit of the Gulf Stream moving south over time (i.e. the baroclinic transport is inversely proportional to the northern most position of the Gulf Stream).

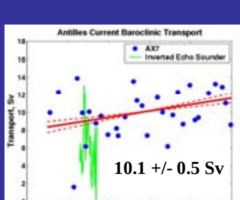


Figure 3: Baroclinic transport from 0-800m with azero velocity reference level at 800m in ferred from XBT data along AX7. Data fit to slope (with 95% confidence) with red lines. Inverted echo sounder derived transports shown in green.

Repeat occupations have shown a decrease over time on -2.2 +/- 1.4 Sv/decade in the baroclinic Florida Current transport (Figure 2), a change on about 10% of the mean transport. At the same time the Antilles Current transport has increased 3.6 +/- 1.3 Sv/decade (Figure 3), representing a substantial fraction of its mean value (over 35%). These two observations together suggest that the upper layer transport has not substantially changed, but where and how the "upper limb" of the meridional overturning circulation is being transported has changed substantially. This suggests that observations within the Florida Current alone may not be adequate to describe the upper layer of the thermohaline circulation.

This XBT line can also help us determine the strength of the exchange in the Northwest Providence channel Figure 4). AX7 data suggests a mean value only marginally different from zero, however a large seasonal cycle is also observed. Previous observations have been sparse in time (e.g. Johns et al 1999 using shipboard ADCP for the upper 0-200m and Leahman et al 1995 using Pegasus velocity), and hence do not rule out a seasonal cycle.

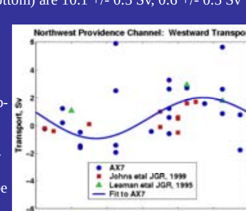


Figure 4: Baroclinic transport from 0-800m (with v=0 at 800m) along AX7 within the Northwest Providence Channel. Seasonal fit to transports in blue and other estimates (see legend).

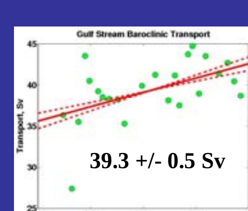


Figure 6: Gulf Stream baroclinic transport from 0-800m relative to a level of no motion at 800m.