Meridional heat transport in the South Atlantic

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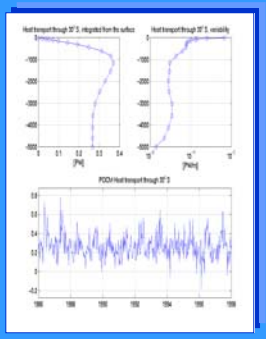
The meridional heat flux in the ocean is a key element of the climate system because of the role that the ocean plays in determining the Earth's climate through its interaction with the atmosphere. In order to predict climate variability, the mechanisms and the pathways of the meridional heat and mass transport in the global ocean must be described and understood. In particular, it is essential to determine the modes of natural variability in heat transport and characterize the variability in important regions with relatively little data coverage. Using repeat sections within the South Atlantic funded by NOAA/OGP, the mean heat transport and variability can be described.

The South Atlantic Ocean connects the three major ocean basins: the Pacific Ocean, the Atlantic Ocean and the Indian Ocean. The meridional gaps between the continents of the Southern Hemisphere and Antarctica allow for a free exchange of water among the basins. Despite its small size, the Atlantic Ocean is responsible for over half of the northward heat transport carried by the global ocean. This meridional heat flux is due to a worldwide vigorous ocean circulation that connects all the basins- the meridional overturning circulation (MOC). The ability to understand and quantify this northward flow is crucial to properly model and forecast the Northern Hemisphere weather and climate.

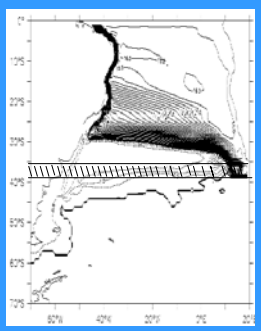
The South Atlantic Ocean is a major conduit for the warm upper layer water that flows northwards across the equator, compensating for the colder southward flowing North Atlantic Deep Water. This large-scale circulation, is responsible for the northward heat flux through the South Atlantic and causes it to be unique among the oceans.

Estimates of South Atlantic meridional heat flux near 30°S				
Lat	Heat Flux	Method /	Source	
°S	PW			
30	0.69	Sea-air fluxes	Hastenrath (1982)	
30	0.39	Sea-air fluxes	Bunker (1980)	
30	0.38	Sea-air fluxes	Hsiung (1985)	
30	0.3	Inverse	Macdonald & Wunsch (1996)	
30	0.29	Numerical model	Marchesiello et al. (1998)	
30	-0.1 to 1.0	Numerical model	Matano (pers. comm., 2003)	seasonal cycle
30	0.22	Direct	McDonogh and King (2003)	
30	0.19	Numerical model	Matano & Philander (1993)	
30	0.56	Numerical model	Saunders &Thompson (1993)	
30	-0.23	Inverse	de las Heras & Schlitzer (1999)	
30	0.5 to 1.05	model	Donners, 2003	seasonal cycle
32	0.66-0.88	Inverse	Fu (1981)	
32	0.16-0.68	Direct	Bennett (1978)	
32	0.4	Direct	Bryan (1962)	
32	0.24	Inverse	Rintoul (1991)	
32.5	0.63	Numerical model	Donners	
32.5	0.23	Direct	Talley (2003)	
37.0*	0.28	Direct		* nominaly
37.0*	0.45 to 0.94	Direct	Saunder and King, 1995	
37.0*	0.67	Numerical model	Saunder and King, 1995	

Previous estimates of the heat transport in the South Atlantic in the 30° to 35°S band varies from negative values to more that 1 PW. This variability may be a consequence of the different pathways and of the different methods to calculate the heat transport, however natural variability in the heat transport, whether annual or interannual, cannot be ruled out using historical data.



Matano (2004, personal communication) calculated the heat transport across 30°S using the POCM model. Results indicate that the northward transport is mostly in the upper 1000m, that most of the variability is on the surface and that the signal follows an annual cycle with values ranging from –0.2 to 0.78 PW.



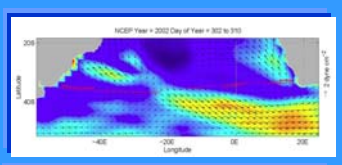
Streamfunction (Sv) of particles traced backward from the Atlantic equator to 20°E or Drake Passage. Only particles lighter than s_1 = 32.16 kg/m^3 are included.

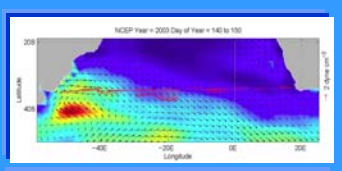
The upper branch of the MOC in the South Atlantic can be supplied by warm and saltier water that enters the South Atlantic via the Agulhas leakage (the warm route, Gordon, 1986) or by cold and fresh intermediate water that enters the South Atlantic via the Drake Passage (the cold route, Rintoul, 1991). According to Gordon (1992) the AAIW derived from the Drake passage returns saltier and warmer via the Agulhas leakage after a loop in the Indian ocean. It is not clear which of these two routes is the most important and or if there is some seasonal or interannual variability that may lead to the discrepancies in values. What it is clear is that in order to better understand the global ocean thermohaline circulation and its impact on climate it is necessary to reduce the heat flux uncertainty in the South Atlantic.

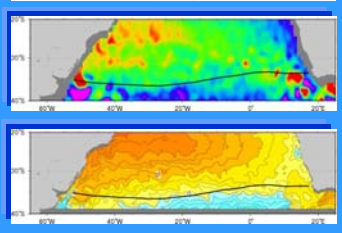
Some recent results (Donners and Drijfhout, 2003 personal communication) analyzed the product of the OCCAM using a Lagrangian path following technique. Results suggest that most of the South Atlantic upper layer limb of the MOC is derived from the Agulhas leakage. This relatively warm water (higher that 10°C on average) leads to relatively large meridional heat fluxes in the band 30° to 35°S. From the same product, Donners (2003 personal communication) calculated time series of the heat flux. Heat flux at 30° S has an annual cycle. Depending of the month may vary from 0.5 to 1.1 PW.

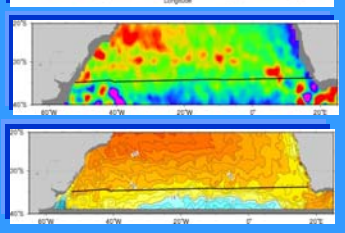
Starting in 2002, and as part of the NOAA Global Ocean Observing System, a new XBT high density line was started in the South Atlantic between Cape Town, South Africa and Buenos Aires, Argentina. The line was originally funded to be repeated twice a year but stating the year 2004 we expect to be able to run it four times a year. The line was conceived to close the upper layer mass budget in the Atlantic and to estimate the variability of the upper limb of the MOC transport. Up to date 5 transects were conducted, the latest in March/April 04 was not yet available for this study. In this poster, preliminary calculations of the mass and heat transport along AX18 are presented.

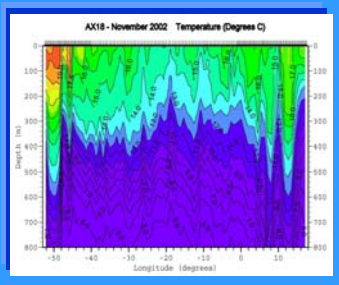
Nov. 02 | **May 03**

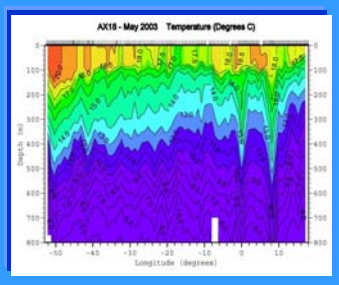












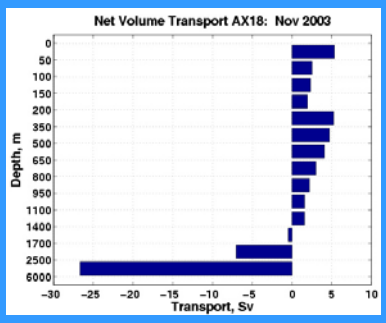
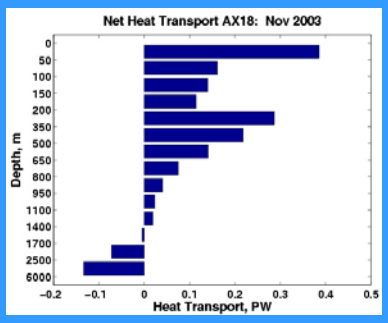
DATE	Total HT (PW)	Corrected (PW)	Total HT (PW)	Corrected (PW)
	NCEP winds	NCEP winds	H&R winds	H&R winds
Jul-98	0.98	0.80 ± 0.18	0.94	0.76±0.18
Nov-98	1.32	1.10±0.22	1.4	1.18±0.22
Apr-99	0.96	0.81±0.15	0.88	0.73±0.15
Oct-99	1.37	1.14±0.23	1.25	1.02±0.23

Total heat transport in PW (1PW = 10^{15} Watts) (to 6000 m) obtained from the XBT sections collected along AX18 during July 2002, November 2002, May 2003, and November 2003. Columns 2 and 3 indicates results from calculating Ekman fluxes from NCEP and Hellerman and Rosenstein winds respectively.

Methodology:

The extendable bathythermograph (XBT) data is collected using an automated launcher with a Sippican Mk 12 circuit board and GPS receiver that stores 6-8 XBTs that are deployed at specified time intervals. XBT data is collected every 0.1 seconds using Sippican T-7 XBTs that typically collect data to depths of about 800 meters. The temperature time series is converted into a depth profile using the fall-rate equation of Hanawa et al (1995). Salinity was estimated for each XBT by using the geographically closest 1998 Levitus World Ocean Atlas gridded profile for that month to construct a climatological temperature vs. salinity relationship. Salinity estimates were derived via linear interpolation of the Levitus T/S data using the XBT temperature. These estimated salinities preserve the water-mass characteristics and are less prone to error in regions where the temperature-salinity relationship is tight, such as the center of subtropical gyres. Geostrophic velocities are determined using the dynamic method where a level of no motion was chosen at a depth just below the northward flowing Antarctic Intermediate Water at σ_4=32.15 kg m^{-3}. Ekman transports were determined using NCEP daily reanalysis winds by interpolating the daily NCEP values to the time and location of the XBT observation. Transports were computed in layers and summed for the entire water column. The level of no motion velocity was adjusted so that the net mass transport across the section was zero using a single velocity correction for each section. Typically, values of this velocity ranged from 10^{-4} to 10^{-6} m s^{-1}. Additional corrections to the net transports were made to account for XBT sections that terminated before fully sampling the Brazil Current or the Malvinas Current. Heat tranport estimates were adjusted according to the mean transports of the current and associated temperature structure.

Results

The values of total heat transport obtained from the data collected during the four realizations of AX18 are on line with previous estimates. Interesting to note is that the 2 values obtained during the November 2003 and 2004 cruises (Southern Hemisphere spring) are very similar and higher than those obtained during July 2002 and May 2003 Southern Hemisphere Summer and fall respectively). This may be an indication of an annual cycle as predicted by the models.

These results should be considered as preliminary. Future work will include: Use of a better climatology for the lower layers of the section based in available CTD data; Improvement of the T/S relation in the region by using all available ARGO CTD data; Use of different wind products. By continuing occupation of AX18 four times per year, it is expected that the values obtained for the total heat transport will achieve statistical significance and that the existence of an annual cycle may be resolved.