Boundary Current measurements at 34.5°S in the South Atlantic: Preliminary results of MOC-related variability

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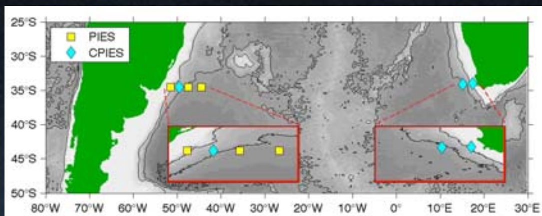
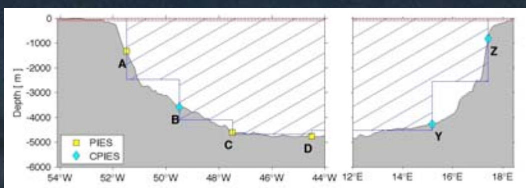
Study description

Recognition that the South Atlantic Ocean plays a major role in the Atlantic Meridional Overturning Circulation (AMOC) has led to discussions on a South Atlantic trans-basin observing system near 30-35°S. This is supported by both the U.S. AMOC panel and the international community through the SAMOC workshops.

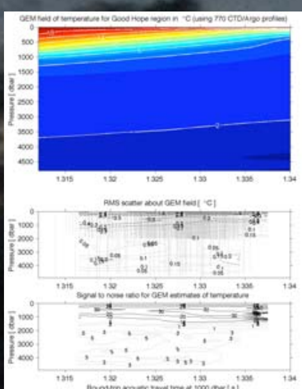




The complete array was in place during Mar. 20, 2009 through Dec. 2, 2010.

As a first step, two small pilot arrays of PIES & CPIES have been deployed near 34.5°S. The western array involves the U.S. NOAA, the Argentine and Brazilian naval hydrographic services, and the Universities of Buenos Aires and Sao Paulo. The eastern array is a collaboration between the Universities of Brest and Cape Town.

Data and Methods



The in situ measurement array is based on inverted echo sounders which are additionally equipped with pressure gauges (PIES) and in some cases with single depth current meters (CPIES).

The inverted echo sounder makes measurements of the round trip acoustic travel time for a 12 kHz pulse to travel up from the bottom-moored instrument to the surface and back.

When combined with hydrographic observations from the region (CTD and/or Argo, which do not necessarily need to be collected contemporaneously with the travel time measurements) via the Gravest Empirical Mode (GEM) method, the inverted echo sounder provides daily time series estimates of the full water column profile of temperature, salinity and density. See the example GEM field for temperature at left.

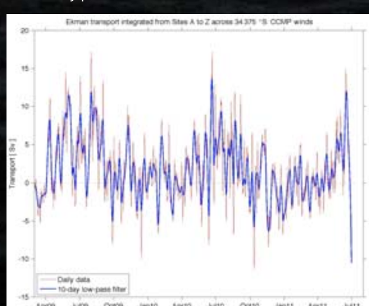
Density profiles can be vertically integrated to provide profiles of geopotential height anomaly, and these profiles can be differenced between PIES/CPIES sites to yield time series estimates of the geostrophic velocity relative to an assumed level of no motion.

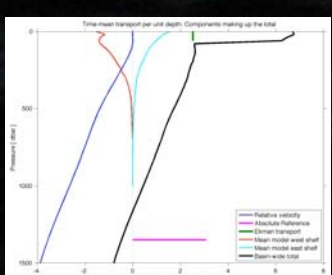
The bottom pressure measurements of the PIES/CPIES can be differenced between sites to yield time series of absolute velocity (excepting the time-mean), which can be used to reference the relative velocity profiles.

The PIES/CPIES therefore provide time series of absolute velocity profiles (a time mean reference velocity is estimated and added from the output of the OFES numerical model).

Transport across the basin can then be determined from the integrated absolute velocity.

The largest ageostrophic component of the meridional transport is the Ekman flow. The Ekman flow is estimated using the Cross-Calibrated Multi-Platform (CCMP) Ocean Surface Wind (Atlas et al., 2011). The 6-hour data were averaged to once per day, and the wind velocities were converted into stress using a constant drag coefficient and air density from Weisberg and Wang (1997).



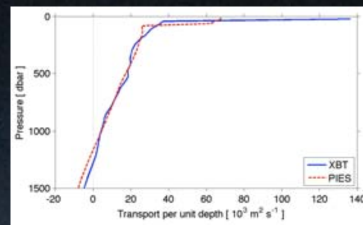


The total basin-wide integrated transport per unit depth was then calculated as the sum of the followiing:

- Geostrophic relative velocity from the IES-GEM between Sites A and Z
- Geostrophic reference velocity variability from the pressure measurements from the PIES/CPIES between Sites A and Z
- Time-mean reference velocity from OFES between Sites A and Z
- Ekman transports estimated using CCMP winds between Sites A and Z
- Time-mean continental shelf velocity from OFES

Note that funded augmentations of the basin-wide array will soon eliminate the need to use the time-mean shelf transports from a model.

Results

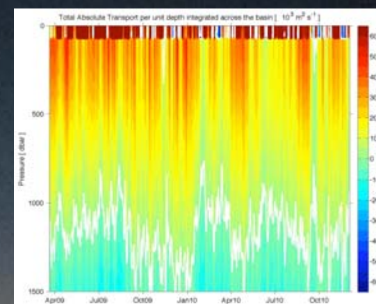


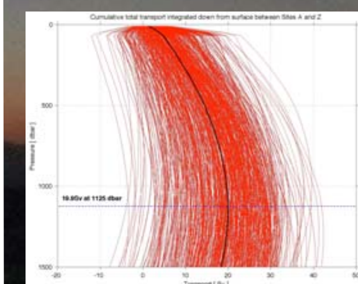
The time-mean basin-wide integrated transport per unit depth agrees well with previous results at this latitude using expendable bathythermograph (XBT) sections (e.g. Dong et al., 2009; Garzoli et al., 2012).

The main difference is the depth range through which the Ekman transport is assumed to apply (60 dbar vs. 20 dbar). This difference has no impact on the vertically-integrated MOC volume transport that is the focus herein (since the northward flowing upper layer spans and is therefore integrated over the upper 1000-1500 dbar), but it is important for the heat transports that will be calculated at a later date.

The above comparison with the mean from the XBT sections is encouraging, and a preliminary comparison with a trans-basin estimate from Argo at the same latitude (not shown), is also fairly consistent. It should be noted, however, that this mainly just indicates that all three methods are getting a consistent mean density structure on the eastern and western boundaries.

The basin-wide transport per unit depth (at right) is quite variable, possibly because the time-varying flows on the shelves are not included in this very preliminary calculation. The depth of the zero-crossing, where the upper and lower limbs of the AMOC change, is also highly variable within a realistic depth range defined by the local water masses, with the transition moving as deep as ~1500 dbar and as shallow as ~800 dbar (white line in figure at right).





The cumulative transport integrating down from the surface reaches a time-mean value of about 20 Sv at roughly 1125 dbar.

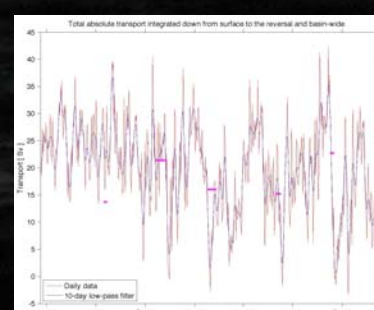
This transport value is ~10% higher than previous XBT estimates at this location (e.g. Dong et al., 2009; Garzoli et al., 2012), and the transition from northward to southward flow is ~10% shallower in our results than was found in the XBT analyses.

Because the time-mean absolute velocity and shelf flows used herein are model-based (from OFES), the time mean is the least robust part of the AMOC calculation presented. Focus is better spent on the time variability of the AMOC.

The only time varying estimates of the AMOC which are available in this region are from the repeat XBT sections that are collected between Cape Town, South Africa and either Buenos Aires, Argentina (June 2010) or Santos, Brazil (July 2009; October 2009; January 2010; & September 2010).

Because the XBT transects can take up to a month to complete, one must think of them as a 'mean' of sorts over the synoptic variability during the cruise.

Overall considering the preliminary nature of the calculations presented herein, the agreement between XBT and PIES/CPIES results is quite good (compare red line and magenta bars in the figure at right).



Conclusions

- The general agreement between the AMOC overturning estimates from the pilot PIES/CPIES arrays and the concurrent XBT sections suggest that, while still fairly crude, the arrays are able to capture the observed variability. The time-mean is highly dependent on the OFES model values used, and so is a less robust result from this study – the focus should be on the observed time variability.
- Planned upgrades to the pilot arrays, including the addition of newly funded instruments on both the western and eastern shelves by Brazil and South Africa as well as increased horizontal resolution of the moorings on the continental slopes on both sides (by Brazil and France), will improve the quality of the AMOC estimates.
- The observed variability when both pilot arrays were deployed (623 days of overlap) suggests high variability on short (<30 day) time scales, similar to what has been observed in the North Atlantic at 26.5°N.
- Further work on the pilot array data is planned to more fully integrate the deeper sites into the AMOC calculations.

Acknowledgements

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