Atlantic Meridional Overturning Circulation: Deep Western Boundary Current transport variability in the South Atlantic – Preliminary results from a pilot array at 34.5°S

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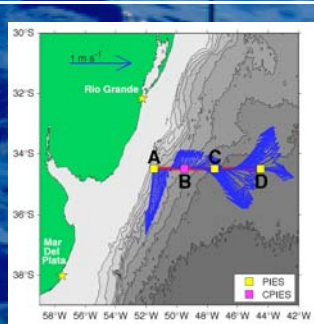
Study description

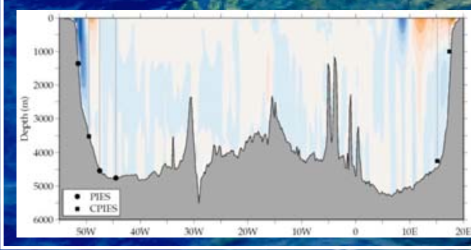
Recognition that the South Atlantic Ocean plays a key role in the Atlantic Meridional Overturning Circulation (AMOC) has led to discussions on the development of a South Atlantic trans-basin observing system similar to the one at 26.5°N. This endeavor has support coming from both within the U.S. AMOC panel and from the broader international science community through a series of workshops entitled SAMOC.

One of the first steps towards the ambitious goal of a trans-basin array in the South Atlantic has been the deployment of a small pilot array of pressure-equipped inverted echo sounders (PIES) at 34.5°S near the western boundary (see figure at right).

The pilot array is a collaboration between the U.S. NOAA and the Argentine and Brazilian naval hydrographic services. A parallel program at the eastern boundary is a collaboration between France and South Africa (see vertical section plot below).



Map illustrating the locations of the four PIES deployed in the pilot array in March 2009. One of the instruments also had a single-depth current meter (CPIES); this instrument was replaced with a PIES in July 2011. Blue vectors are velocity at 20 m measured by SADCP during the deployment cruise.

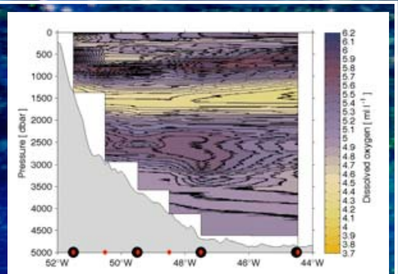


Vertical section of the time-mean meridional velocity along 34.5°S from a 27-year run of the Ocean general circulation model For the Earth Simulator (OFES). Locations of the pilot array sites are noted along with the sites of the initial two French - South Africa instruments.

Water properties

The South Atlantic has not been observed as frequently or at as high a resolution as many parts of the North Atlantic, so the initial efforts at studying the South Atlantic will inevitably involve a great deal more exploratory study than was required in designing the trans-basin AMOC array at 26.5°N.

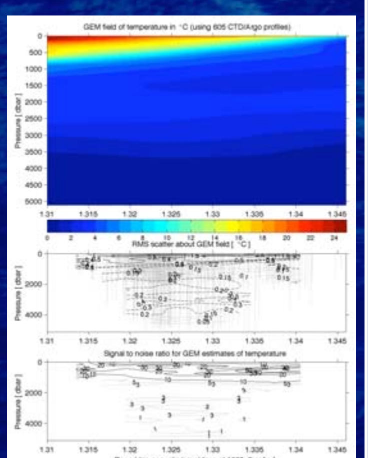
The pilot array at 34.5°S was designed to try to capture the Deep Western Boundary Current (DWBC) and some fraction of an offshore recirculation if it exists. The first few hydrographic sections collected on the research cruises that support the array suggest that the DWBC is well situated within the array.



Dissolved oxygen section collected in July 2010. Red diamonds along bottom axis indicate locations of the CTD profiles, and black dots indicate the PIES/CPIES sites. The relatively high oxygen level expected in the DWBC is clearly seen below 2000 dbar near 48°W.

Interpretation of the PIES data

The PIES data is interpreted by combining it with hydrographic data via the Gravest Empirical Mode (GEM) technique. Essentially, 2-D lookup tables of temperature (example at right), salinity and density are created using hydrography (CTD and/or Argo). These lookup tables are then combined with the travel time record from each PIES to produce estimated time series of the full water column profiles of temperature, salinity and density. The GEM technique also provides error estimates (lower panels at right).



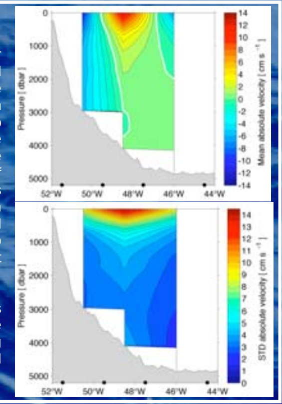
The density profiles estimated at the PIES sites can be vertically integrated to give dynamic height anomaly profiles, and the latter can be differenced between neighboring PIES to yield full water column profiles of geostrophic relative velocity at each time step.

Differencing the bottom pressure data between neighboring PIES yields absolute geostrophic velocity references for the relative velocity profiles. The net product is time series of full water column profiles of absolute geostrophic velocity. Note that OFES model mean bottom velocities are used along with the time-varying PIES-derived absolute bottom velocities due to the well known pressure leveling problem.

Absolute velocities

The time-mean velocity structure during the first year of the array indicates a bottom-intensified southward DWBC flow primarily between sites A and C (figure at right). Keep in mind that the OFES time-mean velocities imposed are only at the very bottom, so the vertical structure is fully based on data. The southward flowing Brazil Current is observed above the DWBC. The blend of north-south meanders of the merged Brazil-Malvinas after the confluence is seen as alternating north and south velocity cores in the upper water column to the east of the southward currents along the slope. (These currents are also seen in the SADCP velocity from the deployment cruise at left.)

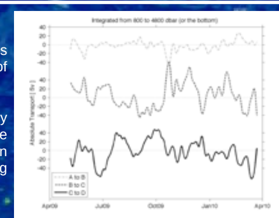
The strongest variability in the meridional velocity is observed between the B and C sites near the surface, illustrating the variability of the meandering of these energetic flows after they have encountered each other in the Confluence just south of the array.

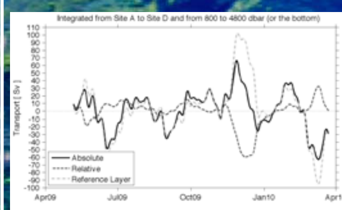


Absolute transports

Vertically integrating the absolute velocities between 800 to 4800 dbar and between pairs of PIES yields absolute geostrophic transports.

In the span between A and B the transport is fairly weak, while the first year of data shows that the transport variations in the other two spans between PIES is quite high, with 40+ Sv changes happening within a few weeks or so.





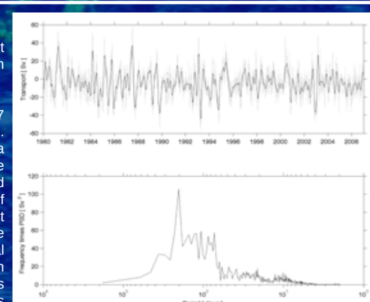
Summing the deep flow across the array shows that the 'DWBC' in this region can vary across a range of 100+ Sv, including significant time periods when the flow is northward.

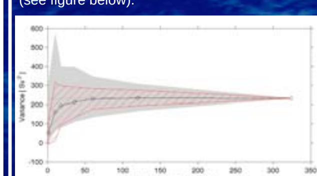
Breaking the flow into transports relative to an assumed level of no motion (i.e. baroclinic) and the reference layer transports (i.e. barotropic) demonstrates occasional compensation, but no correlation.

Model comparison

Because the data record is so short at present, value is found in comparison to high quality models.

The OFES run used here is 27 years in length (see figure at right). The model shows variability at a wide range of periods (see spectrum at right), and it should therefore help in a variety of observing system tests. The first test done was a Monte Carlo-type of test of total variance. The total variance of the 27-year model run was compared to multiple samples of the record with different lengths (see figure below).





Gray band is the maximum and minimum range observed for all random subsamples, while the red cross-hatched area indicates the median values plus and minus one standard deviation.

Based on the model's distribution of variance, it would take roughly four years of data to match the full variance.

Conclusions

- The DWBC appears to be well captured within the initial pilot array based on the hydrographic sections collected to date.
- The time variability of the DWBC is roughly similar in amplitude to that seen in the North Atlantic despite representing only part of the AMOC lower limb at this latitude (the other portion having separated and transited to the eastern boundary near 5-10°S).
- As has been observed elsewhere, the baroclinic and barotropic components of the DWBC transport are uncorrelated.
- Comparison with model suggests 1-year of variance undersamples the true variance greatly, and at least 4 years of data will be needed to capture a realistic variance range.

Acknowledgements

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