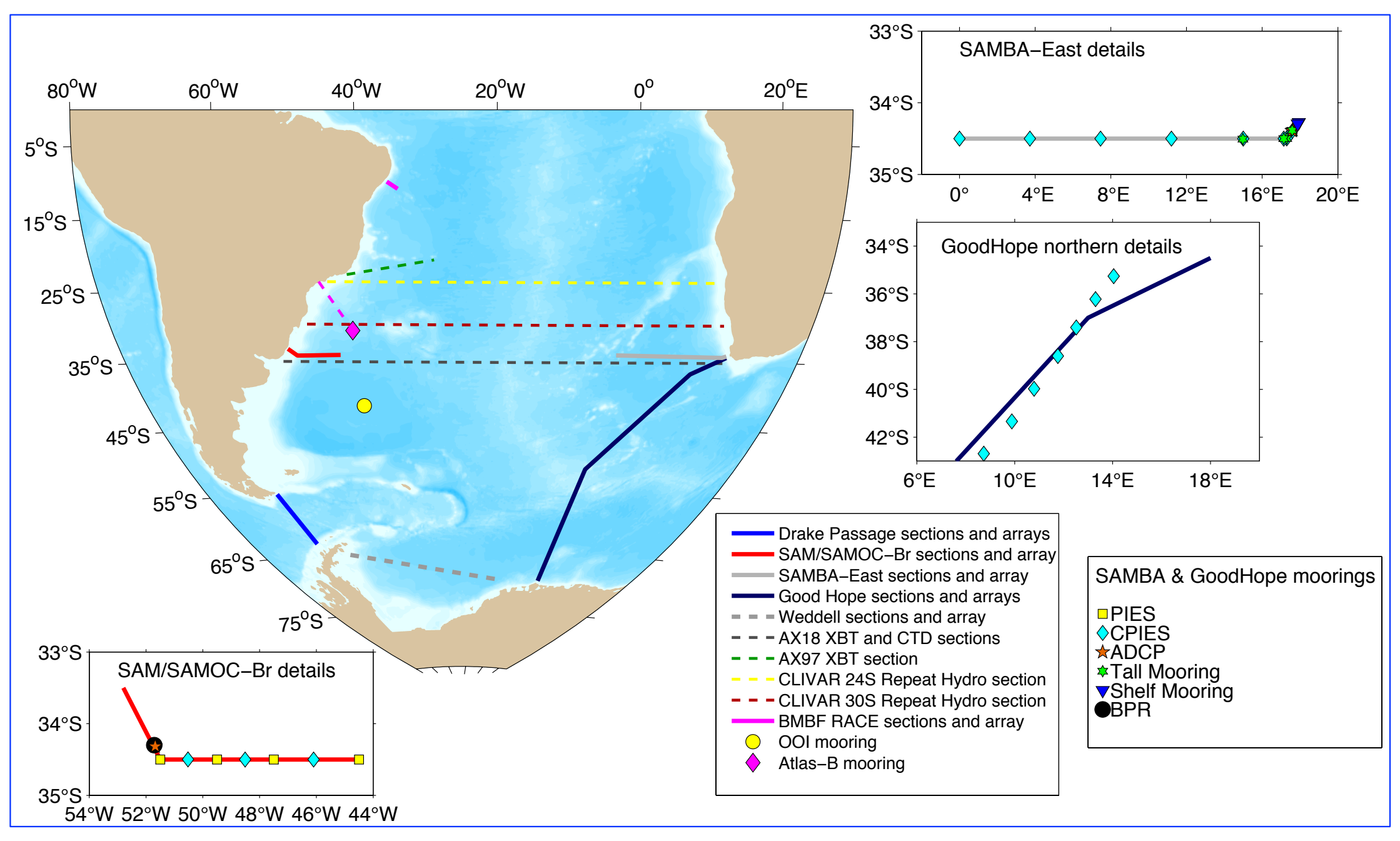
Monitoring the MOC in the South Atlantic: A SAMOC Initiative update

Silvia L. Garzoli[1,2], Alberto R. Piola[3], Sabrina Speich[4], Edmo Campos[5], Mike Roberts[6], Renellys Perez[1,2], Thierry Terre[7], and Christopher S. Meinen[2]
[1]Univ. of Miami/Cooperative Institute for Marine and Atmospheric Studies, Miami, Florida
[2]NOAA/Atlantic Oceanographic and Meteorological Laboratory, Miami, Florida
[3]Departamento de Oceanografía, Servicio de Hidrografía Naval, and Departamento de Ciencias de la Atmósfera y los Océanos, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Buenos Aires, Argentina
[4]Laboratoire de Météorologie Dynamique, École Normale Supérieure, Paris, France
[5]Oceanographic Institute, University of São Paulo, São Paulo, Brazil
[6]Oceans and Coasts Research, Department of Environmental Affairs, Roggebaai, South Africa
[7]Laboratoire de Physique des Océans, Ifremer, Plouzané, France

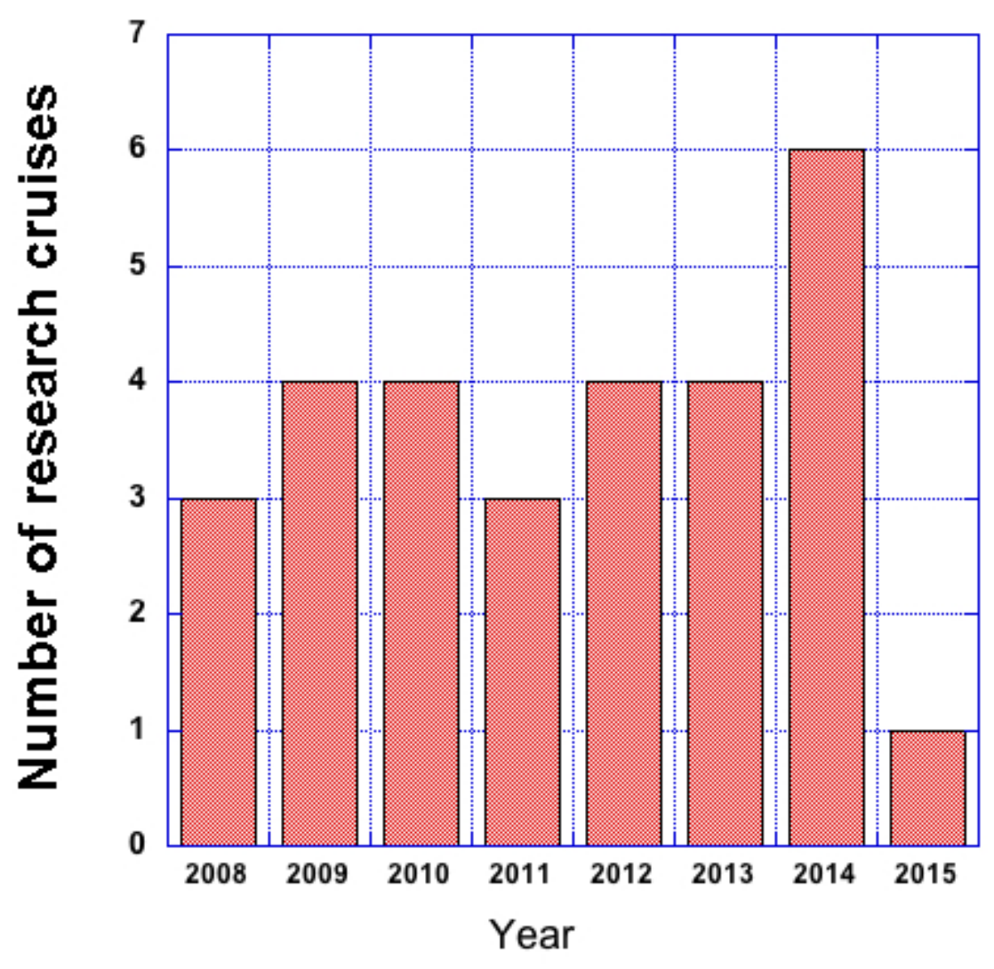
The main objectives of the South Atlantic Meridional Overturning Circulation (SAMOC) initiative is to observe and understand the mechanisms that control the mean and time-varying MOC in the South Atlantic and the interocean exchanges.

Variations in the Atlantic Meridional Overturning Circulation (AMOC) are known to have global implications to the climate system, however until recently most AMOC observing programs have been focused in the North Atlantic. Recent model and data analyses have suggested that critical water mass changes to the upper and lower limbs of the MOC occur in the South Atlantic, and only limited latitudinal coherence has been found to date between the MOC observations made by the North Atlantic observing systems at different latitudes. As a result, a priority for the USAMOC Science Team has been the establishment of a MOC observing system in the South Atlantic, and recently the International CLIVAR panel endorsed a South Atlantic MOC (SAMOC) Initiative to both strengthen existing programs seeking to study the AMOC in the South Atlantic and to encourage further expansion of the AMOC observing system in the region. SAMOC is an international cooperation between Argentina, Brazil, France, South Africa and the USA with collaborators from Germany, Russia, Spain, and the UK. This poster summarizes the present status of the international SAMOC observing system and provide examples of recent observational and modeling results developed through coordination by the international SAMOC Initiative.

The present SAMOC array: Observations to measure meridional fluxes and interocean exchanges



Since 2008, 29 South Atlantic SAMOC related cruises



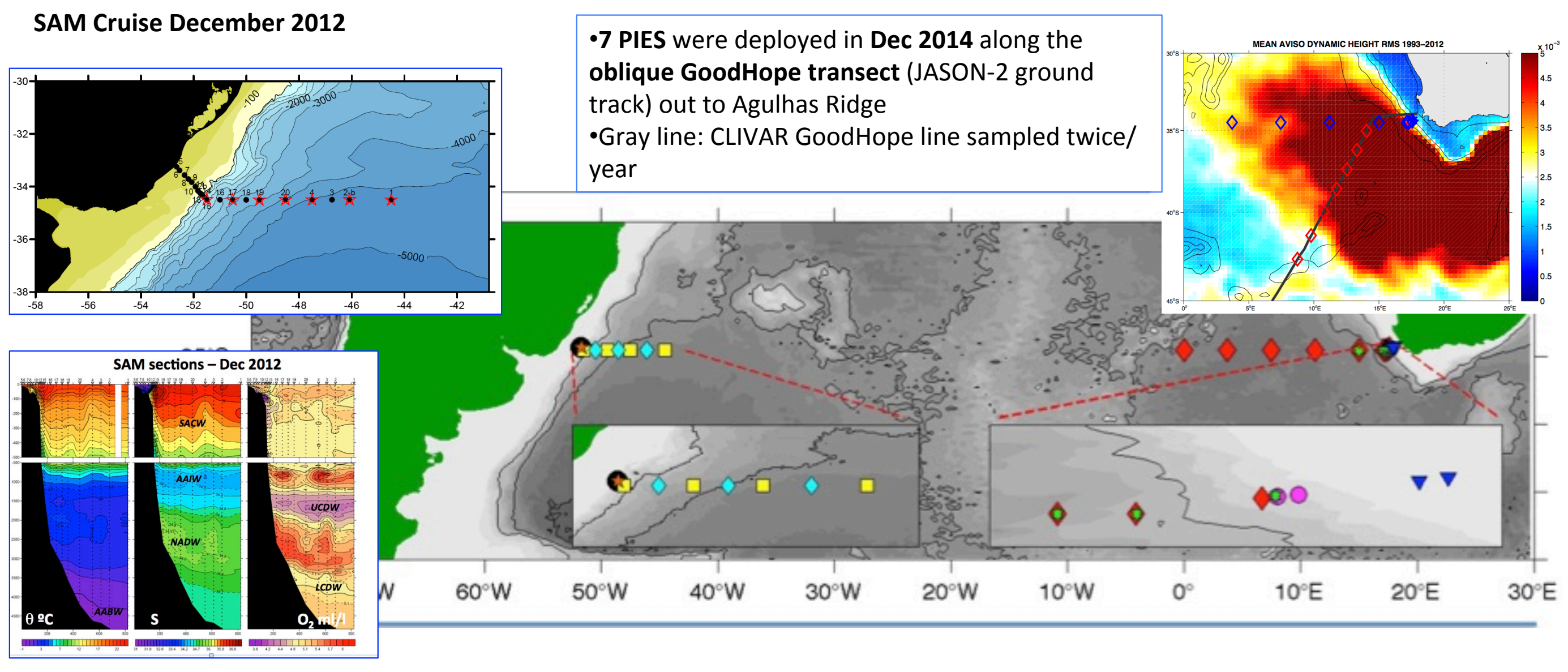
In addition to the 29 research cruises data was collected from:

- **159 High Density XBT transects 2007-2015:** AX18: 24; AX22: 43; AX25: 23; AX97: 47
- Argo floats
- Altimeter

Participating institutions

Argentina:	Servicio de Hidrografia Naval Universidad de Buenos Aires INIDEP
Brazil:	University of Sao Paolo INPE FURG
France:	LPO IFREMER/UBO/CNRS/IRD LMD/IPSL/ENS/CNRS
South Africa:	DEA UCT CSIR
UK:	NOC
United States:	NOAA/AOML/PHOD University of California San Diego, SIO University of Rhode Island, GSO

SAM Cruise December 2012

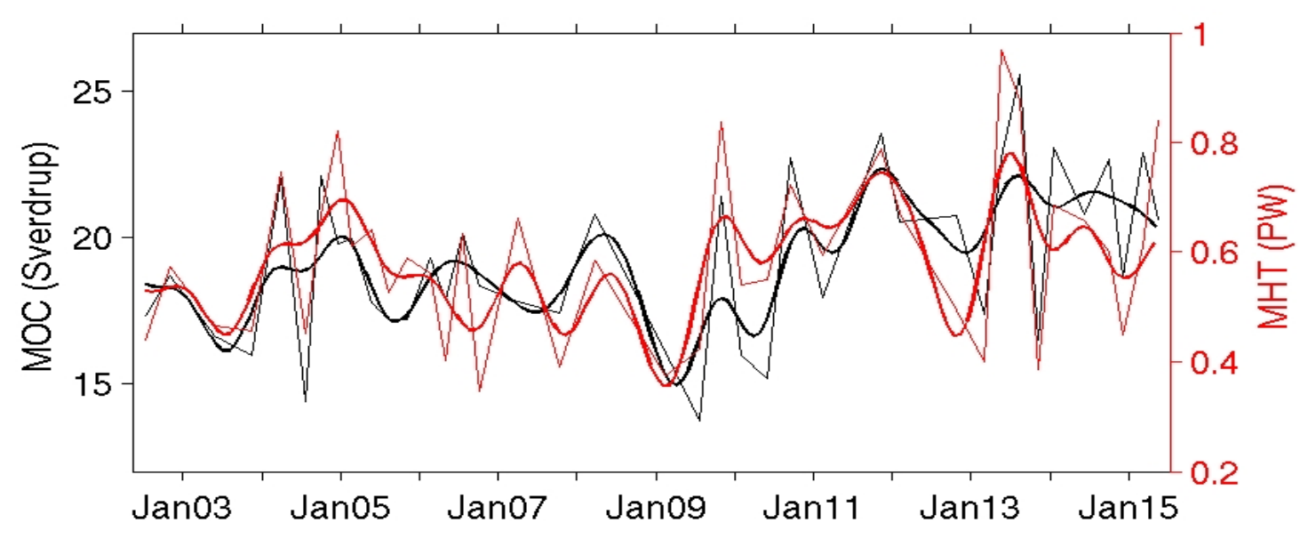


- **7 PIES** were deployed in **Dec 2014** along the **oblique GoodHope transect** (JASON-2 ground track) out to Agulhas Ridge
- Gray line: CLIVAR GoodHope line sampled twice/ year

Temperature, Salinity and Oxygen has been collected during 10 SAM cruises on board of Argentinean and Brazilian research vessels. (From Piola, in preparation).

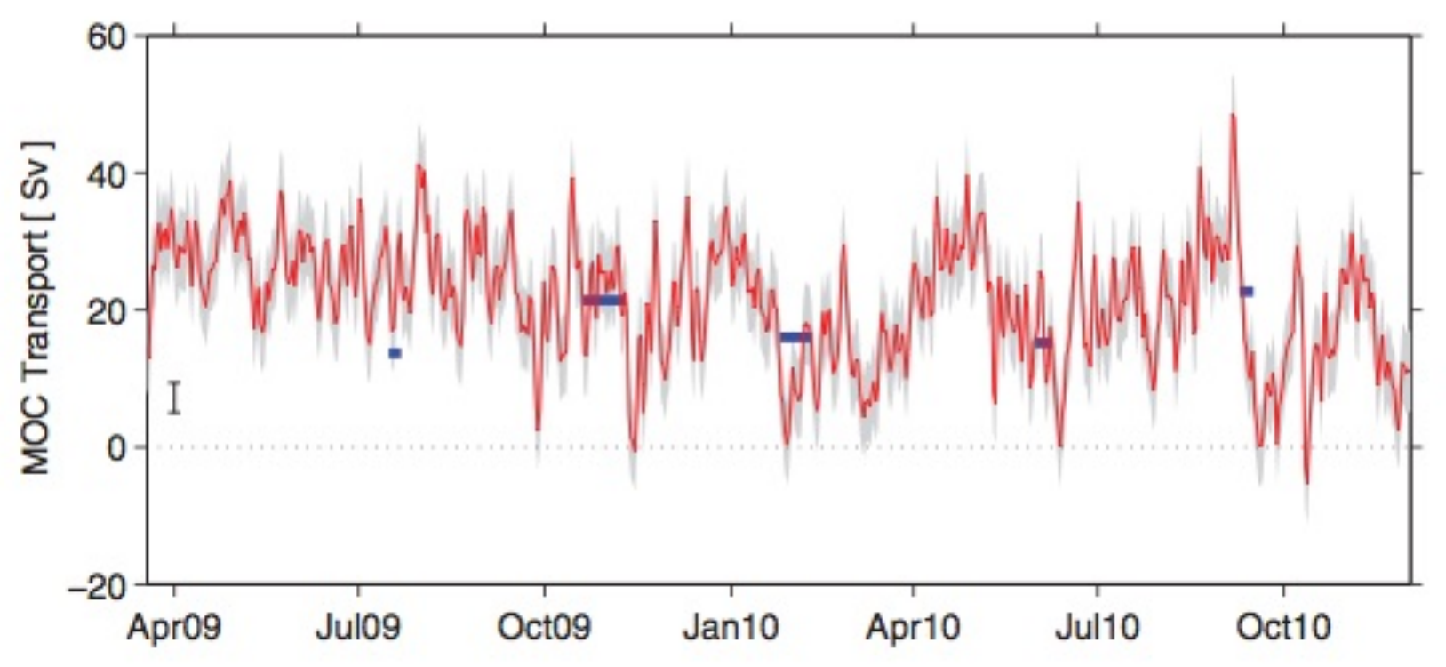
Meridional heat transport and AMOC estimates

From hydrographic data



Data collected from a high density XBT transect nominally at 35°S is used to estimate the meridional heat transport and the AMOC across that latitude. There is a good correlation between AMOC strength and the MHT. A one Sverdrup increase in the AMOC would lead to a 0.04 PW increase in the northward MHT. Estimates of the salt advection feedback (Mov) were made from three different kinds of observations. Contrary to estimates obtained from models, the data reveal a positive salt advection feedback (Mov<0) suggesting that freshwater perturbations will be amplified and that the MOC is bistable. (Garzoli et al, 2013, Dong et al., 2014)

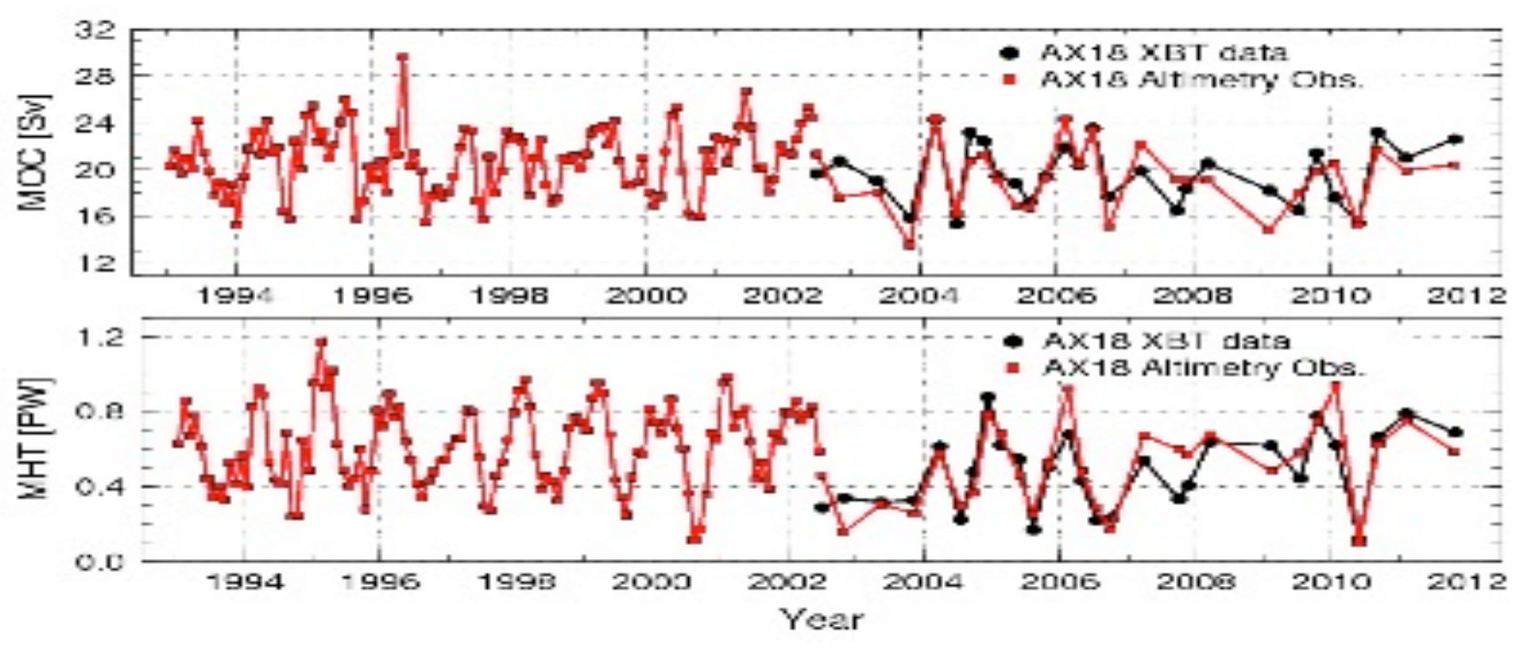
From inverted echo sounders



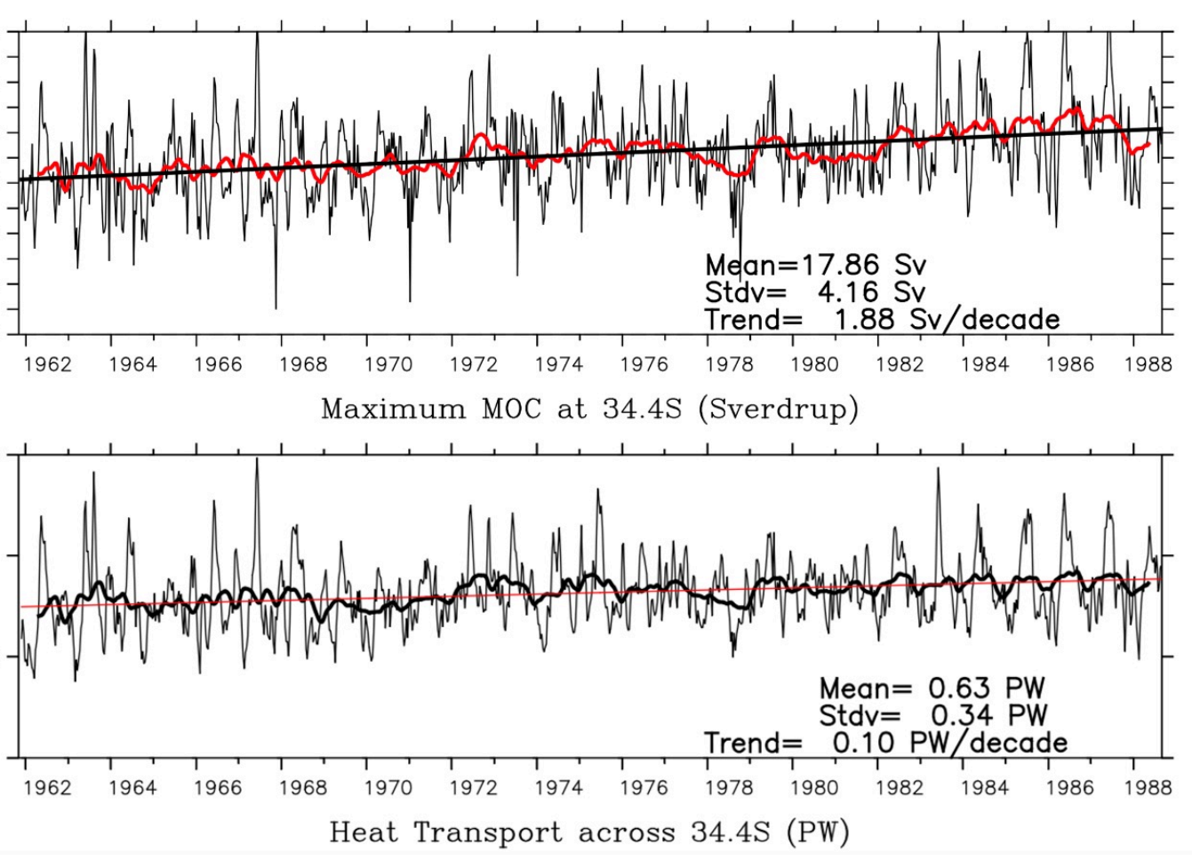
Transport time series of the MOC at 34.5°S (red line) with estimated daily error bars (gray shading). Black vertical error bar at left illustrates the estimated bias accuracy. Also shown are five MOC estimates determined from trans-basin XBT sections where the horizontal length of the bar illustrates the start and end times of each trans-basin cruise. (From Meinen et al., 2013)

Altimetry-derived

Satellite altimetry, together with XBT and Argo observations, are used to investigate the spatial and temporal variability of the Meridional Overturning Circulation (MOC) and Meridional Heat Transport (MHT) in the South Atlantic. Altimetry-derived synthetic temperature and salinity profiles between 20°S and 34.5°S are used to estimate the MHT, which compares well with estimates obtained from XBT measurements. (From Dong et al., 2015)



Modeling results



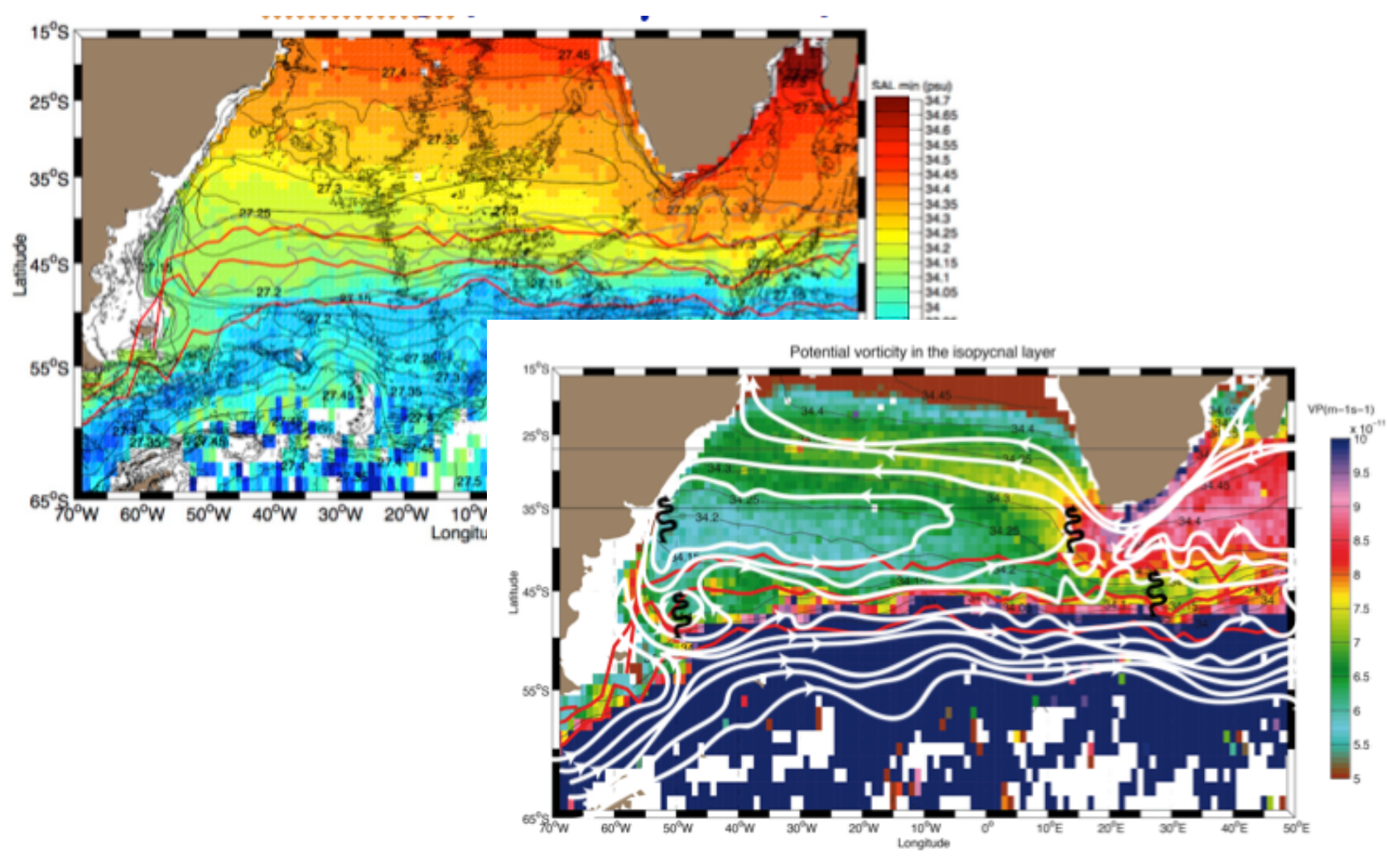
Time series of AMOC (top) and MHT (bottom) from a Global HYCOM experiment. The global resolution is 1/12 degree; the model has 32 $sigma_2$ layers and it is forced with NCEP-1 monthly mean winds from 1949 to present. (From Campos et al., 2015., in preparation)

Summary of results

	MOC (Sv)	MHT (PW)
XBT AX18 (July 2002- May 2015)	19.2 ± 2.8	0.58 ± 0.13
CPIES	16.3 ± 5.5	n/a
Altimetry (1993 to 2011)	20.2 ± 3.2	0.51 ± 0.22
HYCOM model	17.9 ± 4.2	0.63 ± 0.34

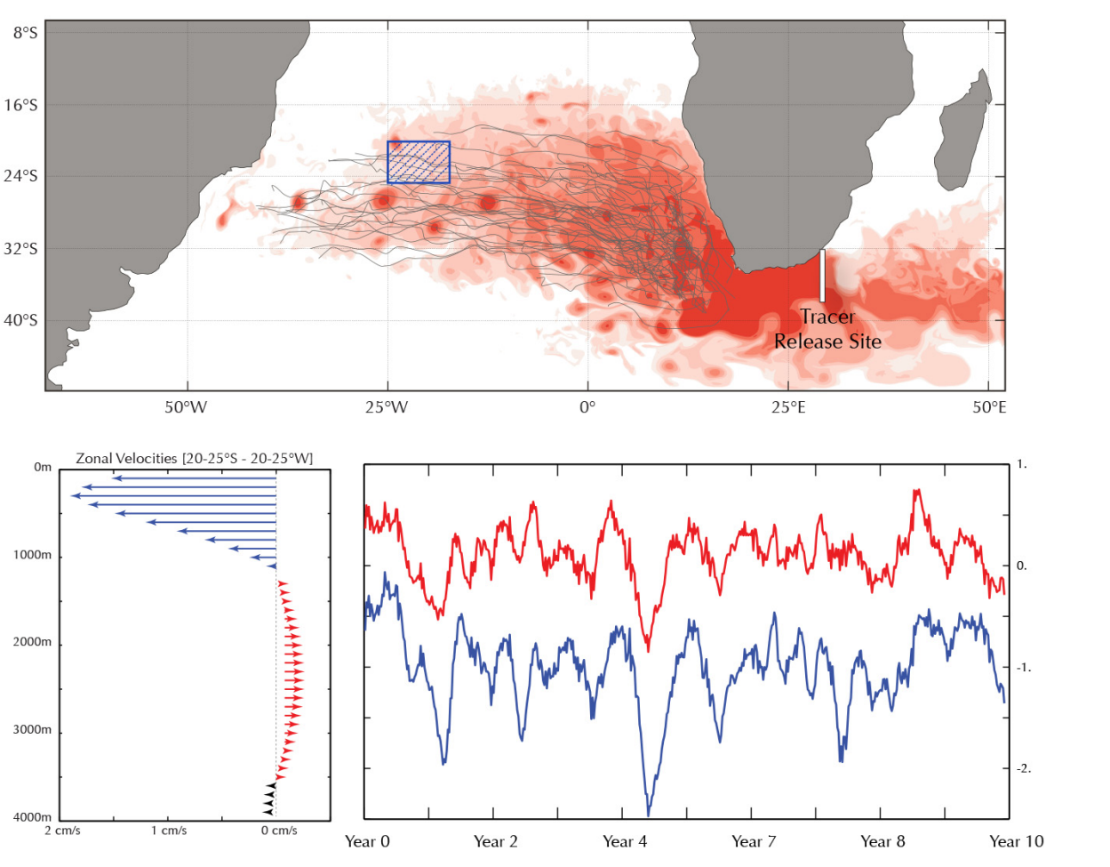
Pathways of the AMOC limbs in the South Atlantic

From Argo floats



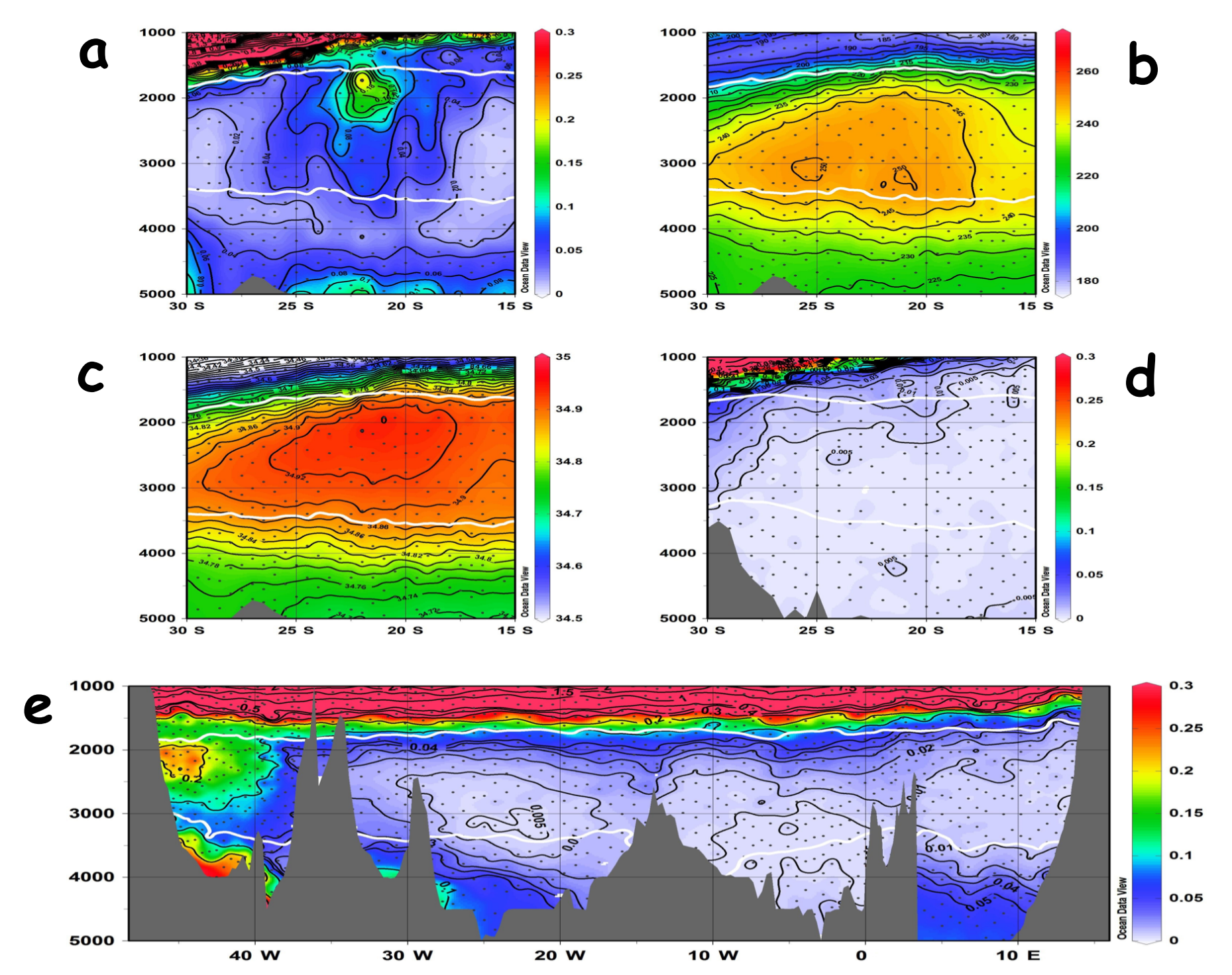
Data from the Argo profiling floats is analyzed to show evidence of the Antarctic Intermediate Water (AAIW) pathways and its transport in the South Atlantic. The top panel shows the AAIW salinity (27.1 < γ < 27.6) and the lower panel the AAIW potential vorticity. (From Rusciano et al. 2012; Rusciano and Speich, in preparation)

From a 20-year ROMS simulation



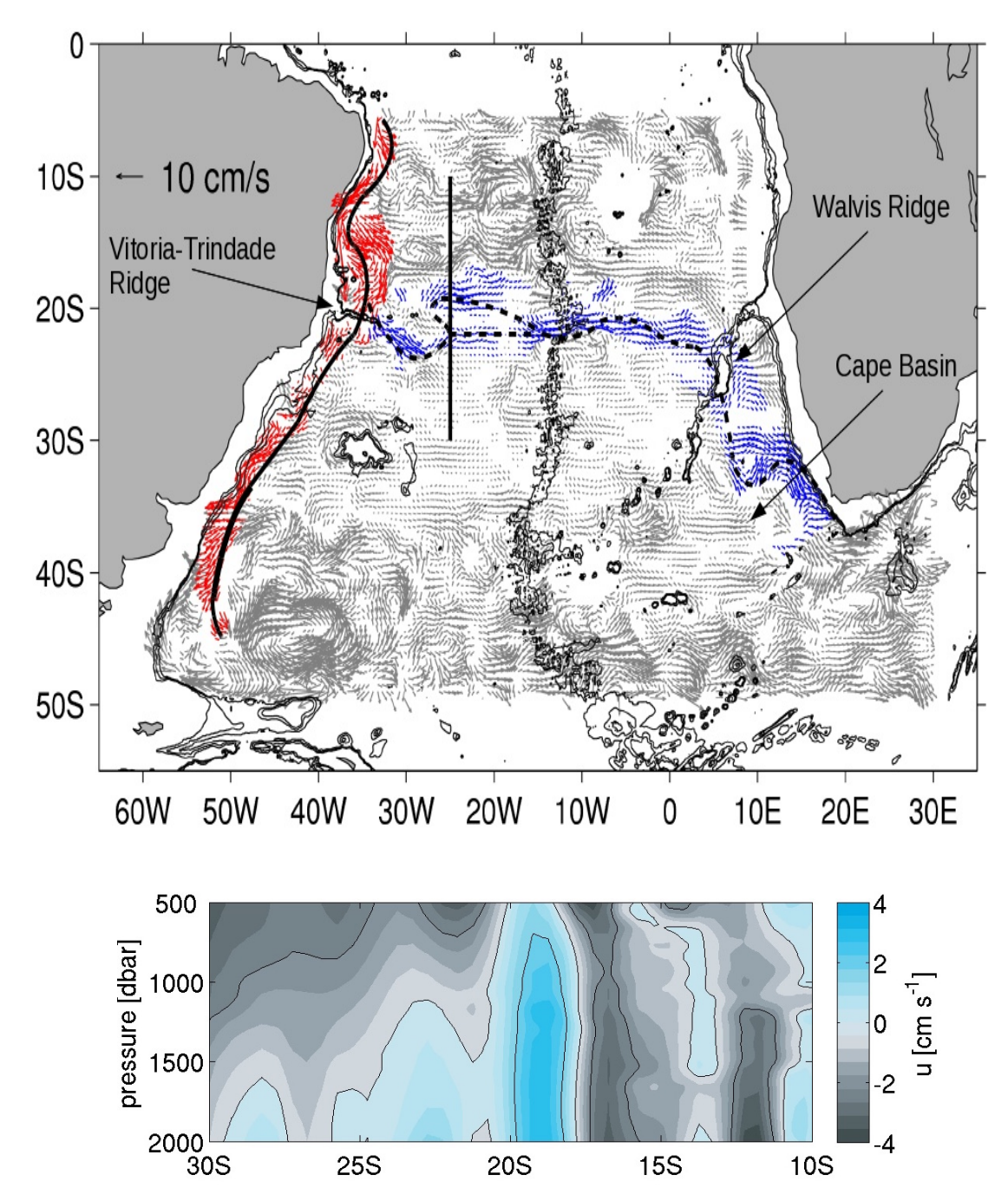
Top panel: Surface distribution of passive tracer released at the surface in a 20-year eddy-resolving (1/12˚), Regional Ocean Model Simulation (ROMS) regional simulation of the tropical and subtropical South Atlantic in the location marked by the white line. The gray line corresponds to the tracks of the Agulhas eddies from altimeter data. The blue box marks the location where average zonal velocities are estimated. Bottom left : Vertical distribution of the average zonal velocities in the blue box. Bottom right: Time series of the zonal velocities averaged over the top 1000 m (red) and between 1000-3000 m (blue). (From Matano et al., in preparation)

From Clivar-era CFC' data

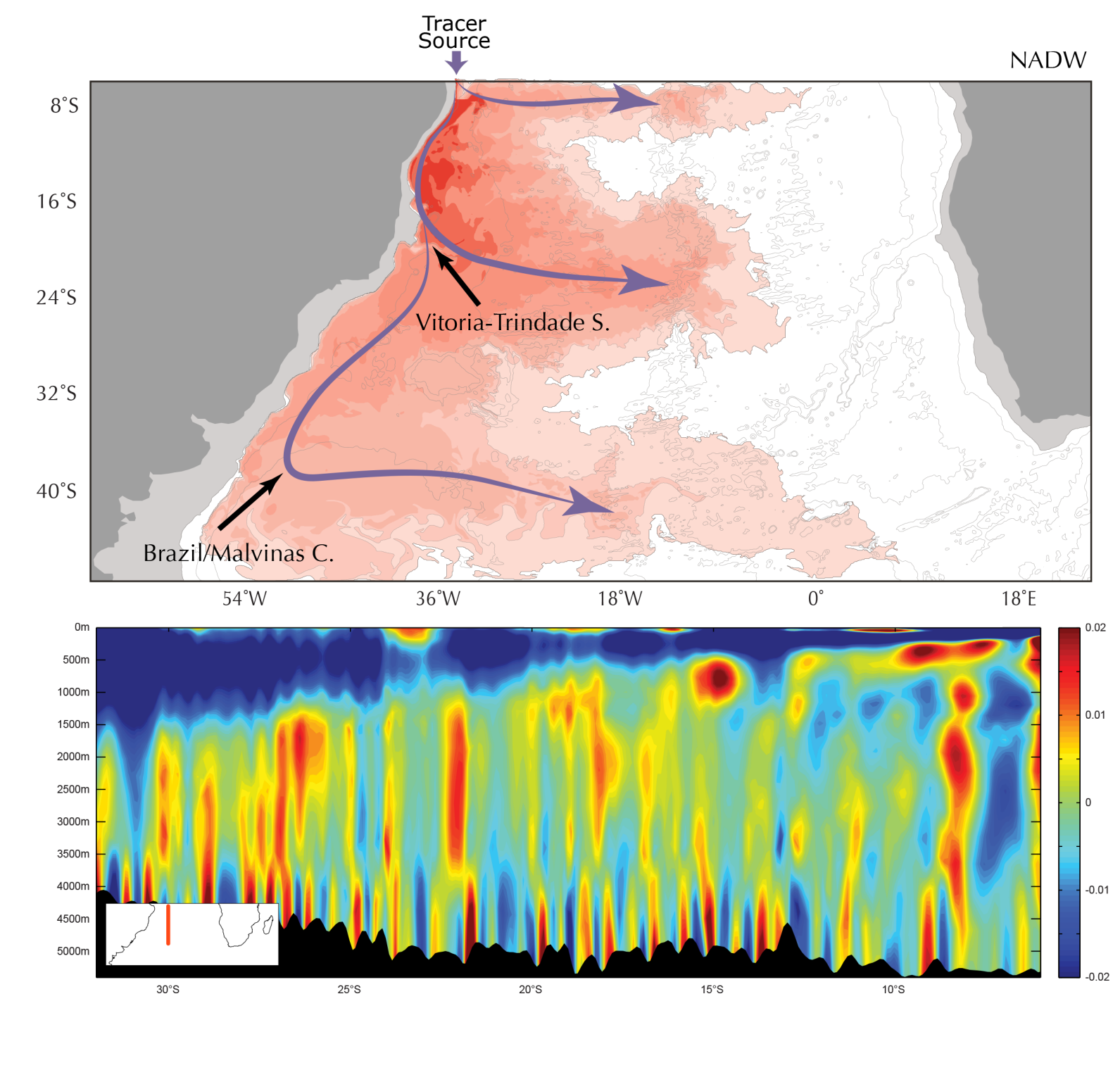


Partial CLIVAR sections illustrating the spread of North Atlantic Deep Water (NADW) eastward into the central South Atlantic Ocean. Vertical axis is depth in meters. Panel a) partial A16S section of CFC-11 from 15°-30°S along about 25°W from 1000-5000 m. The lowest contour for CFC-11 concentration is 0.01 pmol kg^{-1}. Color scale given on the right; two neutral density surfaces are 27.9 and 28.1 kg m^{-3} are identified as white lines. Panel b) Same as panel a) except for oxygen concentration in μmol kg^{-1} . Panel c) Same as panel a) except for salinity. Panel d) partial A13 section of CFC-11 from 15°-30°S along about 5°-10°E from 1000-5000 m. The lowest contour for CFC-11 concentration is 0.005 pmol/kg. Panel e) full cross-basin section of CFC-11 along A10, 30°S from 1000-5000 m. Note for a, d, and e that 0.3 pmol kg^{-1} is the highest concentration CFC-11 contoured and higher concentrations will appear in the same shades as for 0.3 pmol kg^{-1}. (From Garzoli et al., 2015)

From observations and a global ocean-only numerical model (OFES)



Top panel: Velocity field at 2000 dbar derived from the Argo data. Red vectors highlight the southward to southwestward flow along the western boundary; blue indicates the eastward velocity originating near the Vitória-Trindade ridge. Isobaths: 2000, 2500 and 3000 m. Solid curves highlight the pathway of the Deep Western Boundary Current (DWBC) along the South American coast. Dashed lines indicate regions where the eastward pathway is less well defined as it moves to the interior of the basin. The meridional line indicates the location of the vertical section displayed in the lower panel. Areas with no vectors or shading indicate that velocities are too small to be significant with respect to a 95% confidence interval. Lower panel: Meridional-vertical structure of the eastward pathway in the top panel showing the zonal velocity in cm sec^{-1} along 25°W from 10° to 30°S. (From Garzoli et al., 2015)



From a 20-year ROMS simulation

Top: Snapshot of the average tracer distribution at NADW depths after 20-years of the ROMS simulation.

Bottom: Meridional-vertical structure of mean ROMS zonal velocity (m/sec) along 25°W demonstrating multiple eastward jet structure.

(From Matano et al., in preparation)

References

Dong, S. , M. O. Baringer , G. J. Goni , C. S. Meinen , and S. L. Garzoli, 2014: Seasonal variations in the South Atlantic Meridional Overturning Circulation from observations and numerical models , Geophys. Res. Lett., 41 , 4611 - 4618 , doi: 10.1002/2014GL060428

Dong, S., G. Goni, and F. Bringas, 2015: Temporal variability of the South Atlantic Meridional Overturning Circulation between 20S and 35S. GRL, in revision.

Garzoli, S.L., S. Dong, R. Fine, C. Meinen, R.C. Perez, C. Schmid, E. van Sebille, and Q. Yao, 2015: The fate of the Deep Western Boundary Current in the South Atlantic. Deep-Sea Research, Part I, in press.

Meinen, C, S ., S. Speich, R. C. Perez , S. Dong , A. R. Piola, S. L. Garzoli, S.,M.O. Baringer, S. Dong, R. Perez, and Q. Yao, 2013: South Atlantic meridional fluxes. Deep-Sea Res., Part I, 71:21-32, doi:10.1016/j.dsr.2012.09.003.

Garzoli , M. O. Baringer , S. Gladyshev, and E. J. D. Campos, 2013: Temporal variability of the Meridional Overturning Circulation at 34.5°S: Results from two pilot boundary arrays in the South Atlantic, submitted to J. Geophys. Res.-Oceans, 118, 6461-6478, doi:10.1002/2013JC009228.

Rusciano, E., Speich, S. and Ollitrault, M., 2012: Interocean exchanges and the spreading of Antarctic Intermediate Water south of Africa. Journal of Geophysical Research 117: doi: 10.1029/2012JC008266. issn: 0148-0227.