A MONITORING SYSTEM FOR THE SOUTH ATLANTIC AS A COMPONENT OF THE MOC

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ABSTRACT

While the North Atlantic is the sole provider of North Atlantic Deep Water (NADW) to the global ocean the South Atlantic is also the sole recipient for upper and bottom waters flowing into the North Atlantic to balance the NADW export. Export of NADW to other ocean basins is compensated for by net northward flow of surface, intermediate and bottom water layers through the South Atlantic and across the equator of surface, intermediate and bottom water layers. Moreover, during their passage through the South Atlantic water masses formed in other portions of the world ocean suffer significant changes driven by the regional circulation and local sea-air interactions.

In the North Atlantic an observing network has been designed and operated to monitor changes to the MOC in that region and despite considerable effort and expenditure being deployed. In the South Atlantic Ocean there are individual efforts to document the circulation in portions of its natural chokepoints (Drake Passage and South of Africa), but no strategic monitoring system is in place. None of these efforts have previously been coordinated, nor were these systems designed for long-term monitoring purposes. Based on these considerations a group of scientists expressed interests in creating a working group to foster collaborations and to discuss the design and implementation of an observational system to monitor the South Atlantic's branch of the Meridional Overturning Circulation (SAMOC). This group met twice the last three years, to achieve this objective that is becoming more and more concrete.

1. BACKGROUND

The overturning circulation and horizontal fluxes of heat and freshwater in the South Atlantic Ocean are fundamental controls on planetary climate. They are potentially at least as important on a global scale as those in the North Atlantic, to which they are strongly coupled[1].

The South Atlantic Ocean is unique in its role as a nexus for water masses formed elsewhere and en-route to remote regions of the global ocean[2]. In Fig. 1 are represented the pathways of the MOC in the South Atlantic Ocean, which links the strong forcing regions of the Southern Ocean with the North Atlantic, and which includes the large-scale conversion of surface waters (red) to deep waters (blue). Cold/salty North Atlantic Deep Water (NADW) flows southward along the eastern coast of South America and through the basin interior, compensated by a northward flow that is a mixture of warm/salty surface waters and cooler/fresher Antarctic Intermediate Waters (AAIW). In this way, the South Atlantic Ocean is the only major ocean basin that transports heat from the pole towards the equator. Numerous studies have been conducted to calculate the meridional heat transport in the Atlantic and values range from small southward values to close to 1 PW northward. The latest estimate[3] gives a mean meridional heat transport of 0.54PW (1 PW = 10^{15} W) with a standard deviation of 0.11 PW.

The Drake Passage and the Agulhas Retroflection Region are the main gateways for the entrainment of surface and intermediate waters from the Indian and Pacific basins into the South Atlantic Ocean's surface waters[4]. The South Atlantic Ocean is not merely a passive conduit for remotely formed water masses, rather, within the South Atlantic Ocean, these water masses are significantly altered by local air-sea interactions and diapycnal fluxes, particularly in regions of intense mesoscale activity[4,5]. The importance of these contributions to the MOC has been highlighted by paleoclimate studies linking changes in the basin exchanges to abrupt climate changes[6-9].

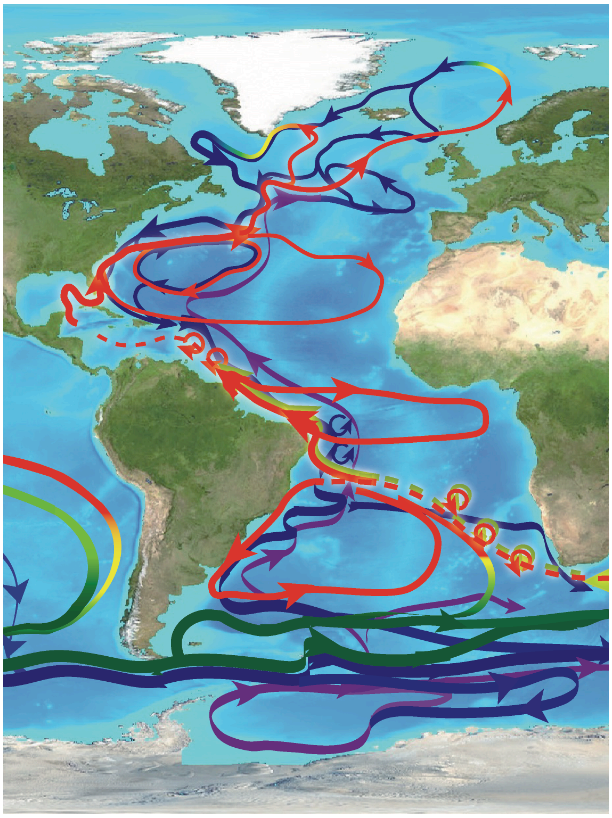

Figure 1 Pathways of the overturning circulation in the Atlantic Ocean that represents the large-scale conversion of surface waters (red arrows) to deep waters (blue arrows in the Southern Ocean; dashed blue line arrows North Atlantic Deep Water) that have global impacts. The Atlantic overturning circulation has many complex and interacting parts (e.g. rings, inter-basin and inter-ocean exchanges) but the most important aspect is the large heat it carries and its apparent sensitivity to the hydrological cycle and climate change (adapted from "Charting the course of the Ocean Science in the United States for the next decade", 2007, to include Antarctic Bottom Water). Graphics: S. Speich adapted from R. Lumpkin NOAA/AOML

The RAPID/MOCHA array is designed to monitor changes to the MOC in in the North Atlantic[10]. However, at present it is not well understood how these changes lead, lag, or are different to changes in the South Atlantic Ocean and how the global transports of mass, heat and freshwater vary in time. Indeed, the role of horizontal gyres in the South Atlantic Ocean provides a scope for understanding the MOC variability in that region[1]. Despite considerable effort and expenditure being deployed in the South Atlantic Ocean (see Fig. 2 for a summary of ongoing/planned observations), the current range of observations being made are not capable of monitoring the MOC, nor do they constitute a sustained observing system capable of monitoring large-scale interbasin fluxes of heat, freshwater, mass and other climate-relevant quantities.

Individual efforts to document the circulation in portions of its natural chokepoints (Drake Passage and South of Africa) are ongoing. Nonetheless, there is no a proper quantitative monitoring system is in place and of these efforts have previously been coordinated, nor were these systems designed for long-term monitoring purposes. These are the reasons that brought a group of scientists to create a working group to foster collaborations and to discuss the design and implementation of an observational system to monitor the South Atlantic's branch of the Meridional Overturning Circulation (SAMOC).

In the last three years, two workshops have been organized to achieve this objective.

During May 8-10, 2007 a workshop was held in Buenos Aires, Argentina to discuss the need for measuring the components of the global meridional overturning circulation in the South Atlantic. The meeting gathered a diverse group of scientists from Argentina, Brazil, France, Germany, Italy, Russia, Uruguay, United Kingdom, and the United States all of whom were working or had plans to work in the South Atlantic region.

Copies of the presentations that were made at the workshop and a complete workshop report are available on the NOAA-AOML web site at www.aoml.noaa.gov/phod/SAMOC/. Some of the key results of the workshop were:

- Meridional overturning circulation variability can be linked to 30ºS/33ºS heat transport but over longer time scales than surface fluxes
- Some discernable changes in sea-surface temperature appear to be linked to the eastern boundary circulation
- Direct measurements of Western Boundary Currents are critical in order to observe accurately either the meridional overturning circulation or heat transport
- Very little is currently in place or even

proposed that will capture all the meridional overturning circulation as a sustained observing system

The Second SAMOC Workshop took place in Paris France, July 1 and 2, 2009.

The main objectives of the workshop were:

- Review the main achievements made since May 2007
- Review and update current collaborations
- Further coordinate the efforts with the Southern Ocean Observing System community and the paleo community.
- To agree and design a poster to be presented at OceanObs'09
- To review the South Atlantic component of the AMOC White paper for OceanObs'09.

The meeting included presentations detailing new advances in science and in observations in the South Atlantic. The importance of monitoring the South Atlantic was emphasized based on modelling results that demonstrated:

1. The SA, the sole generator of the compensating flows for the southward flowing NADW, is not a passive ocean. Water mass transformations occurred in the regions of high variability, i.e., the Confluence and the Cape Basin. Therefore observations of the AMOC are need in the Subtropical South Atlantic.
2. The variability in those regions is highly correlated with the variability of the winds in the South Pacific and Indian Oceans. Therefore, in order to understand the origins of this variability, observations in the SA should be analyzed in conjunction with observations and modelling results in the adjacent basins. The main discussion focused on what parameters are needed to be measured and what were the best locations to observe them.

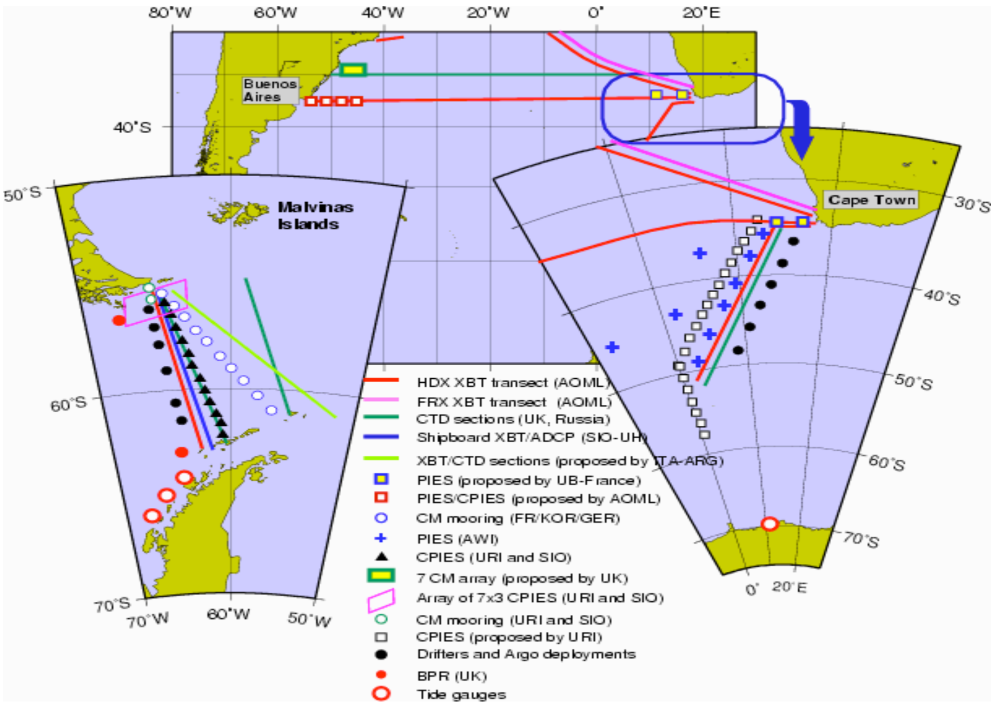

Figure 2 Map of the South Atlantic and Southern Ocean, including the two principal choke point regions, the Drake Passage and south of South Africa, with the current and proposed locations of instrument deployments and the institutes leading the corresponding associated projects.

It was agreed to have the next meeting in Brazil in May 2010. The SAMOC group already started with ongoing collaborative projects that include:

1. The undertaking of proof-of-concept numerical studies to design a monitoring system capable of determining the time-variable overturning in the South Atlantic and its horizontal fluxes of heat and freshwater
2. A number of coordinated observing efforts such as the international GoodHope project and the already deployed arrays of C-PIES and PIES along the high resolution NOAA-AOML XBT AX18 zonal line (Figure 2).

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