The Deep Western Boundary Current Eddies at 8°-18°S

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1 Introduction

The present report is part of the Mesoscale Oceanography (MPO 776) coursework project. Here I discuss the characteristics and importance of the intense mesoscale activity in the deep ocean (i. e., depths $\geq$ 1000 m) along the Brazilian continental slope at 8°-18°S (section 2), as well as what are the open questions related to this phenomenon (section 3). Since the mesoscale motions described in the following paragraphs consist of closed anticyclonic eddies, I refer to the terms mesoscale activity, rings, or eddies as synonyms for clarity.

2 The Deep Western Boundary Current at 8°-18°S

The southward flowing Deep Western Boundary Current (DWBC) is the primary pathway of the cold (or lower) limb of the Atlantic Meridional Overturning Circulation (e. g., *Molinari et al.*, 1998; *Johns et al.*, 2008). It carries the North Atlantic Deep Water (NADW) at depths between 1000 and 3500 m along the Americas continental slope (*Reid*, 1989; *Stramma and England*, 1999).

Although we are aware of the DWBC existence and forcing mechanisms since the 60's (*Stommel and Arons*, 1960a,b), only a few observational experiments (specially in the South Atlantic) have been conducted with the intent of understanding the DWBC structure and dynamics. In fact, the direct observations of the DWBC are so sparse in space and time that important phenomena are poorly studied. One interesting example of such phenomenon is the DWBC structure at 8°-18°S (see Figure 1).

As the DWBC approach the equatorial zone, the NADW pathways become complicated due to the change of sign in the planetary vorticity, involving large scale excursions into the ocean's interior (*Richardson and Fratantoni*, 1999; *Schott et al.*, 2002). However the DWBC is re-organized further south (∼5°S) in a coherent flow along the Brazilian continental margin, until approximately 8°S where it breaks down in large anticyclonic eddies (*Dengler et al.*, 2004). Such southward propagating eddies seem to be unique in terms of structure and play an important role in the AMOC transport.

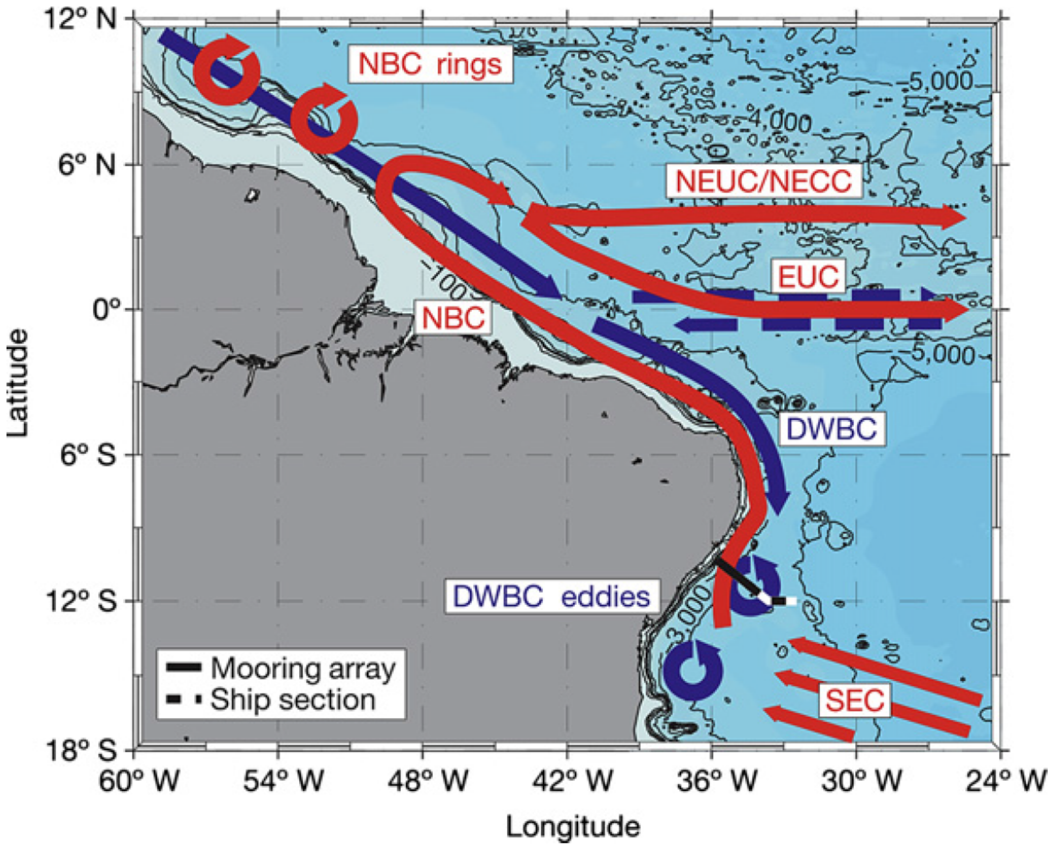

Figure 1: Schematic representation of the mean circulation in the western tropical Atlantic above (red arrows) and bellow (blue arrows) 1000 m depth. The indicated currents are the South Equatorial Current (SEC), North Brazil Current (NBC), Equatorial Undercurrent (EUC), North Equatorial Undercurrent (NEUC) merged with the North Equatorial Counter Current (NECC), and the Deep Western Boundary Current (DWBC). Source: *Dengler et al.* (2004).

2.1 Eddy properties

Based on moored velocity measurements [i. e. currentmeters and Acoustic Doppler Current Profiler (ADCP) records] and lowered-ADCP (LADCP) transects offshore the Brazilian coast at approximately 11°S (solid and dashed lines in Figure 1), *Dengler et al.* (2004) and *Schott et al.* (2005) observed that the DWBC eddies are anticyclonic and propagate southward with translation velocities of $\sim$3.8$\pm$0.9 cm s^{-1}. Those eddies are features confined at depths 1000-3500 m (i. e., 2500 m tall), with horizontal dimensions reaching $\sim$300-500 km and maximum velocities of approximately 30 cm s^{-1} at 2000 m. Figure 2 present an example of an eddy captured in a LADCP transect, and a parametric model of the average velocity structure (*Dengler et al.*, 2004; *Schott et al.*, 2005).

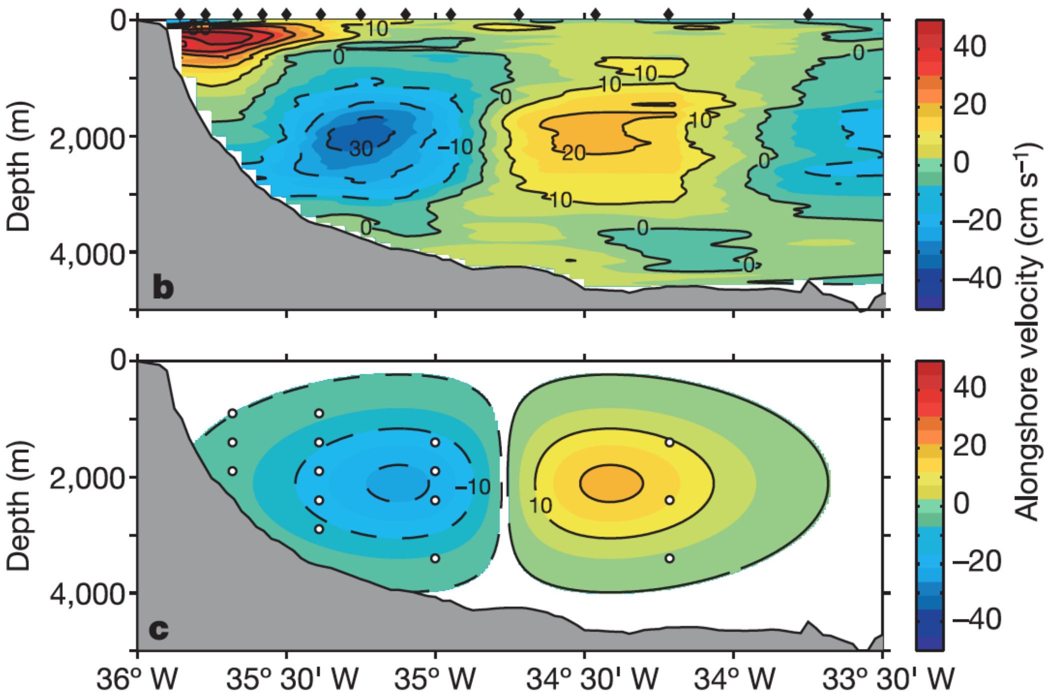

Figure 2: **(b)** Snapshot of alongshore velocity measured by a LADCP in Mach 2000, and **(c)** Parametric representation of the average vertical structure of the DWBC eddies. Negative velocities indicate southward flow. Source: *Dengler et al.* (2004).

In order to verify the behavior of these eddies, *Dengler et al.* (2004) analyzed numerical outputs from the Family of Linked Atlantic Model Experiments (FLAME) and they verified that the DWBC breaks down into rings 60-70 days apart from each other and there is no average continuous NADW pathway, as suggested by the observations. In that sense, they suggested that the DWBC eddies are the Southern Hemisphere counterpart of the North Brazil Current (NBC) rings. Years later other authors have reported similar DWBC behavior in different numerical simulations indicating the robustness of the result (e. g., *Garzoli et al.*, 2015; *van Sebille et al.*, 2012). In *Schott et al.* (2005) work, the authors estimated that each DWBC ring traps approximately 17 Sv of NADW.

2.2 NADW transport variability

The best description available of the NADW transport variability at 8°-18°S is given by *Schott et al.* (2005), where they analyzed the extended version of the *Dengler et al.* (2004) data set. A good example of how the velocity signal fluctuates is represented by the volume transport of the DWBC eddies coastal lobes (Figure 3). The variability is dominated by the 60-70 day period fluctuations due to the eddies crossing the mooring array with average of $\sim$19 Sv and standard deviation of 14 Sv.

Note that the 90-days low-passed times series in Figure 3 also shows a well defined seasonal and inter-annual variation. *Schott et al.* (2005) argue that this low-frequency variability is related to how energetic the eddies are (i. e., changes in the swirl velocities) since the number of eddies and their dimensions do not vary significantly throughout their records.

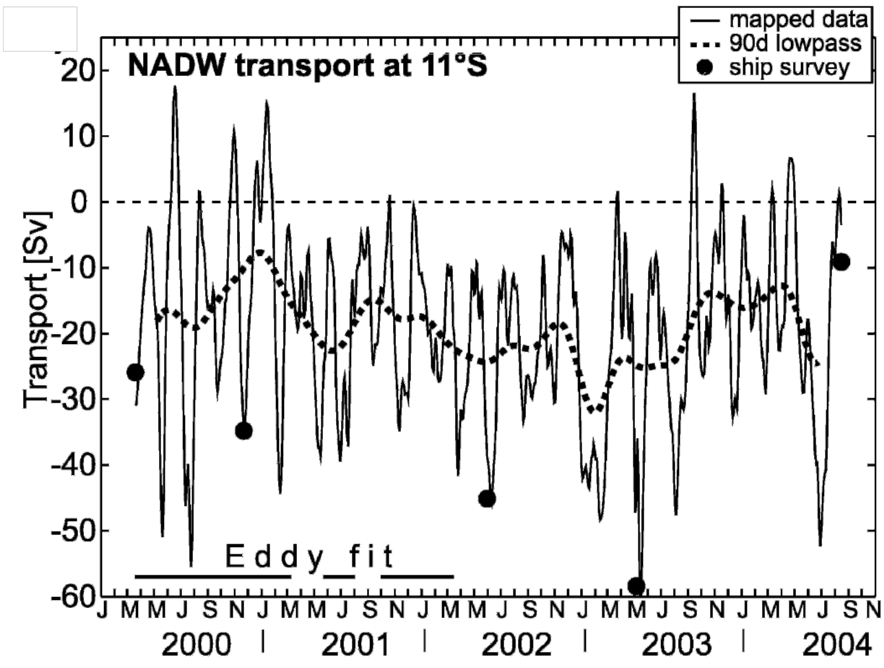

Figure 3: NADW alongshore volume transport across the area 1200 to 3800 m deep and from continental slope to approximately 170 km offshore (i. e., transport of the DWBC eddies coastal lobes). The estimates were based on the mooring (solid line) and LADCP (dots) data at 11°S. The dashed line represents the 90-days low-passed series. Negative velocities indicate southward flow. Source:*Schott et al.* (2005).

2.3 A note on the DWBC eddies dynamics

Unfortunately there is no published studies that address the dynamics of the DWBC eddy formation or how they behave between 8°S and 18°S. In *Dengler et al.* (2004) study, the authors briefly mention that the energy conversion analysis from their numerical simulations suggest the eddies develop due to barotropic and baroclinic instability processes, however they do not show any values of such energy fluxes. Additionally, the authors speculate that the AMOC variability may control possible changes between eddy and continuous flow phases in the DWBC.

3 The Deep Western Boundary Current eddies fate and open questions

Note the content presented in the previous section consist of a very basic description of the DWBC eddies. Therefore there are a lot of open questions related to its downstream fate, dynamics, "connectivity" with the upper ocean, and role in keeping or modifying the NADW properties. Observations and numerical simulations have shown as the eddies collide with the Abrolhos Bank (18°S) and the Victoria-Trindade Ridge (20°S) the coherent features are destroyed and the flux bifurcates being one limb flowing towards the ocean interior and the other southward (e. g., *Garzoli et al.*, 2015). However the dynamics of this interaction and how the DWBC can re-organizes itself in a coherent flow south of the Ridge are still puzzling and very important questions in terms of AMOC dynamics.

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