The seasonal circulation of the Eastern Brazilian Shelf between 10°S and 16°S: a modeling approach

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Introduction

The region of study (Fig. 1) encompasses an important dynamic part of the Eastern Brazilian Shelf (EBS), which hosts the bifurcation of the South Equatorial Current (SEC) into the two major Brazilian Western Boundary Currents (WBC): the southward Brazil Current (BC) and the northward North Brazil Current (NBC/NBUC). The SEC bifurcation, in turn, is driven by the interannual cycle due to the north-south displacement of the marine Inter-Tropical Convergence Zone (ITCZ), reaching a southernmost (northernmost) position at 17°S (13°N) during the northern summer (winter). The bifurcation also undergoes a latitudinal excursion with depth, reaching ~22°S (~400 m depth). As a result, in the region of study, the BC is a shallow and weak flow associated with the Tropical Water (TW) and the upper thermocline, underneath the surface layer, always flows northward carried by the NBC/NBUC.

Methodology

The simulations were performed with the Regional Ocean Modeling System (ROMS) with embedded nesting capabilities based on AGIRF, configured with a refined grid (1/36°) and realistic forcings: i) daily initial and boundary conditions from the 1/12° HYCOM Global Circulation Model (GCM) coupled on the NOCIDA system analysis. The model temperature, salinity and velocity (2D and 3D) were also nudged towards the GCM daily values with a variable relaxation time scale; ii) surface boundary fluxes based on the 6-hourly NCEP Reanalysis2; iii) temperature, salinity and velocity (2D and 3D) were also nudged towards the 6-hourly NCEP Reanalysis2; iv) the northernmost position of the SEC bifurcation, according to Roberto et al., 2007.

Following the large scale seasonality of the trade winds, the shelf currents are driven by the wind forcing, experimental and numerical simulations of the mean flow between seasons due to a similar change in the wind field (Amorim et al., 2011, 2012). The arrival of cold-frontal systems during the spring season is able to cause periodical reversals of the thermocline-integrated flow (Amorim et al., 2012). These authors have also shown that the shelf currents are influenced by topographic changes, which can enhance the upslope regime during the spring/summer seasons.

Based on a long term regional model simulation, this work aims to describe the seasonal circulation along the EBS shelf/slope region, as well as its interaction with the large scale meteorological and oceanic processes.

Results

The monthly mean surface currents derived from the Regional Circulation Model (RCM) are compared with the satellite derived surface geostrophic currents derived from AVISO as a modeling validation approach (Fig. 2). For these analysis and those discussed in Fig. 3, we have adopted the months that represent the austral seasons: October (spring), January (summer), April (autumn) and July (winter). The modeled surface currents for spring and summer clearly show the southward BC as a flow composed by the coastal borders of anticyclones, which is in agreement with Soutello et al. (2011) and resembles the geostrophic currents from AVISO south of 12°S (Fig. 2a-d).

The seasonal flows of the BC/NBUC, following the excision of SEC bifurcation (Fig. 3). As a response, for the months of October and January, the beginning of the BFUC occurs at ~15°S and ~13°S, respectively. To the south of these latitudes, the coastal borders of three robust anticyclones could represent the beginning of the southward BC flow (Fig. 3a-d).

As sub-surface (100 m depth) the circulation is dominated by the SEC bifurcation. The shaded area represents the intensity (cm·s⁻¹) of the meridional velocity component, where positive values are equatorward. The area inside the dotted lines represents the region of study.

The reversal of the WBC during the autumn and winter seasons, where the modeled northward NBC/NBUC are present north of 15°S, is also in agreement with the geostrophic currents (Fig. 2e-h). In addition, and with no sign of seasonality, both modeled and geostrophic currents show a continuous BC south of 17°S.

At sub-surface (100 m depth) the circulation is dominated by the SEC bifurcation. The shaded area represents the intensity (cm·s⁻¹) of the meridional velocity component, where positive values are equatorward. The area inside the dotted lines represents the region of study.

Between September-February (April-July) at 14°S. At 16°S a permanent surface southward flow and a marked mesoscale activity is captured throughout the year (Fig. 4 right), probably ascribed to the flow constraining due to the RCB topography, which alters the circulation pattern between seasons.

Acknowledgements

This research was supported by PIBRIO/BS and approved by the Brazilian regulatory agency ANE, within the special participatory research project Oceanographic Modeling and Observation Network (BETO).

Figure 1: Schematic seasonal variation of the Western Boundary Currents (WBC) at the upper levels along the EBS shelf/slope region. The grey (black) line shows the southernmost (northernmost) position of the SEC bifurcation, according to Roberto et al., 2007.

Figure 2: Monthly mean (2006-2009) geostrophic currents (vectors) derived from AVISO (left panels) and horizontal surface currents (vectors) derived from the RCM. The shaded area represents the intensity (cm·s⁻¹) of the meridional velocity component, where positive values are equatorward. The area inside the dotted lines represents the region of study.

Figure 3: Monthly mean (2006-2009) 100 m depth currents (vectors) derived from the RCM. The shaded area represents the intensity (cm·s⁻¹) of the meridional velocity component, where positive values are equatorward. The area inside the dotted lines represents the region of study.