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The Potiguar Eddy: a subsurface anticyclone associated with the North Brazil Undercurrent at 4º S

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Resumo

Nesta tese descrevemos o Vórtice Potiguar (VP): um meandro frontal da Subcorrente Norte do Brasil (SNB) recentendemente identificado na costa nordeste brasileira, com núcleo em aproximadamente 4°S e 36,5°W. O VP tem formato elíptico com maior e menor eixos medindo 330 e 130 km, aproximadamente, intensificado em subsuperfície. O vórtice se estende verticalmente de 100 a 400 metros, com velocidades máximas de 0,6 m.s^{-1}, recirculando cerca de 2 Sv das águas da SNB. Apesar da presença do vórtice na termoclina, o fluxo em superfície é para noroeste durante todo o ano. A análise da variabilidade da velocidade coletada em fundeio na Bacia Potiguar revela dois principais modos estatísticos de variabilidade; um com maiores amplitudes na porção da coluna dágua correspondente ao VP, e um outro modo, que explica menor porcentagem da variância da série de dados original, associado a processos ligados à camada de superfície. O primeiro EOF é associado a oscilações baroclínicas com períodos de 25 a 35 dias. Este sinal também é identificado em altimetria no Atlântico. Nós caracterizamos esses sinais como expressão de ondas de Rossby, e especulamos que o gatilho para a geração das mesmas seria instabilidade barotrópica gerada pelo cisalhamento de correntes no Atlântico Tropical.

Adicionalmente, com o intuito de analisar o processos de geração do VP, nós desenvolvemos modelos de feição da SBN e Corrente Profunda de Contorno Oeste (CCP), para serem usados como base para o deselvolvimento do campo inicial para simulações de modelagem numérica em uma abordagem de estudo de processo dinâmico. Os Modelos de Feição, desenvolvidos a partir de dados de velocidade, com densidade e temperatura calculados a partir da relação do vento térmico e salinidade da climatologia WOA (2013), capturam os principais atributos das feições de interesse com sucesso, sendo adequados para a investigação das principais características do campo de correntes na Bacia Potiguar.

Dois numéricos experimentos foram realizados: (i) Somente SNB, com profundidade máxima de 1500 m, e (ii) SNB + CCP, com profundidade máxima de 5500 m. O VP foi gerado em ambos os experimentos, com velocidade máxima, profundidade do núcleo e tamanho consistentes com observações sinóticas. Assim, temos que o VP pode ser gerado em um campo de velocidades contendo somente a SNB, e que o cisalhamento vertical induzido pela presença da CCP parece ter um papel importante nas características do mesmo (extensão vertical, velocidades máximas, etc, etc), uma vez que o VP teve um processo de formação diferente em cada experimento.

Palavras Chave: Mesoescala, Vórtice, Subcorrente Norte do Brasil.

Abstract

In this dissertation we describe a newly discovered subsurface frontal meander of the North Brazil Undercurrent (NBUC), centered at about 4 °S, 36.5 °W, hereafter Potiguar Eddy (PE). The Potiguar Eddy is an elliptically-shaped eddy, with major and minor axes of approximately 330 and 130 km, with a subsurface signature. It extends vertically from 100 m to 400 m, with maximum velocities of 0.6 $m.s^{-1}$ and recirculates about 2 Sv of waters from the NBUC. Despite the presence of the PE in subtermocline waters, the surface flow is northwestward throughout the year. The analysis of variability of mooring velocity data in the Potiguar Bight revealed two most important statistical modes of variability (EOFs); one with high amplitudes over most of the portion of the water column which corresponds to the PE, and another one, explaining a lower percentage of the variance, associated with upper-layer processes. The first EOF mode is found to be associated with baroclinic oscillations with periods of about 25-35 days. This signal is also seen in altimetric fields in the Atlantic Ocean. We characterize these signals as Rossby waves, and speculate that the trigger for their generation would be barotropic instability generated by the current shear in the Tropical Atlantic Ocean.

Aditionally, with the intent of analyzing the generation process of the PE, we developed Feature Models of the NBUC and Deep Western Boundary Current (DWBC), to be used as basis for developing the initial field for numerical model simulations in a dynamical process-study approach. The Feature Models, developed from observed velocity data, with temperature calculated through the thermal wind equation, and salinity from WOA (2013) climatology, successfully capture the main attributes of the features of interest, and thus are suitable for the investigation of the main characteristics of the flow in the Potiguar Bight.

Two numerical experiments were set up; (i) a NBUC-only experiment, with maximum depth of 1500 m, and (ii) a NBUC-DWBC experiment, with a maximum depth of 5500 m. The Potiguar Eddy was formed in both experiments, with maximum velocity, core depth and size consistent with synoptic observations. As a result, the PE can be generated by a velocity field containing only the NBUC; and the DWBC - induced vertical shear seems to play a part on the eddy's characteristics (vertical extent, maximum velocities, etc), since the PE had different formation processes in the two experiments.

Keywords: Mesoscale, Eddy, North Brazil Undercurrent.

Chapter 1

Introduction

This dissertation analyzes the Potiguar Eddy, a subsurface anticyclone within the North Brazil Undercurrent domain, on the northeast coast of South America. In the following sections, we describe the main characteristics of the current field in the area, stressing the ones that might influence the Potiguar Eddy. In this Chapter we also state our goals and scientific hypothesis for the present work.

1.1 Equatorial Current System

The South Equatorial Current (SEC) crosses the Atlantic Ocean zonally westward, meridionally extending from about 20º S to 4º N (LUMPKIN and GARZOLI, 2005). Because of its meridional extent, the SEC is divided into three branches by Molinari (1982) and four branches by Stramma and Schott (1999). Here, we will use the division proposed by the latter authors (Figure 1.1):

- South South Equatorial Current (sSEC): The sSEC is the portion of the SEC which extends from about 8º S to 20º S, located south of the South Equatorial Counter Current (SECC) (LUMPKIN and GARZOLI, 2005).

- Central South Equatorial Current (cSEC): The cSEC is the portion of the SEC located north of the SECC and south of the South Equatorial Undercurrent (SEUC), centered at about 4º S, reaching 34±5 cm.s^{-1} velocities at 30º W (LUMPKIN and GARZOLI, 2005) with a transport of about 29 Sv (SILVEIRA *et al.*, 1994).

- Equatorial South Equatorial Current (eSEC): The eSEC is the portion of the SEC located north of the SEUC and south of the Equatorial Undercurrent (EUC), being located along about 1-2º S (SCHOTT *et al.*, 2003).

- North South Equatorial Current (nSEC): The nSEC, the only branch of the SEC located on the northern hemisphere, flows north of the EUC and south of the North Equatorial Undercurrent (NEUC). Molinari (1982) does not distinguish between eSEC and nSEC. The nSEC has velocities of about 33 ± 11 cm.s^{-1} at 2º N (LUMPKIN and GARZOLI, 2005).

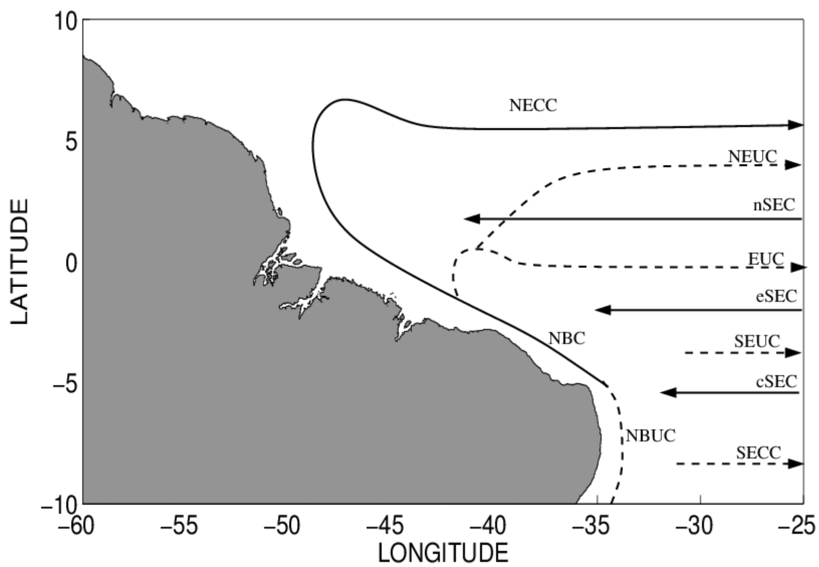

Figure 1.1: Schematic map of the currents in the upper Western Equatorial Atlantic Ocean. Solid lines represent surface-intensified currents, and dashed lines, subsurface currents. Shown are the South Equatorial Countercurrent (SECC), central, equatorial and north branches of the South Equatorial Current (cSEC, eSEC and nSEC, respectively), South Equatorial Undercurrent (SEUC), Equatorial Undercurrent (EUC), North Equatorial Undercurrent (NEUC), North Equatorial Countercurrent (NECC), and North Brazil Current (NBC). Based on Goes et al (2005), Stramma and Schott (1999) and Schott et al (1998).

The currents which separate the different branches of the SEC are mostly subsurface currents, and so the limits of most of the SEC branches are not always very clear at the surface. The nSEC and cSEC become clearly distinguishable, in the mean, only at about 30º W, separated by an eastward velocity core of 6 ± 12 cm.s^{-1} at 1º S. However, this clear distinction does not happen with the other SEC branches. As a whole, the highest westward velocities in the SEC are at the cSEC core, at 4º S, where they are about 34 ± 5 cm.s^{-1} at 30º W, linearly decreasing to about 8 cm.s^{-1} at 8º S, remaining approximately at this value until 20º S (LUMPKIN and GARZOLI, 2005). The distinction between cSEC and eSEC is also not clear at the surface.

The variability of the SEC system is driven by i) resonant response to semiannual variations in equatorial wind forcing (PHILANDER and PACANOWSKI, 1980), and ii) annual variations in South Atlantic wind stress. The second process is important because it connects the southern hemisphere subtropical gyre to the equatorial gyre through the NBC. Both processes influence on the strength of the SEC branches (LUMPKIN and GARZOLI, 2005).

The largest values of seasonal variations occur in the nSEC, which strenghtens in boreal fall (Sep/Oct/Nov) and reverses in boreal spring (Mar/Abr/May). According to Lumpkin and Garzoli (2005), this mode corresponds to the equilibrium response to the annual variation of winds (PHILANDER and PACANOWSKI, 1980). Lumpkin and Garzoli (2005) point that specifically in the western tropics, the wind stress curl reverses in boreal spring, which forces thermocline depth changes consistent with the reversing NECC (GARZOLI and KATZ, 1983) and nSEC (KATZ, 1981). The nSEC also has high amplitudes of semiannual fluctuations (LUMPKIN and GARZOLI, 2005), which are a resonant response to the semiannual component of equatorial wind forcing in the eastern Atlantic (PHILANDER and PACANOWSKI, 1980). It is important to note that in the mean field, the nSEC feeds into the North Brazil Current (NBC) at 0-2º N, so its reversal during boreal spring deprives the NBC of this input (LUMPKIN and GARZOLI, 2005).

1.2 The Origins of the North Brazil Undercurrent

The sSEC reaches the Brazillian coast at approximately 10º S, according to Peterson and Stramma (1991), 12-20º S, according to Stramma and Schott (1999), and approximately 12-14^o S, on the mean, according to Lumpkin and Garzoli (2005). With the Ekman transport removed, these authors indicate that the sSEC bifurcates further south, at about 15-17^o S. At this bifurcation, the sSEC divides into a southern branch, which is called the Brazil Current (BC), and a northern branch, called the North Brazil Undercurrent (NBUC) (SILVEIRA *et al.*, 1994).

The Rodrigues *et al.* (2007) numerical model results suggest that there is a seasonal variation of the position of the bifurcation, and that this variation is related to changes in the local wind stress curl due to annual north-south excursion the the Intertropical Convergence Zone (ITCZ). More specifically, their results show that as the SEC bifurcation latitude moves south (north), the NBUC transport increases (decreases) and the BC transport decreases (increases). The southernmost position of the bifurcation latitude, in the first 200 m of the water column, is reached in July ($\approx$ 17^o S) and its northernmost location is reached in November ($\approx$ 13^o S).

Even though the sSEC has surface expression, the Ekman drift in the region is southwestward, therefore the surface expression of the NBUC is weakened. The eastern coast of Brazil then has a subsurface-intensified boundary current, with its core located at approximately at 100-200 m depth (SILVEIRA *et al.*, 1994).

1.3 NBUC Characterization

At 11^o S, the core of the NBUC is found at 200 m depth, with a transport of 12.3 Sv between the isopicnals 24.5 kg.m^{-3} ($\approx$ 70m) and 26.8 kg.m^{-3} ($\approx$ 250 m) (GOES *et al.*, 2005). The NBUC surface-layer transport at this latitude is less than 2.5 Sv - evidence of its subsurface nature. From the surface down to about 1000 m, Silveira *et al.* (1994) found at 10.5^o S a total transport of 23.7 Sv, with a 50 cm.s^{-1} core somewhat shallower, at 150 m depth. The mean total NBUC transport at 11^o S (from five realizations) is reported by Schott *et al.* (2005) as 25.4 $\pm$ 7.4 Sv above 1100 m.

From a 4-year-long transport time series at 11^o S, Schott *et al.* (2005) found a 2.5 Sv amplitude seasonal variation in the NBUC transport, with maximum northward transport in July. This corroborates the numerical results of Rodrigues *et al.* (2007), who relate the NBUC maximum transport in July to the southernmost position of the sSEC bifurcation. Variability of the NBUC at 11°S was also investigated by Veleda *et al.* (2012), who describes intraseasonal variability with periods of two-three weeks in the alongshore velocity component measurements, consistent with Coastally Trapped Wave theory.

There are no dramatic changes in the NBUC on its northward pathway. At about 5° S, its core is still located at the subsurface, at about 100-150 m depth, with a transport of 19.9 Sv above 1000 m (SILVEIRA *et al.*, 1994). At the same latitude, Schott *et al.* (2002) found a 25.0 $\pm$ 4.4 Sv transport above 1100 m, with only 2.7 $\pm$ 1.8 Sv between the surface and the 24.5 isopicnal, and 13.4$\pm$ 2.7 Sv between 24.5 and 26.8 isopycnals, which is the density range that feeds the EUC (SCHOTT *et al.*, 1998). It is noteworthy that Schott *et al.* (2002), from 5 realizations, did not find a seasonal signal at 5° S in the NBUC transport.

The water mass structure of the NBUC at 5° S is characterized by Tropical Water, Subtropical Underwater, South Atlantic Central Water and Antarctic Intermediate Water , with a transport of 26.5 ± 3.7 Sv above 1100 m (SCHOTT *et al.*, 2005), from 9 sections. At the same latitude, Goes *et al.* (2005) found a smaller (compared to their 11° S estimate) transport, of 12.6 Sv, between the σ_0 = 24.5 kg.m^{-3} and σ_0 = 26.8 kg.m^{-3} isopicnals. However, it must be noted that these authors calculated the NBUC transport down to the σ_0 = 26.8 kg.m^{-3} isopicnal, which at this region is located approximately at 700 m depth. Therefore, their total transport for the NBUC is calculated in a smaller portion of the water column than the calculations from other authors.

1.4 The cSEC and its Influence on the NBUC

As the cSEC approaches the equator, it begins to influence the transport, velocity and core depth of the NBUC. Therefore, it becomes important to know the characteristics of the cSEC in order to understand the effects it will have on the NBUC.

The westward cSEC flows zonally along about 4° S (LUMPKIN and GARZOLI, 2005) with a transport upper bound of 26 Sv according to Molinari (1982) and a 29 Sv transport indicated by Silveira *et al.* (1994) at the western part of the Atlantic, where it reaches the Brazillian coast. At 30º W, this surface-intensified current has 34±5 cm.s^{-1} velocities, and is separated from the nSEC by a mean eastward speed of 6±12 cm.s^{-1} at 1º S (LUMPKIN and GARZOLI, 2005), even though it must be noted that these authors apparently do not differenciate the cSEC from the eSEC.

At 35º W, Schott *et al.* (1995) found in March, 1994 a combined cSEC and eSEC transport of 18.6 Sv, with a surface core of 0.4 m.s^{-1} and a weaker subsurface core of 0.2 m.s^{-1}, extending from the surface to about 400 m depth. On the other hand, Schott *et al.* (2003) describe the mean (from 13 sections) transport associated with the cSEC and eSEC as much smaller, of only 7 Sv between 4 and 2º S, and not clearly distinguishable from the NBC, which they consider to flow south of 4 º S. Even though there is not a clear distinction, the authors associate a 50 cm.s^{-1} surface core identified at 35º W to the cSEC. It is noteworthy that in the study of Schott *et al.* (2003) the SEUC was connected to the EUC, therefore limiting the vertical extent of the eSEC and cSEC, thus reducing its transport, which may be the cause for such a difference between the calculated transport from Schott *et al.* (2003) and from Schott *et al.* (1995). Both cSEC and eSEC extend deeper than the σ_0 = 24.5 kg.m^{-3} isopicnal, as described by Goes *et al.* (2005) and Schott *et al.* (2003), and since the eSEC is considered to be the flow north of the SEUC and the cSEC is defined as the flow south of SEUC, once the SEUC has no surface expression, the combined mean flow is also over the SEUC, extending from about 2º S to 4º S (SCHOTT *et al.*, 2003) (Figure 1.2).

Mesoscale activity has been reported upon the arrival of the cSEC on the western boundary. Silveira *et al.* (1994) found that, in May-July 1986, this current bifurcates at about 6-5º S into two branches at 31º W. One of them (with a transport of about 14 Sv) flows southwestward until 9.5º S and them makes a cyclonic turn and coalesces with the NBUC, already formed by the sSEC. The other branch of the cSEC (with a transport of about 15 Sv) flows northwestward and coalesces with the NBUC north of 5º S, where the NBUC had already been originated by the sSEC and fed by the other branch of the cSEC. However, only Silveira *et al.* (1994) identified this bifurcation, suggesting that it might be seasonal/occasional. The superposition of the cSEC and NBUC cores was also reported by, for example, Stramma *et al.* (1995), and the current originated by the superposition of these two cores is then called North Brazil Current (NBC) (SCHOTT *et al.*, 1998).

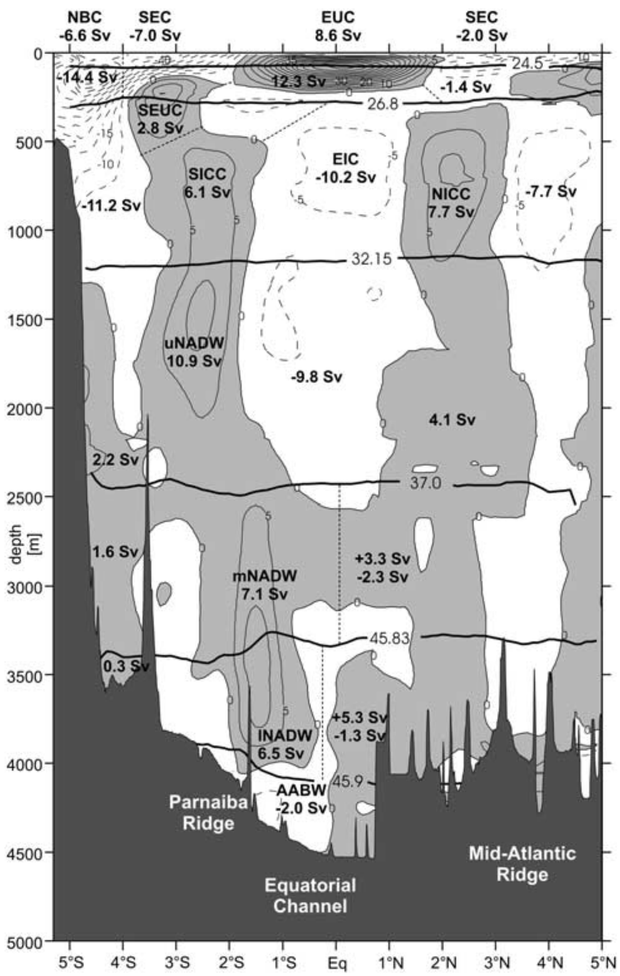

Figure 1.2: Mean 35^o W velocity section from Schott et al (2003) (from 13 sections). Shown are the North Brazil Current (NBC), South Equatorial Current (SEC), South Equatorial Undercurrent (SEUC), South Intermediate Countercurrent (SICC), Equatorial Undercurrent (EUC), Equatorial intermediate Current (EIC), North Intermediate Countercurrent (NICC), upper, middle and lower North Atlantic Deep Water (uNADW, mNADW and lNADW, respectively), and Antarctic Bottom Water (AABW). Positive values indicate eastward flow.

1.5 The NBUC North of 5º S

North of about 6-4º S, the NBUC receives contribution from the cSEC (SILVEIRA *et al.*, 1994; LUMPKIN and GARZOLI, 2005), which greatly increases the NBUC transport, also being capable of originating a double-core current system. This kind of structure was observed, for example, in March 1994 at 35º W, by Schott *et al.* (1995), who found the NBUC/NBC system with a 0.6 m.s^{-1} core at about 150 m depth and a surface core of about 0.3 m.s^{-1}. The total transport for the NBUC/NBC system in this realization was 26.2 Sv. Transport increase due to the superposition of the cSEC and NBUC cores is large not only at the surface layer: Goes *et al.* (2005), for instance, reported an increase from 12.6 Sv at 5º S to almost 17 Sv at 35º W within the σ_0 = 24.5 - 26.8 kg.m^{-3} layer, implying that the cSEC extends deeper than the σ_0 = 24.5 kg.m^{-3} isopicnal.

In the upper layer (surface-σ_0 = 24.5 kg.m^{-3}) at 35º W, the boundary transport is also enhanced, increasing from less than 2.5 Sv to 12.3 Sv (GOES *et al.*, 2005). This results in a contribution of about 14 Sv between the surface and the σ_0 = 26.8 kg.m^{-3} isopicnal by the cSEC. In the study of Schott *et al.* (2003), due to the cSEC contribution, the NBC/NBUC system at 35º W transports 32.2 Sv above 1200 m depth. Summing the mean transport found by the same authors in the cSEC and eSEC (7 Sv) to the NBC/NBUC system transport, the mean northwestward transport at 35º W south of 2º S is 39.2 Sv above the σ_1 = 32.15 kg.m^{-3} isopycnal, with a 60 cm.s^{-1} core at about 100 m depth (SCHOTT *et al.*, 2003).

1.6 Dissertation Hypothesis

As mentioned on the previous sections, most of the information on the NBUC before its coalescence with the cSEC is found at approximately zonal sections at 11º S and 5º S. Information on the horizontal synoptic structure of the NBUC, as well as its vertical structure, is scarse between those latitudes - the only NBUC description between 11º S and 5º S is by Silveira *et al.* (1994). In addition, the subsurface nature of the current prevents altimetry-based studies of the NBUC in this area. Further downstream, on the region of superposition of the cSEC and NBUC cores, the information is even more scarse. West of 35º W, the next section in which the NBUC was repeatedly studied was 44º W, where the NBUC and cSEC are already merged and are, on the mean, not distinguishable (SCHOTT *et al.*, 1998). Between 35º W and 44º W the only study that addresses the horizontal structure of the NBUC is Goes *et al.* (2005).

This data scarcity leaves a knowledge gap on the three dimensional synoptic structure and time variability of the NBUC on the region between 35º W and 44º W, i. e., between the latitudes where the cSEC reaches the western boundary and where these two currents are already merged. In this context, in this dissertation we describe the Potiguar Eddy (PE), a mesoscale anticyclonic eddy identified at the Potiguar Bight, centered at about 36.5º W, 4º S. Considering the existence of this feature, we hypothesize that

The NBUC has important mesoscale activity in the Potiguar Bight region, and this activity, on the form of meandering, is associated with the interaction of the NBUC with the continental margin physiography and the Deep Western Boundary Current (DWBC).

To test this hypothesis, we describe the Potiguar Eddy based on synoptic hydrographic and current data, moored current data, and global numerical model simulation results. Besides describing the eddy through observational data, we also characterize it through a process-oriented study approach, carrying out simulations with the *Regional Ocean Modeling System* (ROMS).

1.7 Objectives

This dissertation aims to characterize the mesoscale feature referred here as Potiguar Eddy as well as investigate its formation, maintenance, and recurrence processes. To achieve this goal, we analyze hydrographic and current synoptic data, moored current data, altimetry data, and global numerical model outputs. Furthermore, for a better understanding of the feature, we turn to idealized numerical model simulations, using the process-study approach with the oceanic feature modeling technique.

Specifically, the objectives of the dissertation research are:

- to three-dimensionally characterize the PE based on hydrographic and vessel-mounted *Acoustic Doppler Current Profiler* data;
- to assess the dynamical regime of the PE based on *in situ* synoptic data;
- to analyze moored current data and altimetry data in terms of the PE persistence/recurrence and its intraseasonal variability;
- to understand the processes involved on the PE persistence/recurrence through longer time scales (semiannual and annual variabilities) by way of an analysis on global numerical model outputs;
- to address the importance of the vertical shear due to the interaction with the DWBC on the dynamics of the PE through idealized experiments, by applying a Feature Model technique in a primitive-equation numerical model.

In Chapter 2, we characterize synoptically the eddy and investigate its vertical structure, based on data from two oceanographic cruises. In Chapter 3, the temporal variability is analyzed, using moored and altimetry data, as well as model results. In Chapter 4, we describe and analyze the results of numerical simulations carried out using the process-study approach. The summary and conclusions are presented in Chapter 5.

Chapter 5

Summary and Conclusions

Over this study we were able to achieve the objectives set on Chapter 1, which were:

- *to characterize three-dimensionally the PE based on hydrographic and vessel-mounted Acoustic Doppler Current Profiler data*

In this dissertation we analyzed *in situ* and altimetry data, as well as numerical model results, with the intent of describing the main characteristics of a subsurface frontal meander of the NBUC centered at about 4 °S, 36.5 °W, hereafter Potiguar Eddy (PE). The PE was first identified in synoptic cruises data, in VMADCP velocity fields. Here we show, from these fields, that this feature was observed during two cruises in different times of different years, suggesting a possibly stationary character. The synoptic data served to characterize spatially and vertically the PE, specially considering its subsurface character, which prevents the study of this feature through altimetric data. The Potiguar Eddy is an elliptically shaped eddy, with major and minor axes of approximately 330 and 130 km, with a subsurface signature. It extends vertically from 100 m to 400 m, with maximum velocities of 0.6 $m.s^{-1}$ and recirculating about 2 Sv of waters from the NBUC. As a frontal meander of the NBUC, the PE is assymetric, with a stronger and deeper-reaching nortwestward (offshore) velocities lobe when compared to the southeastward (nearshore) velocities one. It must be stressed that, being a subsurface feature, there is no signature of the PE at surface near the shelf break; the surface velocity field is persistently northwestward throughout the year.

- *to assess the dynamical regime of the PE based on in situ synoptic data*

After obtaining the general synoptic characteristics of the PE, we used the cruises data to make an assessment of the dynamical regime of this feature. A simple calculation of the Rossby and Burger numbers confirmed that the feature of interest is an anticyclone with typical mesoscale characteristics; estimated Rossby number ≈ 0.3 and Burger number of ≈ 1, comparable to that estimated by Silveira *et al.* (2000) for the NBC retroflection deep eddies at 5^{o} N. Due to the dominant geostrophic balance in the PE, we also found reasonable correspondence between geostrophic velocities within the eddy and global numerical model outputs.

- *to analyze the PE persistence/recurrence and its intraseasonal variability through moored current data and altimetry data*

After the synoptic description of the PE, we turn to the investigation of its variability and persistence. For that, we use currentmeter mooring data from two lines deployed in the Potiguar Bight, with an 8-month and a 12-month long time series, which confirmed the stationary character of the PE, with a slightly larger vertical extent than that seen on the VMADCP velocity sections.

An EOF analysis of the variability of the moored velocity data revealed two important statistical modes of variability (EOFs); the first with high amplitudes over most of the portion of the water column which corresponds to the PE, and the second, associated with upper-layer processes. The amplitude time series of the first mode of variability is found to have a distinct 25 to 35 day period of oscillation. In order to identify these oscillations, we project the dynamical modes onto the statistical ones, to find that the first EOF is related with the second baroclinic mode. We then hypothesize that second-mode baroclinic waves are reaching the Potiguar Bight and imposing variability of the vertical extent of the PE by deepening and shoaling its lower limit. With the assumption that these oscillations are due to westerward phase-propagating waves, we apply a finite-impulse-response (FIR) filter to the altimetry data. The goal is to investigate the existence of signals with periods coincident with the ones we found on the EOF amplitude time series. The altimetry filtering revealed 34-day waves in the region, generated west of 15^{o}W in the Atlantic and propagating westward along 4°S. These waves are generated during the month of June and reach the Potiguar Bight during September-December, corroborating the high energy patches during these months found in the wavelet analysis conducted on the amplitude time series of the first EOF. In order to further investigate the physical nature this variability, we calculate the wave number from the dispersion equation for second-mode baroclinic Rossby waves. As a result, we obtain the confirmation that the 35-day variability seen on the EOF amplitude time-series is associated with linear free planetary Rossby waves about 800 km in length, and probably generated by barotropic instability caused by the shear between different zonal currents in the Equatorial Current system.

- *To understand the processes involved on the PE persistence/recurrence through longer time scales (semiannual and annual variabilities) via performing analysis of global numerical model outputs*

The limited duration of the currentmenter mooring velocity time series prevented the investigation of longer-period variability. Considering that we had found reasonable agreement between the synoptically-observed PE and global numerical model outputs, we analyze the model outputs for lower-frequency variability. We found that the second (first) numerical model statistical mode is associated with the first (second) EOF mode from the observed mooring data. Fitting an annual signal to the amplitude time series, we find that the surface-trapped mode (first EOF mode for model outputs, second EOF mode for observed mooring data) has a strong component of annual period, confirming our suspicions that the surface-trapped mode would be related to upper layer processes and consequently to the trade winds annual cycle over the Atlantic. On the other hand, the second EOF mode is associated with the deep structure variability, and therefore more closely affecting the PE. For this second mode, the annual harmonic amplitude is virtually negligle compared to the intraseasonal variability due to the planetary Rossby waves.

- *To address the importance of the vertical shear due to the interaction with the DWBC on the dynamics of the PE through idealized experiments, applying a Feature Model technique in a primitive-equation numerical model.*

In order to develop insight into the PE generation, we apply the Feature Oriented Regional Modeling System (FORMS) (GANGOPADHYAY and ROBINSON, 2002) technique within a process-study framework. The Feature Models for the NBUC and DWBC were defined based on a number of observational studies in the region. The developed Feature Models seemed to successfully capture the main attributes of the features of interest, being suitable for a process-study assessment of the main characteristics of the flow in the Potiguar Bight.

We set up two experiments, i. e., a NBUC-only set up, with a maximum depth of 1500 m, and a NBUC+DWBC set up, with a maximum depth of 5500 m, in order to investigate if (i) the PE would be generated in a velocity field which contained only the NBUC, and (ii) which is the influence, if any, of the NBUC-DWBC shear for the generation and maintenance of the eddy. After a long calibration procedure, stable configurations for the experiments were reached, yielding realistic mean current speeds and transports, as well as current width and location, according to extensive literature (e. g. Silveira *et al.* (1994); Schott *et al.* (2002)). Therefore, we regard the model results as realistic, considering the process-study aproach here employed. The Potiguar Eddy was formed in both experiments, with maximum velocity, core depth and size consistent with synoptic observations. As a result, we conclude that the PE can be generated in a velocity field containing only the NBUC; and the DWBC - induced shear seems to play a part on the eddy's caracteristics (vertical extent, maximum velocities, etc), since the PE had a different formation processes in each experiment.

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