A MESOSCALE BRAZIL CURRENT FRONTAL EDDY OBSERVED THROUGH AVHRR IMAGES AND CURRENT METER MOORINGS

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ABSTRACT

During the period from Dec. 29, 1994 to Jan. 17, 1995, a meso-scale oceanic eddy, with a diameter of approximately 100 km, was detected in thermal infrared AVHRR/NOAA images near the inshore Brazil Current (BC) front SE of Cabo São Tomé. Beneath surface, the presence of the eddy was observed in current meter mooring data collected during this period at depths up to about 350 m as flow perturbations and reversals. The analysis of both data sets together with some CTD data collected during the same period indicated that the eddy formation can be related to an intensification of a cyclonic meandering of the BC at the continental margin, which was probably associated with strong coastal upwelling present on the continental shelf. The AVHRR images showed that large filaments of colder water of upwelling origin were advected towards the BC front, wrapping around the eddy.

INTRODUCTION

The most conspicous feature of the surface oceanic circulation in the Southwestern South Atlantic, south of 10° S, is the Brazil Current (BC) whose origin is at the southernmost portion of the South Equatorial Current. The BC represents the western boundary of the subtropical circulation in the South Atlantic. Between 20° and 30°S, its transport appears to be considerably smaller than that of analogous current systems in the Southern Hemisphere, for example, the Agulhas and East Australian Currents. The Brazil Current transport estimates vary from 1.9 Sv (Stramma et al, 1990) to 9.4 SV (Schmid et al, 1995); most of these estimates were done using 600 m as the reference level for the geostrophic calculations.

A large uncertainty exists about the spatial and temporal variability of the BC (Peterson and Stramma, 1991). The BC plays an important role all over the upper continental slope and shelf break regions of Brazil and Uruguay. Most of the time, the BC is characterized by warm temperatures (> 25°C) and high salinity (≅37 PSU) and a southern flow closely associated with the continental margin, well represented in the region by the 200 m isobath. Meandering and frontal eddies are frequently observed south of 21°S, disturbing the characteristic southern flow. These instability processes present in the BC inshore frontal region can sometime grow and generate cyclonic eddies.

Most of the efforts developed to study the BC have been based on the traditional method of hydrographic data collection, using oceanographic ships. More recently, this method is being complemented by the use of moored equipment, satellite tracked drifters and satellite images. The high repetitiveness and large scale synoptic view provided by the environmental satellites, have allowed the observation of the BC and related oceanographic features, such as meandering, eddies and their life cycles, time and space scales. The analysis of these images has proved to be very efficient in describing and studing the wind driven seasonal coastal upwelling present between Cabo de São Tomé and Cabo Frio. For example, Garfield (1990) analysing a large data set of infrared images of the BC showed that, between 20° and 31°S, the BC is continuous and can be characterized by several eddies and meanders to the west of the main stream. Stech et al. (1994) presented some wintertime features observed from an analysis of a set of thermal infrared images. Schmid et al. (1995), by using a hydrographic data set, drifting buoy observations and satellite imagery studied a BC frontal eddy near Vitória, describing the anatomy of this feature and its interaction with the BC. In their paper it is suggested that the strengthning of the coastal upwelling might be related to the generation of the studied eddy. Stech et al. (1995) utilized an AVHRR set of images to study the seasonal variation of this upwelling.

The objective of this work is to combine some thermal infrared satellite images with current meter and hydrographic data available to provide a kinematical description of another observed BC frontal eddy, similar to that analysed by Schmid et al. (1995), but more to the south, near Cabo São Tomé.

THE DATA SET

Satellite Data

Daily images of the Advanced Very High Resolution Radiometer (AVHRR) aboard the TIROS-N/NOAA satellites have been recorded in the High Resolution Picture Transmission (HRPT) mode by INPE since September 1992. The digital satellite data were processed using the SEAPAK software to generate the Sea Surface Temperature (SST) maps for analysis. The digital image processing data set involved: a) image ingestion with the separation of the five channel images from the interleaved original data; b) application of one of the Multichannel Sea Surface Temperature (MCSST) NOAA algorithms for atmospheric correction and generation of the SST images; c) remaping to a common map projection (Mercator) and geographical gridding; and d) digital image enhancement to increase the contrast and to facilitate interpretation of the thermal features present.

For the generation of the final SST maps, a Lookup Table was created to color the images according to the different temperature ranges and a colored hard copy was printed in a thermal wax printer. This procedure facilitates the visualization of the oceanographic features of the image.

Hydrographic and Moored Data

For part of the period covered by satellite image sequence, data from six current meter moorings and one meteorological/ oceanographic buoy were available. The positions of these moorings are indicated in Fig. 1. The current meter mooring at the center of the southern array, which "better sensed" the presence of the eddy, sampled the water column at five depths (50, 100, 350, 500 and 1000 m), allowing a good view of its vertical flow structure. The current meter data set was complemented by CTD data collected during the same period. This last data set was used to characterize the water masses present.

RESULTS AND DISCUSSION

Near 22°S latitude , the BC normally shows an offshore meandering forced by a similar displacement of the shelf break line. Some AVHRR IR images collected for this area from December 1994 through January 1995, revealed a process of intensification of this meandering. This process began on Dec. 24, with the complete formation of an eddy by Dec. 29. The surface thermal field observed in these images shows a very clear cyclonic (clockwise) sense of rotation of the eddy (See Fig.2). The satellite images show that the eddy has a diameter of approximately 100 km and is formed by BC warm water. During the entire observed period, the eddy was very close to the BC inshore frontal zone, and didn't present any significant translation.

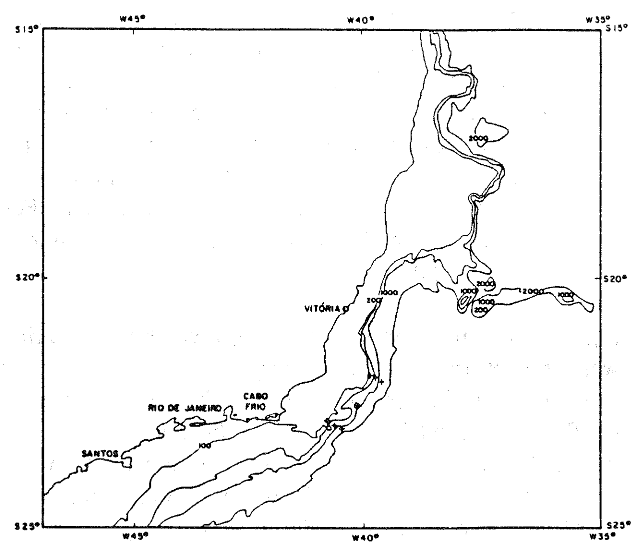

Fig. 1 Positions of current meter moorings (+) and meteorological buoy (•) with isobaths in m.

Colder shelf water associated with a strong upwelling event was observed being advected toward the BC front and wrapping around the east and southeast portions of the periphery of the eddy. This colder water made it easier to visualize the eddy shape. In Fig.2 it is possible to observe the large thermal contrast of the shelf waters, with temperatures as low as 19° C, to the warm BC water, with temperatures of 26 to 27°C. The upwelling is present in this region mostly from September to March, and is forced by a prevailing NE wind. The seasonality of the upwelling is supposed to be linked to the seasonal variation of the depth of the South Atlantic Central Waters (SACW), observed at the shelf break. Schmid et al. (1995) observed a similar eddy more to the north, near 20° S during February of 1991. That feature seemed also to be associated with a strong upwelling event. Fig. 3 shows that the eddy was present almost at the same location in January 17, 1995. The colder water wrapping around it is very clear in this figure.

Fig. 4 shows the progressive vector diagram for the current at 50 m depth and for the period 12/15/94 to 02/06/95. Between days 15 and 29 of December, the flow was typical of the BC, that is, from NE to SW, with an average velocity of 32 cm s^{-1}. This velocity is similar to that derived from drifters and geostrophic calculations (Schimid et al., 1995), by the Pegasus profilers (Evans and Signorini, 1985), and by geostrophic calculations (Signorini et al., 1989). In agreement with Fig. 3, the eddy signal started to be observed in the current field in December 30 changing the flow to a zonal direction, and indicating that the mooring line was sampling the southern portion of the eddy. From 01/04 to 01/14 of 1995, the flow showed a complete reversal from its typical pattern, that is, it was from SW to NE, indicating that the current meter was now sampling the NW portion of the eddy and that the feature had migrated to the SE. From 01/15 to 02/01, the flow was typically to the NW suggesting that the eddy had moved northwards. After 02/01, the signal of the eddy is not seen in the current meter data and the flow is again typical of the BC. For the 100 m depth, Fig. 5 shows that the flow is similar to that observed at 50 m.

Fig. 6 shows that for 350 m depth, a weak perturbation was present in the flow during the last few days of December. In the remaining part of the observed period the flow is to the NE. A "zoom" of this period, presented in Fig. 7, shows that the flow is zonal and to the W as observed at upper levels of the water column. Schimid et al. (1995) also observed eddy signatures up to several hundred meters depth near Vitoria. The Fig. 8 shows that the flow at 500 m is to the NE during entire observed period. A TS diagram obtained from CTD casts during this period indicates that the South Atlantic Central Waters (SACW) are present at this depth in the region. No eddy signal was observed at this depth.

CONCLUSIONS

This work shows that satellite and ***in situ*** data present an excellent complementarity, allowing different characteristics of the oceanic features to be visualized and understood. Although each of these two data set has very different characteristics in terms of spatial and temporal resolutions, they can be combined to provide information that could hardly be obtained by using each one separately.

For the case analysed, the satellite data showed that the ***in situ*** current anomalies observed at depth were caused by an oceanic meso scale (diameter ~ 100 km) cyclonic eddy. This feature was possibly generated by a strong coastal upwelling event. Some large filaments of colder upwelled waters were observed in the satellite images being advected toward the BC front and being wrapped around the eddy. The ***in situ*** data provided information about the vertical structure of the eddy as well as the magnitude of the rotational velocities at various depths and about the water mass characteristcs present in the area. The combined data sets showed that the observed eddy had characteristics similar to those observed in the summer of 1991 near Vitória by Schmid et al. (1995).

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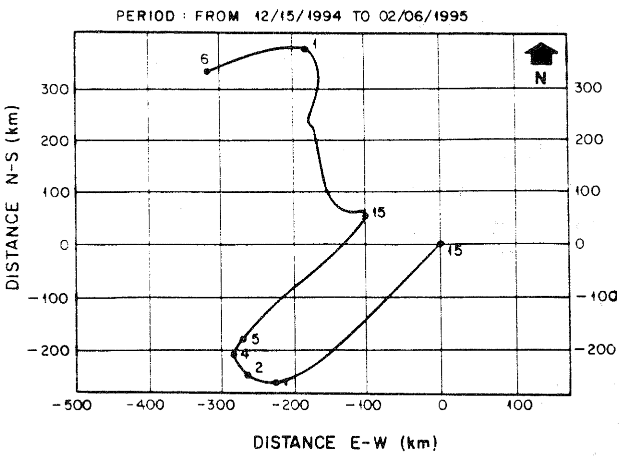

Fig. 4 Progressive vector diagram for the central mooring of southern line. Depth = 50m

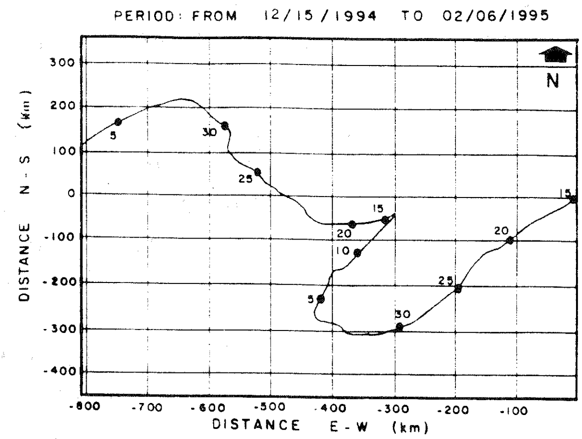

Fig. 5 As in Fig. 4 except for depth = 100 m

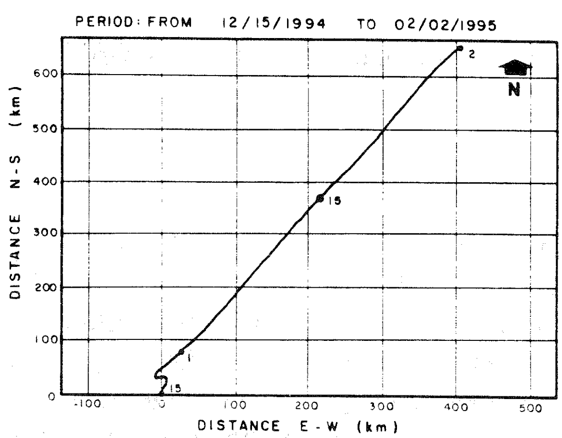

Fig. 6 As Fig. 4 except for depth = 350 m.

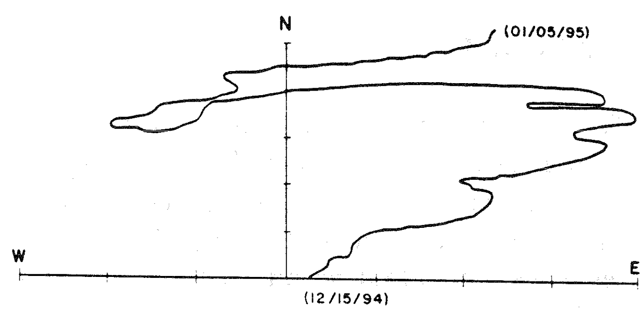

Fig. 7 A zoom of Fig. 6 for the last few days of December 1994.

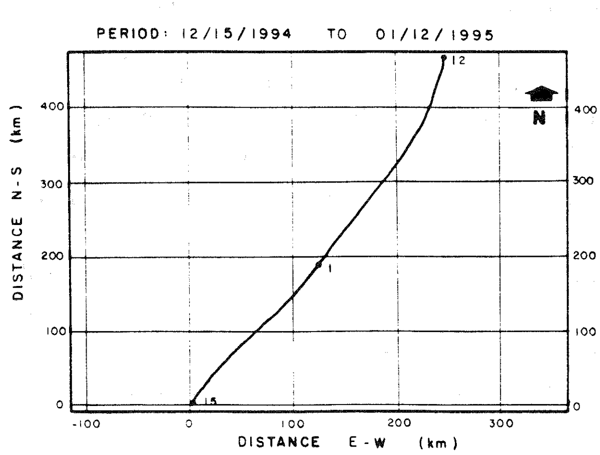

Fig. 8 As Fig. 4 except for depth = 500 m.