Proceedings of 8 ICSHMO, Foz do Iguaçu, Brazil, April 24-28, 2006, INPE, p. 1315-1320.

MARINE TOPOGRAPHY INFLUENCE IN VITÓRIA EDDY USING A COUPLED OCEAN-ATMOSPHERE MODEL

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ABSTRACT

In this work was investigated the marine topography influence in the Vitória eddy. The Vitória eddy was first described in 1995, during an oceanographic cruise that included Vitória-Trindade chain. Generally it is observed about 100 Km offshore Vitória city with cyclonic vortices characteristics and cold core. The study region is situated 10˚S to 27˚S latitude and 30˚W to 50˚W longitude, including Caravelas city, in Northeast region until Itajaí in South region of Brazil coast (Southwest Atlantic Bight). A coupled modeling system atmosphere and ocean, that includes MM5 (Mesoscale Modeling System – 5th Generation), Princeton Ocean Model (POM) and auxiliary routines has been used aiming to simulate the hydrodynamics of that area, using as initial and boundary condition for ocean temperature, salinity and horizontal velocity components, results obtained from Ocean Data Assimilation (ODA) Experiment developed by the Geophysical Fluids Dynamics Laboratory (GFDL) using the Modular Ocean Model (MOM). The Global Forecast System Model (National Centers for Environmental Prediction - NCEP) analysis has been used as initial and boundary conditions, updated every six hours, in MM5. In order to investigate the marine topography influence in the Vitória eddy, the bathymetry has been changed, including a barrier between two highs under ocean in Vitória-Trindade chain. Results were obtained both for marine topography changed and not changed. Differences found have shown that are some influence from topography in the ocean circulation, mostly related to eddy formation, in the Vitória – Trindade chain. Observations collected near this area were used to compare to model results.

1. INTRODUCTION

This work had origin in the project FITOSAT/PETROBRAS context that consists of environmental occurrences monitoring in Campos Basin using remote sensor and data observed information. Brazilian Navy and PETROBRAS have concentrate efforts in studies since they accomplish their activities in that area, with intention of knowing better the dynamics of coastal circulation, used for several ends as petroleum exploration, terminal activities and safety of navigations.

The studied area is placed among latitudes varying from 10°S until 27°S and longitude varying from 30°W until 50°W, including Caravelas city in Northeast until Itajaí in South . In this region there are some of the main ports as Salvador, Vitória, Rio de Janeiro, Santos and Itajaí, representing a great importance economical area.

One of the oceanographic features observed in this area is the Vitória eddy. The first hydrographical and dynamics description of this cyclonic vortex, usually located about 100 Km of Vitória coast, has been done by Schmid et al. (1995), during an oceanographic measurement campaign along the area that includes Vitória - Trindade chain.

Vitória eddy had been also detected by Gaeta et al. (1999). The authors found a cyclonic vortex with 50 Km diameter, with cold core, centered at 20.3°S in latitude 38.9°W in longitude. Nutrient and phytoplankton analysis presented by them showed that Vitória eddy has been contributed significantly to increase primary production in this area. According to Schmid et al. (1995), the water transport due it migration is approximately a third of Brazilian current transport. This indicates that the eddy is also important for the local circulation and for the energy levels distribution.

The objective of the present work is analyze the marine topography influence in the eddy formed from the Brazilian current passage through

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Vitória - Trindade chain, as suggested by Schmid et al. 1995, using a coupled model for simulations during the FITOSAT project campaign for which there was observed data.

2. COUPLED MODEL

The coupled model used was described by Da Silva (2006) and works changing information in synchronous and two-way mode. For such the Princeton Ocean Model (POM) is a subroutine of the Mesoscale Model System (MM5), an atmospheric model. Code characteristics revealed to be favorable to use that technique however it yields the creation series of auxiliary subroutines in order to bring the models together (Figure 1).

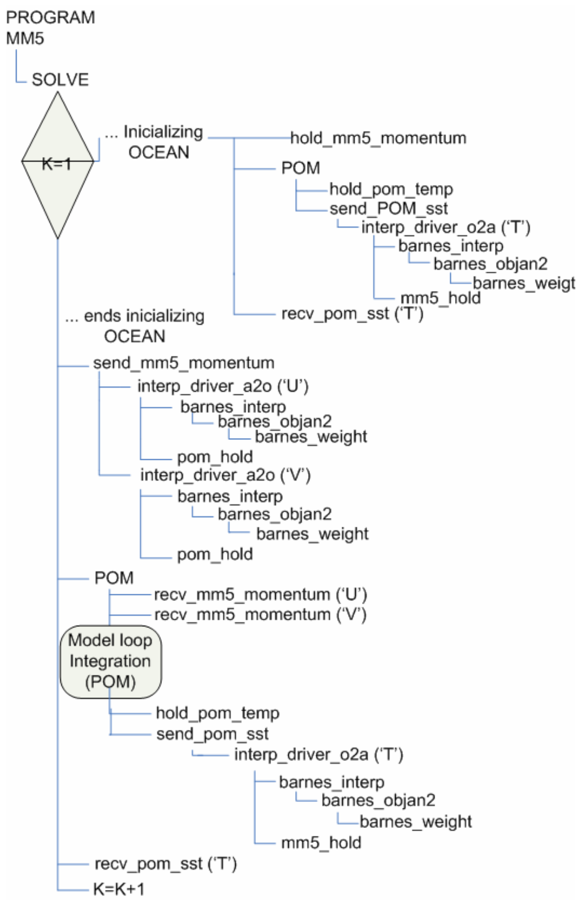

FIGURE 1 - FLOWCHART OF SUBROUTINES CREATED FOR COMMUNICATION K, MM5 STEPTIME AND SOLVE CONTROLS MM5 EQUATIONS SOLUTION.

Once the models domain area is approximately equal, interpolation was necessary and used with two purposes. One would be the needs of fine adjustment due the areas are not exactly the same and in function of models use different grid lattices (MM5 B-grid and POM C-grid). Another reason is the need to adjust the grid borders that do not coincide in an exact way, have been used in this case four grid borders points, where interpolation is applied again.

Initially it was just selected the field of close horizontal momentum to 10 meters of MM5 to be transferred to POM and the field of SST to be transferred from POM for MM5.

OCEAN MODEL

Princeton Ocean Model is a pseudo-three-dimensional model with free surface developed by Blumberg & Mellor (1983 and 1987), in Geophysical Fluids Dynamics Laboratory (GFDL) of NOAA (National Oceanic and Atmospheric Administration) located in Princeton University USA. In this work the most recent version, released in 2000 year (Mellor 2002) was used.

The model is based on the primitive hydrodynamic equations and it uses the sigma-z coordinate system in vertical.

POM is a hydrostatic model and makes use of Arakawa C grid. The governing equations are described through prognostic fields of momentum horizontal components, temperature, salinity that join with continuity equation, hydrostatic equation, turbulence kinetic energy, turbulence macroscale and the free surface.

Due increase computational efficiency, the continuity and momentum equations are solved for the internal mode (baroclinic) and for the external mode (barotropic).

ATMOSPHERIC MODEL

MM5 is the fifth generation of a series of atmospheric limited area models developed in a join effort between Penn State University and National Center for Atmospheric Research (NCAR). The first version documented date from the 70's decade (Anthes and Warner, 1978). Ever since it has been diffused and several versions have been released, with so many improvements and additions of different physical options. No-hydrostatic, with coordinated sigma-p in vertical, it was designed to simulate regional scale and mesoscale atmospheric circulation although it has already been applied even in global domains (Dudhia and Bresch, 2002).

The last version included grid nesting options (one and two-way), parallel processing versions (shared and distributed memory) and four dimensional data assimilation. One of the differentials when compared to other atmospheric models is the number of physical options in the code available through simple changes in the configuration files.

In the present work was included the microphysics parameterization taking into account the ice phase in the clouds, convection parameterization (Grell, 1993), shortwave and longwave atmospheric radiation, with effect of clouds included, and boundary layer parameterization proposed by Hong and Pan (1996).

3. METODOLOGY

Three simulations were performed. The first one had as objective verifying if the ocean model was capable to represent the eddy's features using the original bathymetry. In the second, still using just an ocean model, the bathymetry was modified obstructing the water passage through a channel formed by bathymetrical irregularities in that area (Figure 2) had as objective evaluates the importance of marine topography for the eddy formation, according to the hypothesis suggested by Schmid et al., (1995) when trying to explain this formation. In the third, the coupled model was used and the results compared to the first simulation. The purpose of the last one was initiates a series of tests with the coupled system so as to identify their differences. The bathymetry was generated through a composition of collected data during the LEPLAC project (Levantamento da Plataforma Continental Brasileira), REVIZEE (Programa de Avaliação do Potencial Sustentável de Recursos Vivos na Zona Econômica Exclusiva) and USGS (United State Geological Survey).

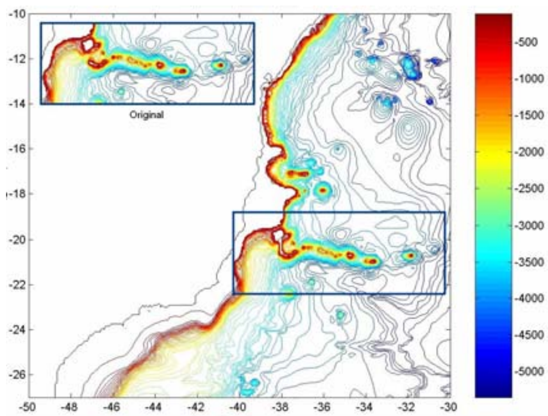

FIGURE 2 – VITÓRIA - TRINDADE CHAIN BATHYMETRY MODIFIED (BOX REPRESENTS SAME REGION). COLOR SCALE IS DEPTH IN METERS.

To better visualize the modification a vertical latitudinal cut is presented for original and modified bathymetry (Figure 3a and 3b), where a depth variation can be observed in agreement with latitude. The used longitude was 38°W. The modified channel is outstanding in the figure.

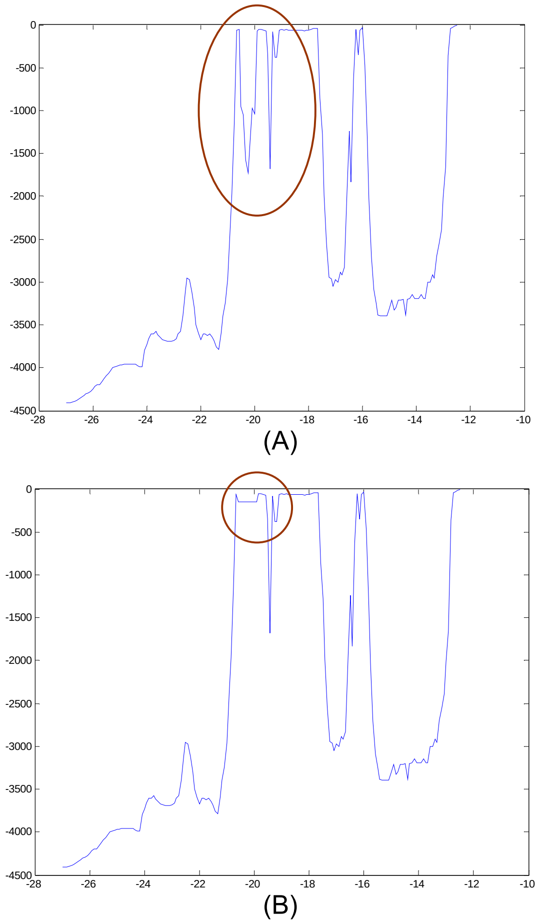

FIGURE 3A E 3B – VERTICAL LATITUDINAL CUT IN ORIGINAL AND MODIFIED BATHYMETRIES.

The ocean model was configured with 5 minutes of degree (approximately 9 Km) space resolution with a regular grid in latitude and longitude, with 15 levels in vertical. The timestep in baroclinic mode used was 360 seconds and in barotropic mode was 12 seconds. The domain was defined between 10°S and 27°S in latitude and 30°W and 50°W in longitude.

Temperature, salinity, and the horizontal components of momentum obtained from ocean data assimilation experiment developed in GFDL (Schneider et al., 2003) using MOM (Modular Ocean Model - Pacanowski et al. 1991) were used as initial condition. Those data are available with 1° horizontal resolution with 40 levels in vertical. It was horizontal and vertical lineally interpolated for POM grid. Obtained values in the lateral from the same experiment were maintained constant as north, south and east condition. Bathymetry was used as bottom condition.

Zonal and meridional 10m wind components were obtained from Global Forecasting System (GFS - Kanamitsu et al. 1991) of NCEP (National Centers for Environmental Prediction) analyses was used as surface boundary condition to ocean model simulations. This condition is updated every 6 hours and the fields are lineally interpolated in time. The 10m wind components were horizontally interpolated for POM grid using third order Bessel method.

MM5 was configured with a domain that includes Atlantic South Southwest border, going from Itajaí (~27°S) about 200 Km extending to Salvador (~10°S), with longitudes varying from 50°W to 30°W with 5' degree resolution (~9 Km), and 23 levels defined in vertical, being the first sigma level defined about 9 meters height and the last reaching 13 Km approximately. NCEP (GFS - Caplan and Pan, 2000) global model fields, with 1° resolution in latitude and longitude were used as initial and boundary condition for MM5.

The used period for simulations was November 2004 due to the FITOSAT project period campaign. For both simulations, the first 20 days worked as a spin-up for the model. And the period between 20th and 30th the results were obtained every 6 hours.

4. RESULTS

In Figure 4 the surface current fields presented were obtained from the first simulations described in the methodology. For that, is shown the more representative day that was noticed the best configuration of the vortex. The color scale represents the depths. In this simulation was noticed the presence of a cyclonic vortex, configured in similar way to Vitória vortex, in the same place, starting from the 22 intensifying on the 23 with the contribution of a current coastal direction north, that settled down due to the passage of a frontal system. The vortex formation probably happens, due to the passage of the coastal current through the channel formed by bathymetry, with the moving of the closest layer to the side west of the chain. In the Figure 5, the results obtained from the second simulation are presented for the same day. In this case, such vortex was not observed. However, was formed a vortex close to that area, where was observed the Vitória vortex, with anti-cyclonic turn in function of the vorticity loss.

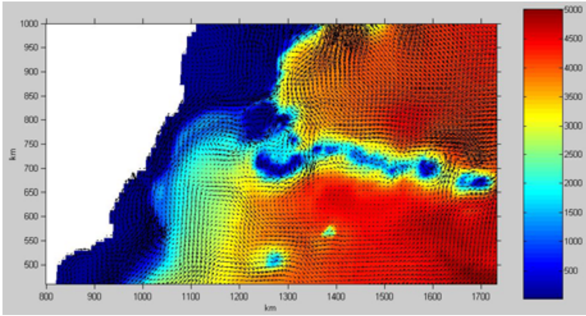

FIGURE 4 – SURFACE CURRENT FIELD AND BATHIMETRY FOR THE DAY 23 FOR FIRST THE SIMULATION (OCEAN MODEL).

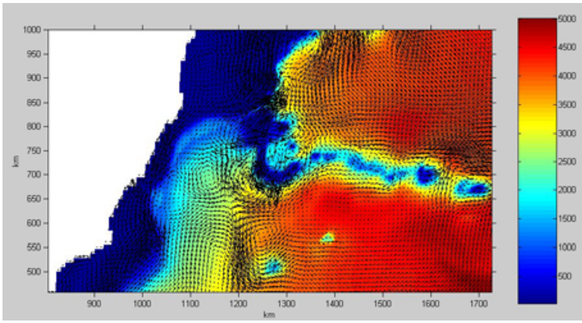

FIGURE 5 - SURFACE CURRENT FIELD AND BATHIMETRY FOR THE DAY 23 FOR SECOND THE SIMULATION (OCEAN MODEL).

For the coupled simulation has been used momentum and solar radiation from atmosphere to ocean, and SST from ocean to atmosphere. Nevertheless as solar radiation feedback estimate was used an area average of incident solar radiation. Results showed that such approach was not enough to guarantee the atmosphere-ocean flux balance. Ocean temperatures were highly overestimated, reaching values around 30°C and even more.

In Figure 6, the first sigma level analysis from coupled ocean-atmosphere model shows the overestimated temperatures. Even using such fields, the Vitória eddy can be observed (Figure 7), but vertical thermodynamic can be analyzed properly. These results can indicate that using more appropriated approximations for fluxes conservation model could yields to better results.

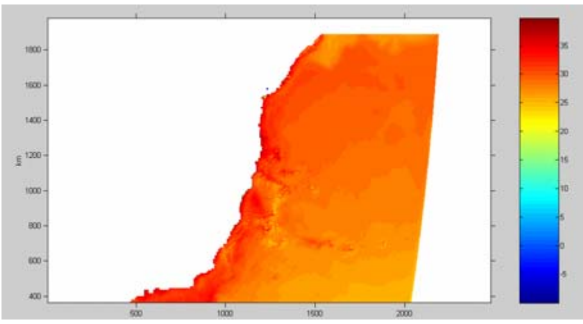

FIGURE 6 – TEMPERATURE OBTAINED FROM THE THIRD SIMULATION (FIRST SIGMA LEVEL).

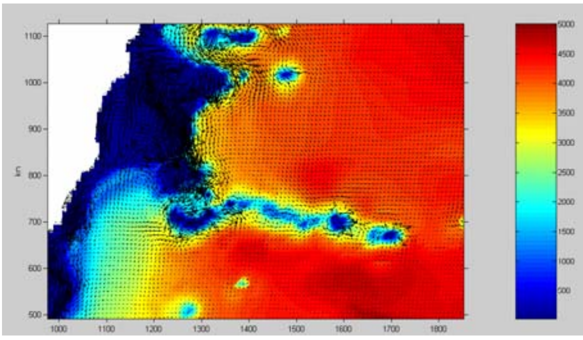

FIGURE 7 - SURFACE CURRENT FIELD AND BATHIMETRY FOR THE DAY 23 FOR THIRD THE SIMULATION (COUPLED MODEL).

5. CONCLUSION

In the first simulation can be observed that the model was capable to simulate the main oceanic features in the area. One of them was the formation of a close vortex to the place where was observed the Vitória vortex (Schmid et al. 1995).

With the second simulation, using the modified bathymetry, it was noticed in fields the appearance of other vortexes. However, the formation of close vortexes is not observed, nor of characteristics similar to the Vitória vortex.

Comparing the two simulations can be noticed that the bathymetry influence in oceanic circulation, mainly in relation to vortexes formation in the Vitória – Trindade chain area.

The third simulation reveals that coupled model can be a great tool to evaluate these kind of ocean-air interactions, but some care is needed, mostly related to flux and mass conservation between systems. Even that Vitória vortex is qualitatively well simulated showing that better approximations could yield to better results.

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