Results and Validation of The Ocean Circulation around Southeast Brazilian Coast - Towards Ocean Prediction for the Oil Industry

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Introduction

One of the REMO project main goals is to undertake research in physical and operational oceanography within the Brazilian coast using numerical ocean models. For this purpose, several models and assimilation techniques are used in different regions and configurations, within the scope of ocean forecasting and to support the oil industry activities and environmental management. Here we present preliminary results of the regional modeling group, using ROMS inside a high resolution ($1/24°$) grid that encompasses the major regions of Brazil oil exploration and fishing areas, with realistic forcing in both lateral and surface boundary conditions.

The study region (Fig. 1) extends from $12°$S to $33°$S, encompassing the South Brazil Bight (SBB), an important oil exploration area. It covers several key processes, including the formation and variability of the Brazil Current (BC), eddies and high mesoescale activity (*Calado et. al 2010,Soutelino et al 2011*) , coastal and shelf-break upwelling (*Castelao et al 2006*) and sub-inertial dynamics over the shelf.

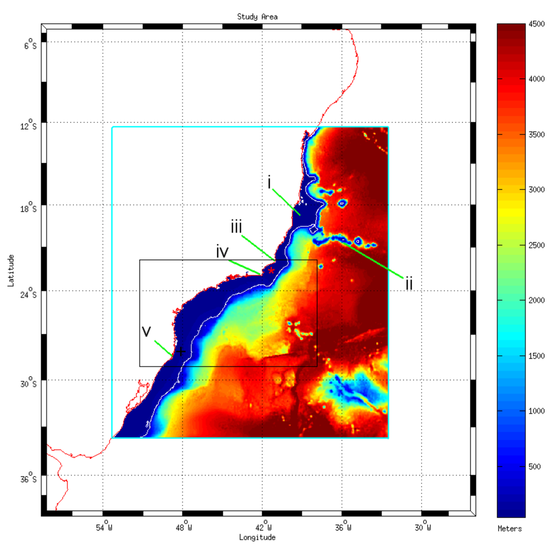

Figure 1. Numerical domain of the study region - The southeast Brazil coast : i)Abrolhos Bank ; ii) Vitória-Trindade seamount chain ; iii) São Tomé Cape ; iv) Cabo Frio Cape ; v) Santa Marta Cape ; Red asterisk) Macaé GLOSS Station ; Black cross) Imbituba GLOSS Station ; Black retangle) South Brazil Bight. The white line shows the 200m isobath.

The analyses presented focus on comparisons of the numerical results with satellite observations and products that are used extensively for assimilation and validation. Clearly some work still need to be done, particularly related to the boundary treatment, because the coupling sometimes is not optimal and the presence of some features (rim currents) are aggravated when running with tides.

Methodology

The simulations use the ROMS 3.4 version *SVN523*, with a unrotated $1/24°$ grid, 40 levels and a custom bathymetry provided by the Brazilian Navy (Nautical Charts blended with ETOPO) relaxed towards the OGCM bathymetry and masking at the boundaries. One of the most common problems when working around Abrolhos bank and the Vitória-Trindade seamount chain, is the very steep topography. Over this region we have used an alternate filter to force a maximum $rx = 0.21$, in order to preserve the shape and form of the seamounts. The model realistic forcings are the following:

- Daily lateral boundary conditions from the $1/12°$ Global HYCOM/NCODA model (momentum *M3* and tracers *T/S*);
- 6-hourly surface boundary conditions from NCEP-R2 via bulk formulation without flux correction.
- Main tidal constituents from TPXO/OSU (elevation + barotropic components).

Chapman and Flather boundary conditions were used for the barotropic mode plus nudging/radiation on tracers and velocities, and a sponge/overmixing layer in the open boundaries. The model integration covers the period from 2004 to 2011. The analysis of the results presented here encompass the 2006-2010 period. We choose not to use a nudging relaxation zone in this run, in order to investigate the numerical sensitivity to the external data and numerical issues. Results are compare with MSLA data from AVISO/CNES, SST from OSTIA/GHRSST , and coastal tides gauges from the brazilian GLOSS network.

Results

Fig. 2 presents the mean SST for 2010 period , where a qualitative comparison with OSTIA was reached. It is clear that the model still need some adjustments, mainly on the boundary conditions (south and east), where some decoupling regions occur. Over that window the bias in SST was significantly larger south of $25°$S, in both tidal and non-tidal solutions, and an excessive upwelling near the coast was detected in the tidal results(up to $1.5°$C, differences where HY-NCODA maximum values are near $0.6°$C over the same area). When comparing the sea surface height, some differences over the southern boundary are expressive when comparing to both AVISO and HY-NCODA data (Fig. 3). These sea surface patterns start to grow noticeable in the same period that HY-NCODA shows significant changes all forcing variables.

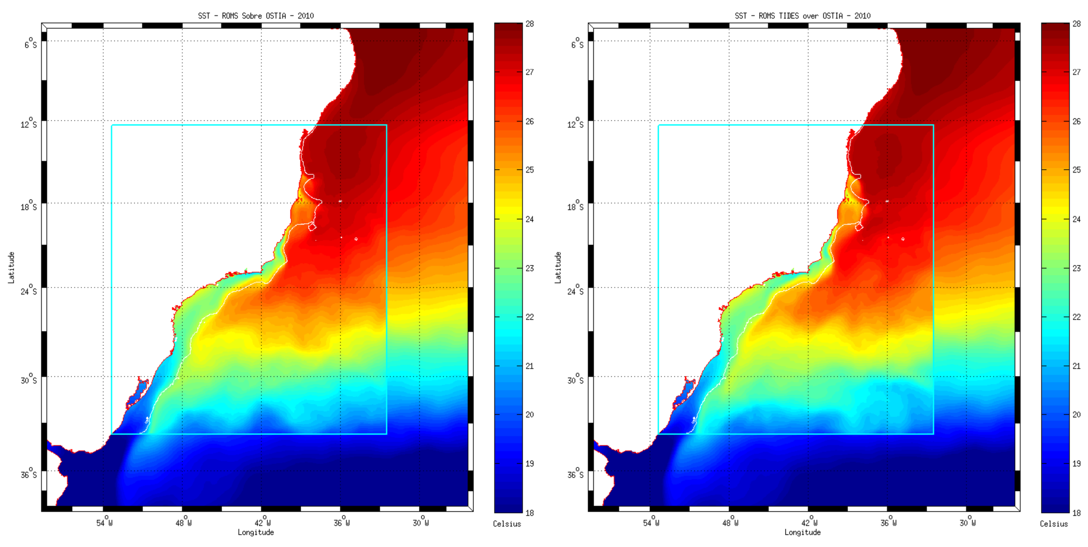

Figure 2. Comparisons between mean SST from ROMS and OSTIA , with (right) and without (left) tides for the 2010. It's clear that some displacement of isotherms occurs near the east boundary and heat transport. A stronger upwelling happens when tides are included. The standard deviations follows the same pattern (not show).

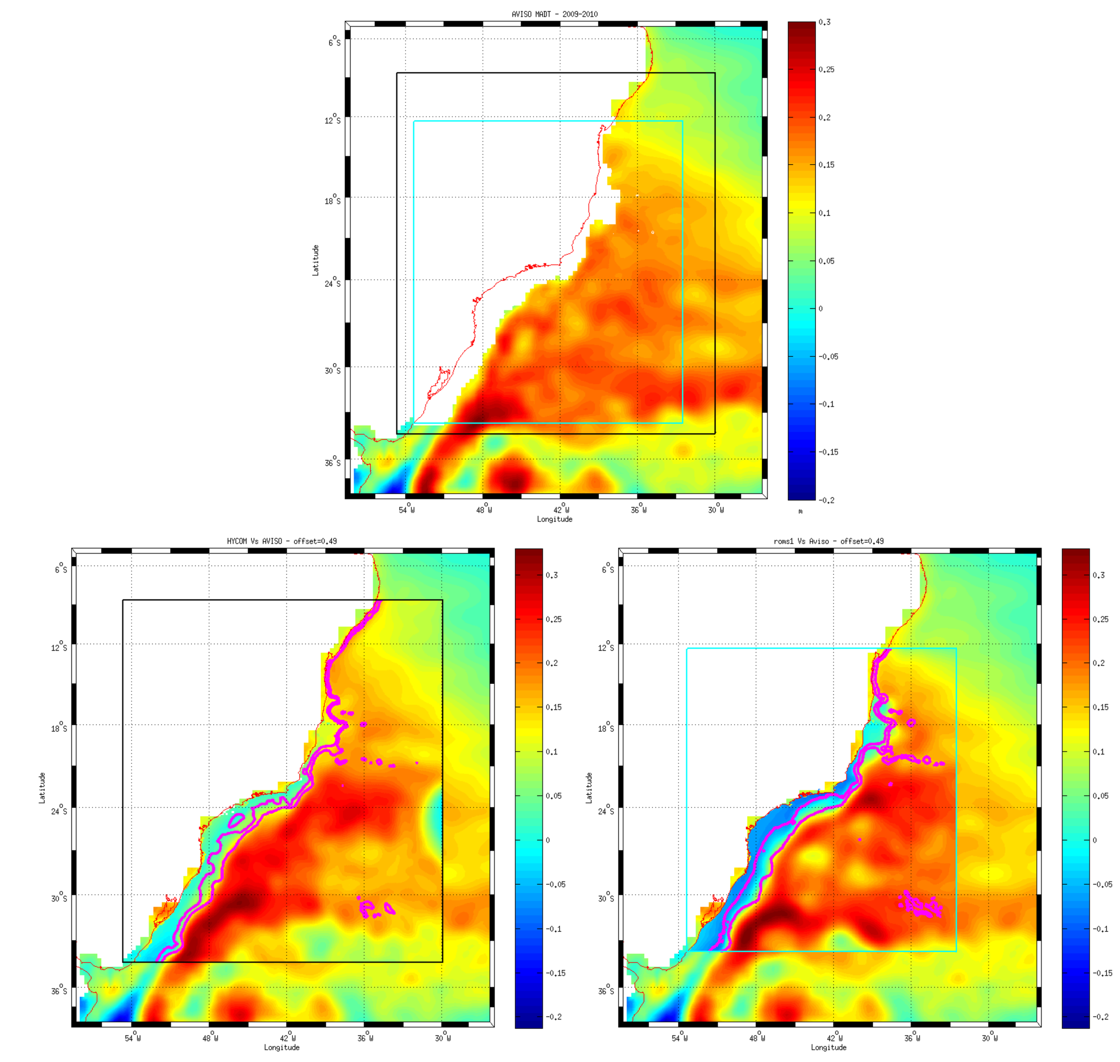

Figure 3. Coupling Comparisons between HYCOM-NCODA and ROMS with AVISO as background benchmark (2009-2010). Top - Mean MSLA ,Left - HYCOM-NCODA and Right - ROMS (without tides). Note the rim currents that happens near the south boundary and extends beyond $3°$ of latitude in ROMS. Even HY-NCODA have larger deviations near the east boundary from where ROMS are fed with.

Probably the roots of this behavior lies on the differences over the source data and fluxes, like those tested in *Mason et al 2010* and the lack of a strong nudging to absorb/supress these errors *Modave et al 2010*. These patterns in sea-level (Fig.5) and the velocities resembles the findings in the former study. Additionally the boundary data from the NCODA dataset have strong changes over deep regions inside the 2009 year, making things worse and difficult to point out the main problem on the sea level. Over a largest period of simulation (5 years), the mean profile of velocities near $30°$S agrees qualitatively with WOCE moorings (Fig 4), but for the smaller window, the results are degraded (not show).

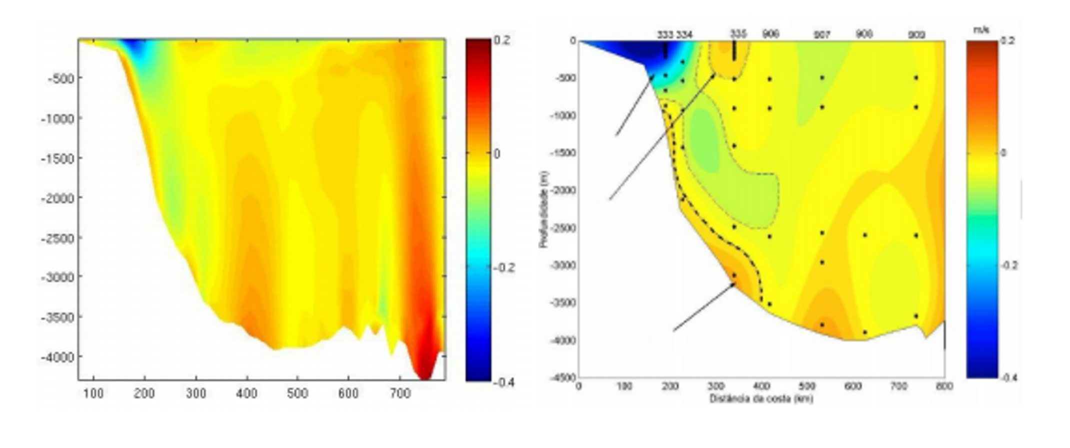

Figure 3. Comparisons between ROMS (5-year mean) and WOCE mooring data near $30°$S. The modeled Brazil Current, bottom and return currents and patterns qualitatively agrees with the observational data.

For the sub and supra inertial bands, the results shows better agreement, in particular with the tidal charts and time series of elevation (Fig. 4-6). The Vitória-Trindade seamount chain acts like a hot spot for the internal waves patterns, and all the major constituents are well represented inside the model (Fig. 4-5). Note the internal waves patterns and hot spots. The maitanance of the seamount chain was crucial to be able to represent this patterns.

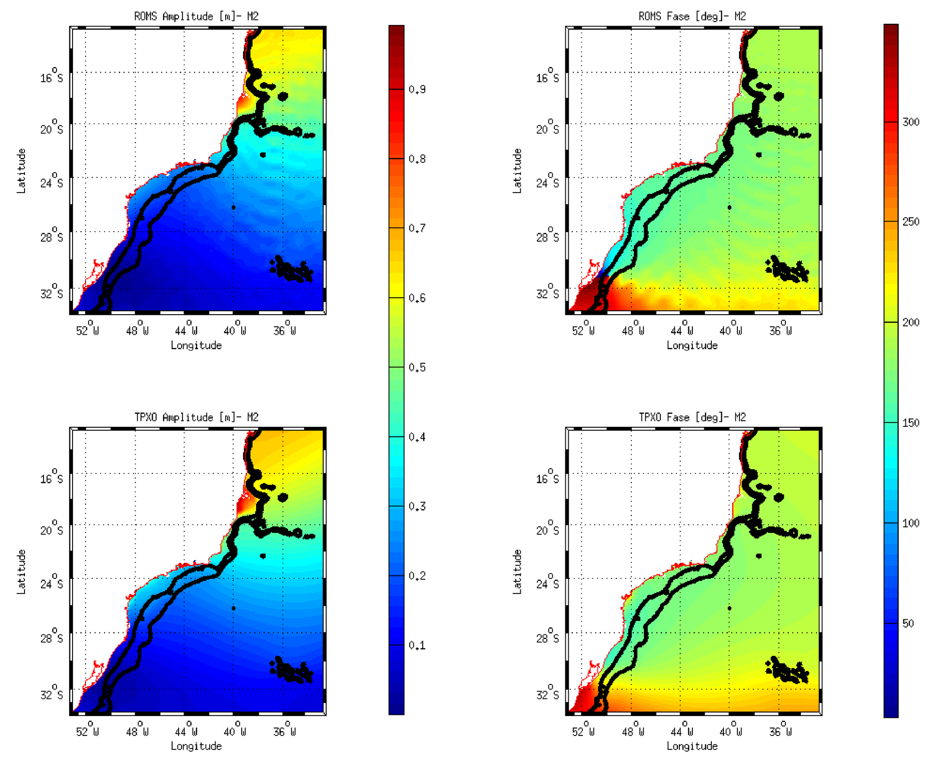

Figure 4. Tidal Charts comparison between TPXO and ROMS for M2 constituent based on harmonic analysis.

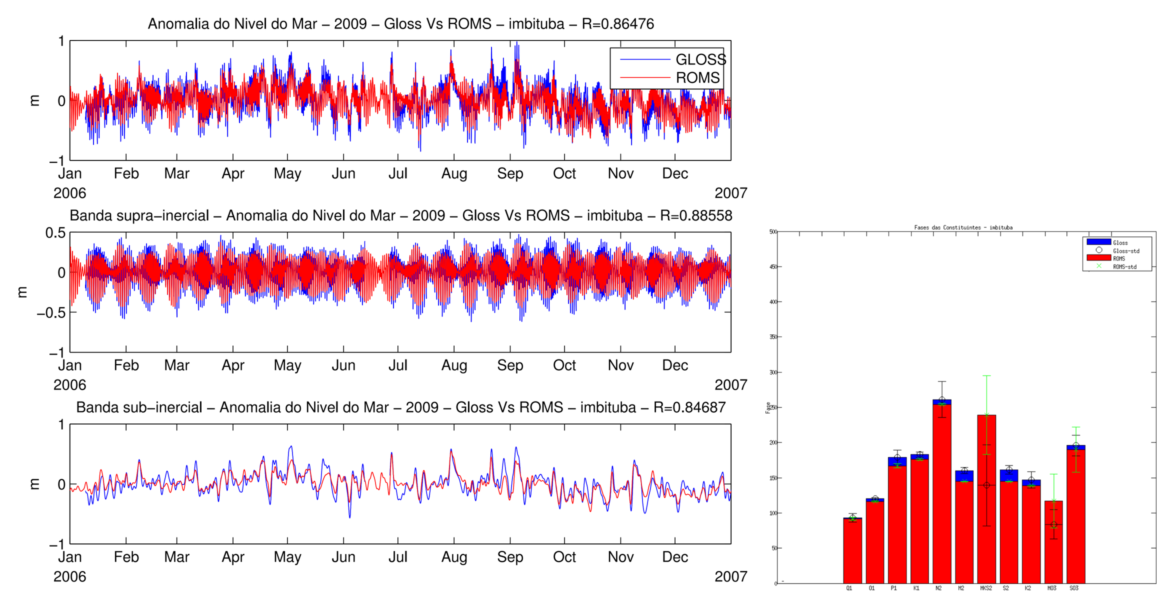

Figure 5. One year comparison between ROMS and Tidal Gauges of Brazilian GLOSS stations in Imbituba. Both supra and sub inertial bands are well correlated with data and shows an correlation coefficient *R*. The tidal constituents phases are well correlated.

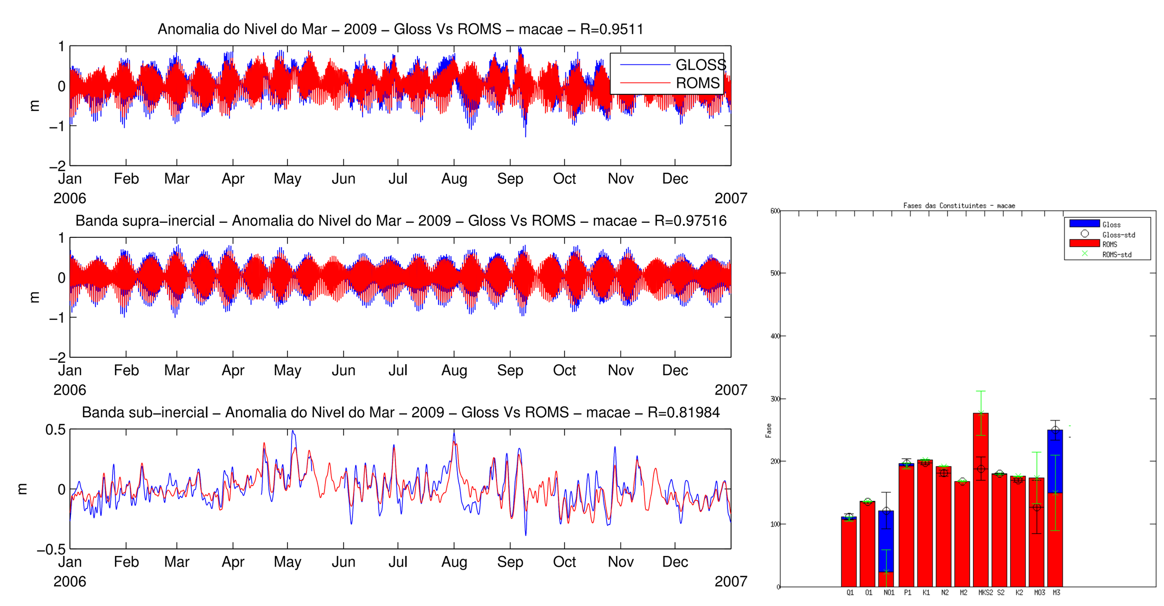

Figure 5. One year comparison between ROMS and Tidal Gauges of Brazilian GLOSS stations in Macaé.

Questions, Solutions and Future

1. Search for corrections of these behaviors are valid before tighten the nudging layers ? So can't we run from stronger nudging layers in this cases !?. . . *It's seems to be. . .*
2. What to do with the external "bad" data windows!? Use anomalies,corrections and/or change back to a large window boundary forcing? Will we still need atmospheric corrections ?
3. The use of the same atmospheric data from OGCM probably can help elucidate some problems *Mason et al 2010*.
4.More tests are under way before the near real-time and assimilated system is online. We're still testing the assimilation method in short windows away from this period.

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