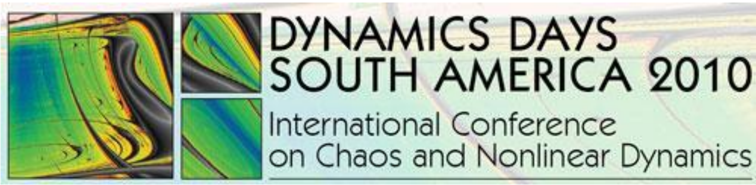

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DYNAMICS OF THE BRAZIL-MALVINAS CONFLUENCE

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INTRODUCTION

In this work, we investigated the mesoscale dynamics of the Brazil-Malvinas Confluence (BMC), using both theoretical and numerical modeling.

The BMC region is a key region for climate studies, and the comprehension of its dynamics is crucial for the development of more accurate climate predictions, mainly in the southern hemisphere.

We were particularly interested in the role of geophysical instability in the formation and development of the mesoscale features commonly observed in this region.

Figure 1 presents a satellite AVHRR image showing the confluence, occurring around 38°S, of the Brazil Current, flowing southwest and carrying warm waters (hot colors), with the Malvinas Current, that carries cold waters (cold colors), and flows northeast.

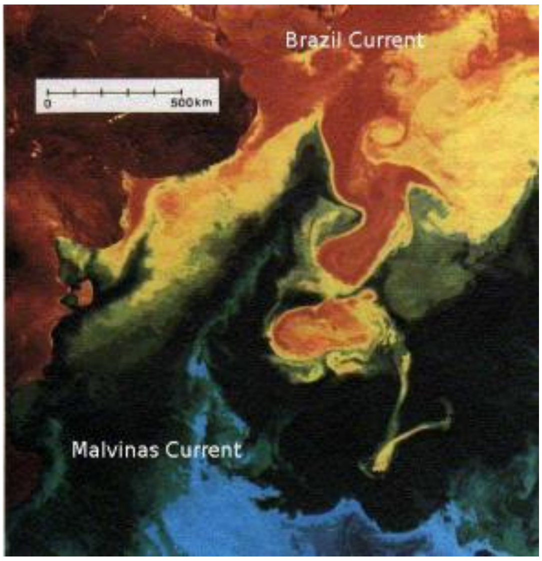

Figure 1 – AVHRR image showing the Brazil-Malvinas Confluence region. Edited from [1].

DYNAMICAL MODELING

We dinamically analyzed the results of numerical simulations of the CBM region conducted with 'Hybrid Coordinate Ocean Model" (HYCOM).

Initially, we used a coarse grid resolution of 1/3° and 21 layers for the Atlantic Basin, around 60° N and 65° S, using wind and ocean climatologies given by [2] and [3]. After 25 years, a 1/12° grid is implemented for the southwest region of the Atlantic Ocean, located between 30° S and 45° S and 60° W and 45° W. This high resolution simulation was computed for 1 year, using the same climatological conditions used in the coarse resolution simulation

Analyzing the dynamical fields obtained through the simulations, we verified that the necessary conditions for instability to occur in the modeled flow were satisfied, following Arnol'd's theorem [4].

In order to explore the main results of the dynamical analysis of HYCOM simulations, we constructed theoretical process study models. We isolated the baroclinic instability effect on the mesoscale dynamics of the confluence of two western boundary currents using a quasi-geostrophic, inviscid f-plane two-layer ocean approach.

THEORETICAL MODELING OF THE INSTABILITY PROCESS

We calculated the simplified vertical structure through employing a dynamical calibration scheme based on the first dynamical mode structure of the BMC region.

We constructed two Contour Dynamics (DC) [5] models for a layered ocean: a linear and a nonlinear version, based o potential vorticity (PV) conservation,

$$D_t\, q_i = [\, \partial_t + u_i \partial_x + v_i \partial_y]\, q_i = 0, \qquad (1)$$

where q_i represents the PV field in each layer, and D_t is the material derivative.

The basic flow configuration consisted of two converging western boundary currents that form a zonal eastward jet in the upper layer. The lower layer flow was essentially divergent as a result of a westward zonal jet impinging on the western border. This choice of vertical shear, showed in Figure 2, assured that the system was baroclinically unstable.

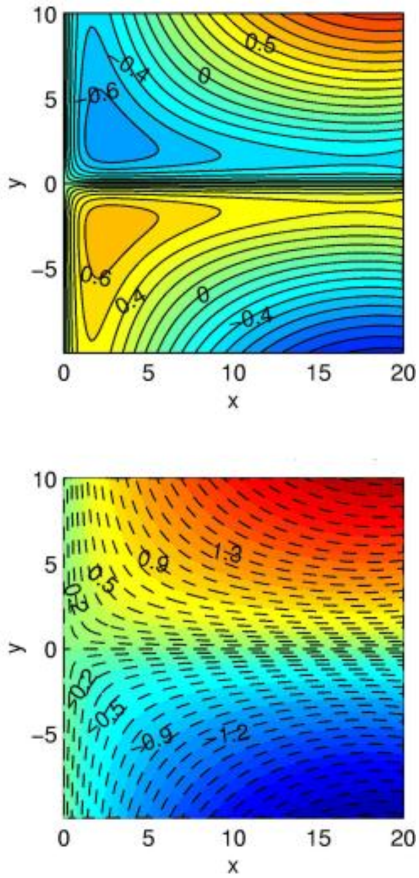

Figure 2 – Streamfunction amplitude for layers 1 (upper panel) and 2 (lower panel).

EDDY-MEAN FLOW INTERACTIONS

Finally, we investigated the effect of isolated eddies, assumed to be previously shed from the BMC region, on the mean flow through the development of a third CD model.

We intended with this study to confirm that the effect of barotropic forces, on the mean flow, was to induce vorticity. We developed a 1-½ layer quasi-geostrophic, inviscid, f -plane CD model of the confluence of two simmetric western boundary currents. These currents interacted with a cyclonic point vortex, located in the BC domain, and an anticyclonic point vortex, located in the MC domain. We runned six experiments where we varied the initial position and circulation intensity of the point vortices.

CONCLUSIONS

We quantified the effect of barotropic and baroclinic instabilities in the modeled flow and showed the dominance of the latter in the region.

Also, we studied the wave-mean flow interactions and verified that baroclinic eddy forces were associated with the deformation of the flow while barotropic eddy forces induced vorticity.

These results lead us to formulate a theoretical model, aiming to quantify the role of baroclinic instability effect on the BMC flow.

We showed through our experiments that the presence of the confluence, the western meridional boundary and the barotropic mode in the dynamical structure of the basic flow favored long wave patterns.

Three experiments were conducted with the nonlinear model, exhibiting the development of both a reflection pattern and vortical dipoles. The dipoles pinched off from either the retroflection lobe (i.e, the primary crest of the wave train) or the primary trough when the baroclinically unstable current system was perturbed at the boundary vicinities.

We verified that the nonlinear model simulations followed the instability properties predicted by the linear model in terms of meander growth rates, phase speeds and most unstable wavelengths. This suggested that while the baroclinic instability mechanism was responsible for the temporal growth of the meanders, the nonlinear effects caused the dipole isolation and pinch-off of the finite amplitude meanders.

These dipoles could leave and propagate away from the current axis.

So we can expect that, once the vortices are detached from the meandering flow, they should interact with it. In order to verify how this interaction could occur, we developed a 1-½ layer CD model, with two point vortices of opposed sign interacting with a PV front.

We observed vortex formation due to the roll-up of the PV front around the point vortices, and the formation of dipoles, and meanders without a defined pattern. The formation of these structures strongly depended on the initial conditions.

The interactions seemed to agree with former results that pointed out the role of eddy momentum forces in inducing vorticity in the flow. They also revealed the occurrence of strong exchanges of waters between the two domains of different potential vorticity, mainly during the events of the front roll-up around the point eddy structures.

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