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Instability Processes in the Brazil-Malvinas Confluence

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Abstract
In this work, we investigated the mesoscale dynamics of the Brazil-Malvinas Confluence (BMC). Particularly, we were interested in the role of geophysical instability in the formation and development of the mesoscale features commonly observed in this region.
We dynamically analyzed the results of numerical simulations of the BMC region conducted with the "Hybrid Coordinate Ocean Model" (HYCOM). We verified that the necessary conditions for instability to occur were satisfied in the modeled flow, following Arnol'd's instability theorem for nonparallel flows. Additionally, we quantified the effect of barotropic and baroclinic instabilities, which revealed the dominance of the latter phenomenon in the region.

Keywords: Brazil-Malvinas Confluence, energy conversion processes, HYCOM simulations.

Introduction
The motivation for this study is the intense mesoscale activity commonly observed in the Brazil-Malvinas Confluence (BMC) region, which is characterized by the confluence, around 38° S, of the warm waters carried by the Brazil Current (BC) and the cold waters carried by the Malvinas Current (MC). As a result of this confluence, we have the formation of a quasi-zonal flow that often retroflects and sheds both warm and cold core rings within and nearby the western boundary layer.

The processes that lead to the formation of the retroflection pattern and eddy-shedding are akin to occur via geophysical instability process. Moreover, analytical contour dynamics models constructed by Francisco & Silveira [2004], allowing only the baroclinic instability mechanism, exhibited the development of both retroflection pattern and baroclinic vortical dipole formation. The authors verified that dipoles were 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. Particularly, their results showed that dipole formation occurs at the boundary vicinities, when unstable waves propagate phase westward.

Formulation
As the theoretical results obtained by Francisco & Silveira [2004] pointed that the baroclinic instability could be the source of meander growing in the BMC region, we performed, in this study, a energy conversion analysis of the flow using the numerical simulation outputs of

HYCOM. The intent was to account for the effects of both baroclinic instability and also barotropic instability, not possible in the Francisco & Silveira [2004] more idealized study.

The implementation of HYCOM, for the study region followed Campos [2006]. First, a 21-layers coarser resolution (1/3-degree) version for the entire Atlantic Basin, from 65°S to 60°N, was forced with monthly mean winds, obtained from COADS base, and initialized with Levitus climatological hydrography (Boyer et al., 2005). This initial configuration was run for 25 years. After such period a one-way nesting with 1/12-degree resolution and 21 layers was implemented for the western South Atlantic region delimited by the latitudes 30°S and 45°S and the longitudes 60° W and 45° W.

The nested model was run for one full year, forced with the same COADS climatological data and lateral boundary conditions provided by the coarse resolution model, using a 20 grid-points relaxation.

The BMC flow was obtained using the nested modeled year average and the corresponding 26th year data of simulation of the whole domain generated by HYCOM, for the fields of velocity, temperature and salinity. Those fields compared well with the observed data.

Particularly, the velocity field clearly showed the intense vortical activity associated with the BMC front, showing the presence of two large anticyclonic structures in both sides of the confluence.

With the dynamical fields of the modeled BMC we performed the energy conversion calculations utilizing the method developed by Cronin & Watts [1996] and obtaining both baroclinic and barotropic energy conversion maps for all depths of the flow.

Discussion and Conclusions

The results of energy conversion calculations showed that both barotropic and baroclinic energy conversions occur in the region leading to meander growth of the BMC system, but were concentrated in different locations. Furthermore, the baroclinic conversion was about 10 times greater than the barotropic one. Therefore, we concluded that in the sites where energy conversions took place, the baroclinic conversion mechanism was primarily responsible for the formation of unstable wave patterns observed in the region. The barotropic conversion occured mainly in the borders of the current and eddies, converting mean kinetic energy into eddy kinetic energy in these locations.

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