Numerical Modelling of Small Scale Processes on the Southern Brazilian Inner Shelf

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Introduction

The Southern Brazilian Shelf (SBS) is an environment with unique characteristics. It is characterized by a large continental shelf, extending between 28°S and 35°S, being majority influenced by the presence of two western boundary currents, the Brazil and Malvinas currents, respectively. The influence of the two major freshwater sources, the Patos Lagoon and the La Plata River, is also important on the region dynamics due to the buoyancy driven circulation caused by their freshwater plumes. The attention is given to the Tramandaí-Imbé region because the presence of oil capturing buoys where oils spill are frequent and may interact with the structures analyzed in this work.

This work presents the results obtained for the coastal circulation off the coast of the mid-to-northern portion of the SBS during summer of 2012. Several small-scale features could be observed such as bottom-induced eddies, episodes of intense vertical circulation and short-term wind-driven circulation patterns. These phenomenon can have important effects in the coastal area, triggering episodes of high biological production or even carrying oil from nearby spill.

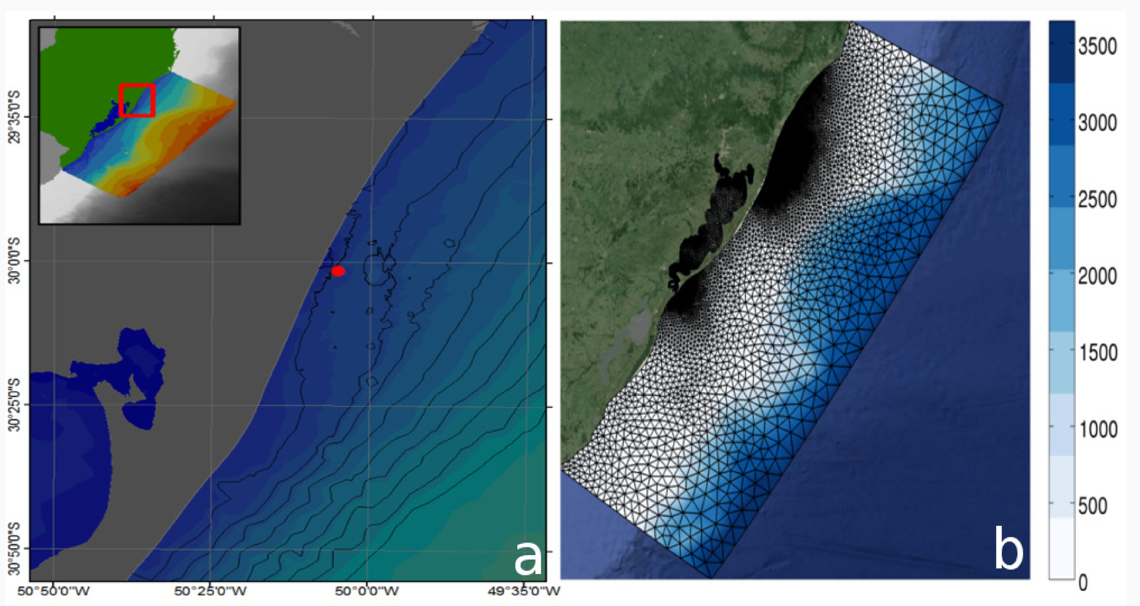

Figure 1: a) Study Region: the mid-northern region of the SBS with contour lines spaced by 10 meters. The red dot indicates the position of an oil capturing buoy. b) Numerical domain and the finite element mesh with greater resolution in the mid-northern region and near the Patos Lagoon mouth.

Material and Methods

The three-dimensional finite-element model Telemac3D model (http://www.opentelemac.org) was chosen to investigate the small-scale circulation of the SBS. This model solves the Navier-Stokes equations considering the local variation of the free surface, ignoring the density variation in the mass conservation equation and considering the Boussinesq approximation to solve the momentum equations [1].

A domain performed by 771694 triangular elements within fifteen sigma levels was built in order to represent the coastal portion of the SBS (figure 1-b). The discretization provides a resolution around 100 metres in the coastal region near Tramandaí beach. The oceanic boundary conditions are given by the Hybrid Coordinate Model (HYCOM) and the Grenoble Tidal Model. The freshwater discharge values are from the Brazilian Water Agency and the atmospheric conditions (winds and air temperature) are from NCEP Reanalysis data sets.

Bibliography

[1] Hervouet, J. M. (2007). Free surface flows: Modelling with finite element methods.

[2] Jacobs, P., Guo, Y., and Davies, P. A. (1999). Boundary currents over shelf and slope topography.

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Results and Discussion

The Hovmoller diagram in the figure 2 represents the temporal variability of the vertical circulation near the location indicated by the red dot in the figure 1-a. At this location, there is a regular pattern during almost the whole simulation with small (high) current velocities following periods of low (strong) wind action, respectively. There is an intense episode of vertical circulation at thirteenth day along the water depth and other minor events on the eighth, tenth and twenty-second days. Analyzing the evolution the current and sea surface fields it is possible to observe several small scale eddies being formed which induces the vertical movement of the water masses. The panel in the figure 3 shows the evolution of one these eddies.

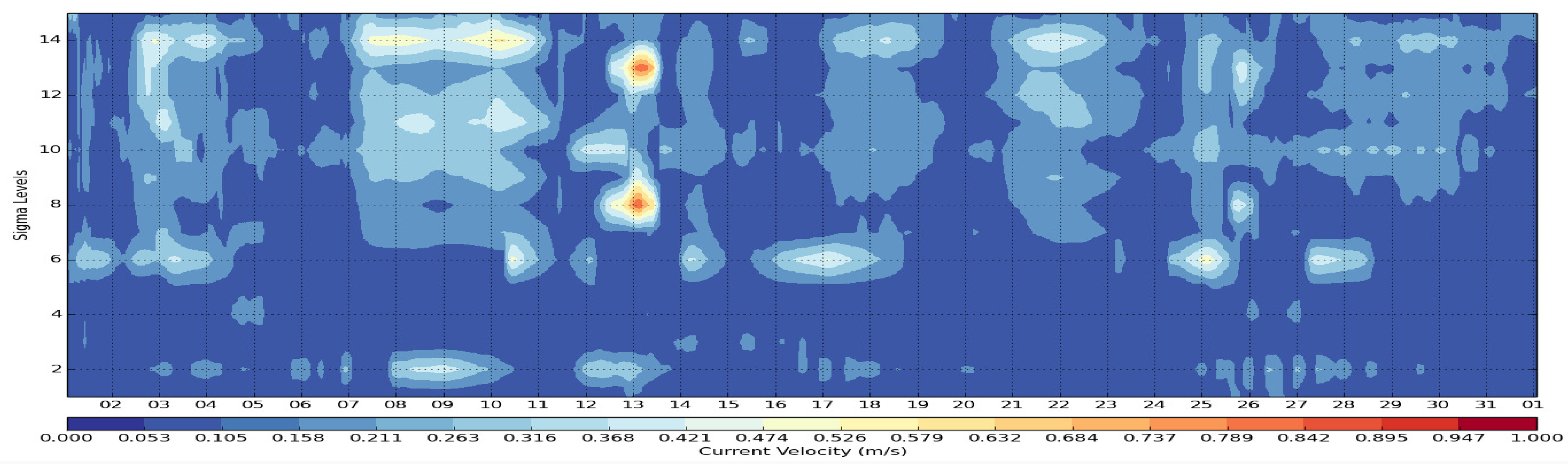

Figure 2: Hovmoller (time x depth) diagram for the simulation period showing intense episodes of vertical circulation triggered by bottom induced.

The explanation to the occurrence of these eddies relies on the changing of bottom topography (figure 1a) which could lead to variations on the flux, modifying the potential vorticity and consequently creating these eddies. Moreover, the changes in the wind direction due to the frontal systems passage also may induce an increase in the potential vorticity and create those structures. Jacobs et al. [2] conduced laboratory experimental studies to evaluate the influence of the bottom slope on the dynamics of a stratified fluids. These authors showed that in fluxes with large height above the shelf, the variations on the bottom topography increases the potential vorticity which leads the vertical circulation due to Eckman dynamics and also acts trapping the eddies onshore.

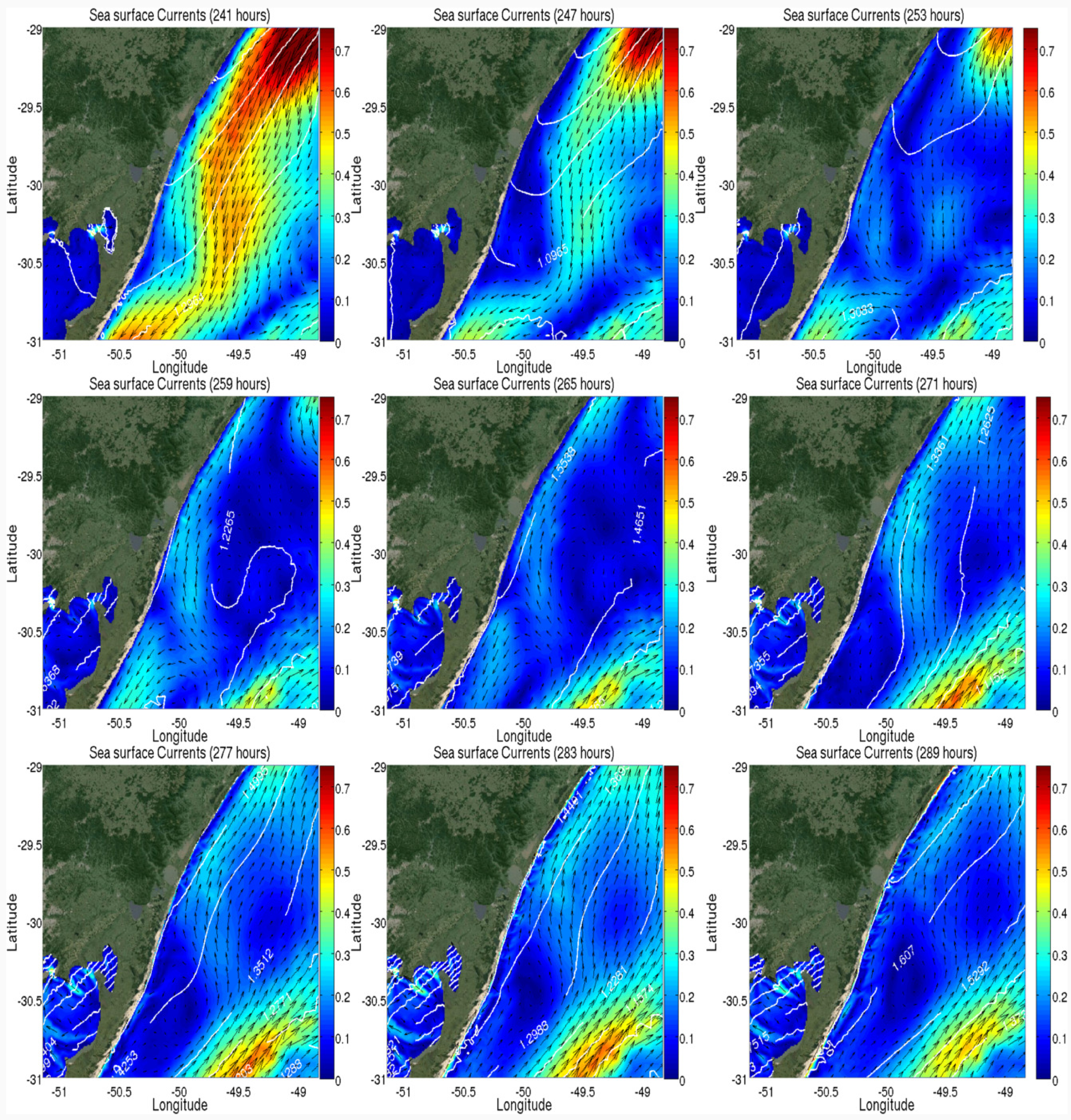

Figure 3: Snapshots of the Sea Surface Currents and Sea Surface Heights.

Final Considerations

The small scale process observed in this work seems to occur with certain frequency in this region following cycles from hours to weeks. The most probable causes are the combination of changes in the wind direction due to the frontal systems passage occurring over regions with complex bottom topography.

Acknowledgement

The authors are grateful to the Agência Nacional do Petróleo - ANP for the fellowship regarding the Programa de Recursos Humanos (PRH-27), the Fundação de Amparo à Pesquisa do Estado do Rio Grande do Sul (FAPERGS) and to the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for sponsoring this research under contracts: 179912-3, 456292/2013-6 and 305885/2013-8