Upwelling Processes along a Western Boundary Current: the Abrolhos Campos Region, Brazil

A. Aguiar[1,2], M. Cirano[1,2], J. Pereira[1,2] and M. Marta-Almeida[2,3]

1 – Programa de Pós-Graduação em Geofísica, Universidade Federal da Bahia, Salvador, Brazil
2 – Rede de Modelagem e Observação Oceanográfica / Grupo de Oceanografia Tropical
3 – Department of Oceanography, Texas A&M University, College Station, TX, Texas, EUA

alexlaguiar@yahoo.com.br

ID 3.1.2

1 – Introduction

Upwelling mechanisms are generally classified in two categories: wind-driven and current-driven. The wind-driven upwelling can occur due to Ekman transport and Ekman pumping. Concerning current-drive upwelling, a WBC can interact with the coastal system in terms of promoting or enhancing upwelling.

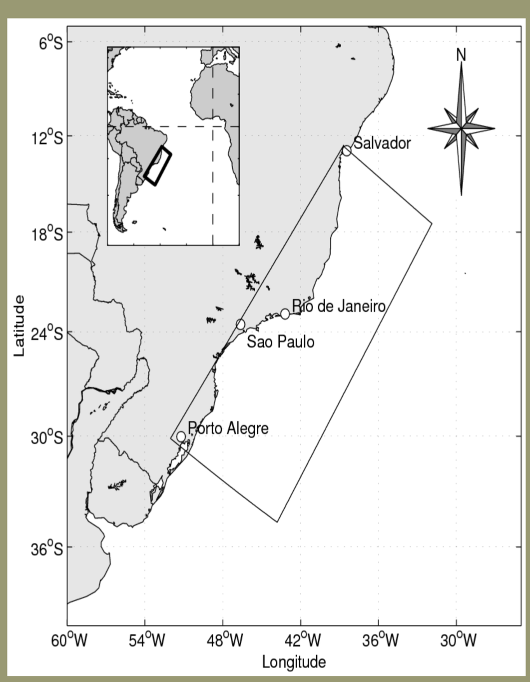

Figure 1: Model domain indicated by the rectangle (Marta-Almeida et al, 2011).

In order to study upwelling processes and their mechanisms, a Regional Ocean Model System (ROMS) simulation for the Brazilian coast south of 13°S was used (Figure 1). This study was done in the scope of the Oceanographic Modeling and Research Network (with Portuguese acronym REMO).

2 – Methodology

The Abrolhos-Campos Region (ACR), extending from 15°S to 23°S, is a division of the Brazilian Continental Shelf adopted by Castro and Miranda (1998). The SST data employed was a product from REMO produced daily with a 5.55 km spatial resolution. ROMS simulations had atmospheric forcing from NCEP2 (spin-up phase, 2003 - 2008) and GFS (operational phase, 2009 - 2011). Three cross-shore sections were chosen: Prado (PRA) at 17°S, Marataízes (MRT) at 21°S and Cabo Frio (CBF) at 23°S (Figure 2). In order to estimate the role of each upwelling mechanism in the ACR, the following upwelling indices (UI) were established (Table 1):

Wind-driven UI	Current-driven UI
Ekman Transport (T_{ek})	BC intensification (BC_{intens})
	BC proximity (BC_{prox})
	BC separation (BC_{sep})
Ekman Pumping (T_{pump})	Shelf-break upwelling (T_{shelf})
	Cyclonic eddy ($Eddy_c$)

Table 1: Wind-driven and current-driven upwelling indices.

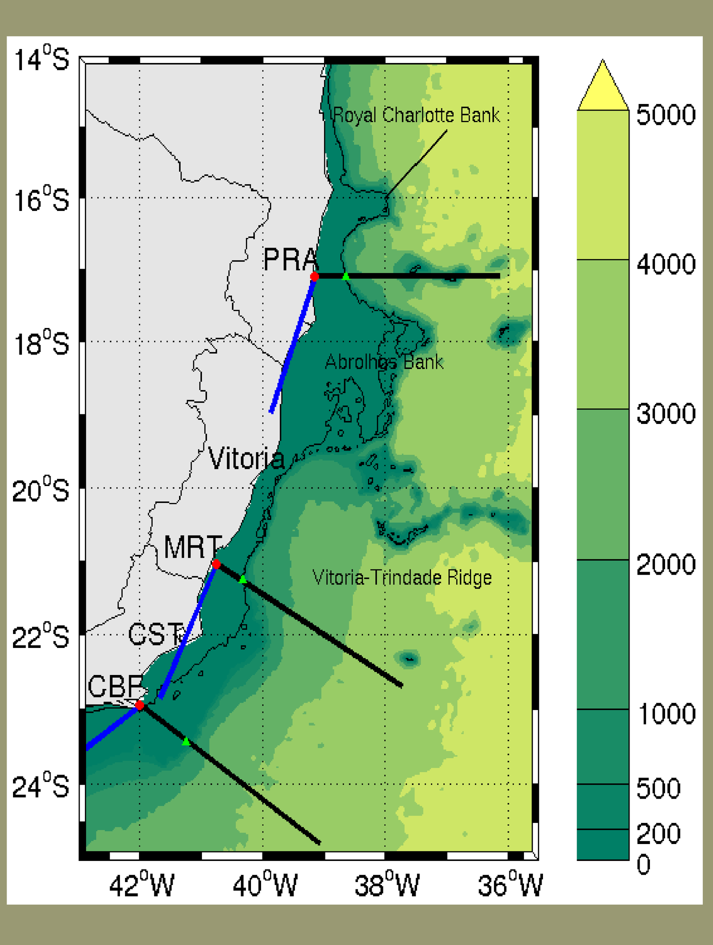

Figure 2: Bathymetry for ACR with the 50 m isobath (light black line) and the three radials. The blue lines indicate the alongshore wind orientation. The red dots (green triangles) indicate the most onshore grid point (shelf-break position). The abbreviations indicate the following locations: Prado (PRA), Marataízes (MRT), Cabo de São Tome (CST) and Cabo Frio (CBF).

3 – Upwelling Mechanisms

Figure 3 shows the SST and the identified events for each section. The occurrence of events increases southward from 10 events in PRA, to 18 events in MRT and 22 events in CBF. More than 90% of events occurred with T_{tot} being upwelling favorable, in all the 3 sections (Figure 4a). In MRT, T_{ek} influence on events percentage is 100% and its average magnitude during the events is twice the amount of T_{pump} (Figure 4b). In PRA, T_{ek} presents a higher percentage, but both T_{ek} and T_{pump} have approximately the same intensity. In CBF, T_{pump} is qualitatively and quantitatively more important than T_{ek}, thus Ekman pumping is clearly the predominant wind-driven upwelling mechanism, what is in good agreement with Castelão and Barth (2006).

Concerning the proposed current-driven upwelling mechanisms, BC encroachment (favorable BC_{intens} and favorable BC_{prox}) is predominant during events in MRT (Figure 5). In PRA and CBF, however, the meander/eddy mechanism (favorable BC_{sep} or favorable $Eddy_C$) plays a more important role during the events. PRA events are predominantly influenced only by BC meanders, while, in CBF, both meanders and eddies are key features in promoting current-driven upwelling. As it can be seen, current-driven upwelling intensity and frequency varies depending on the section. The BC dynamic characteristics studied, through current-driven UIs, appear to be mostly determined by alongshore changes in bottom topography. This findings agrees with the studies of Rodrigues and Lorenzetti (2001) and Palma and Matano (2009).

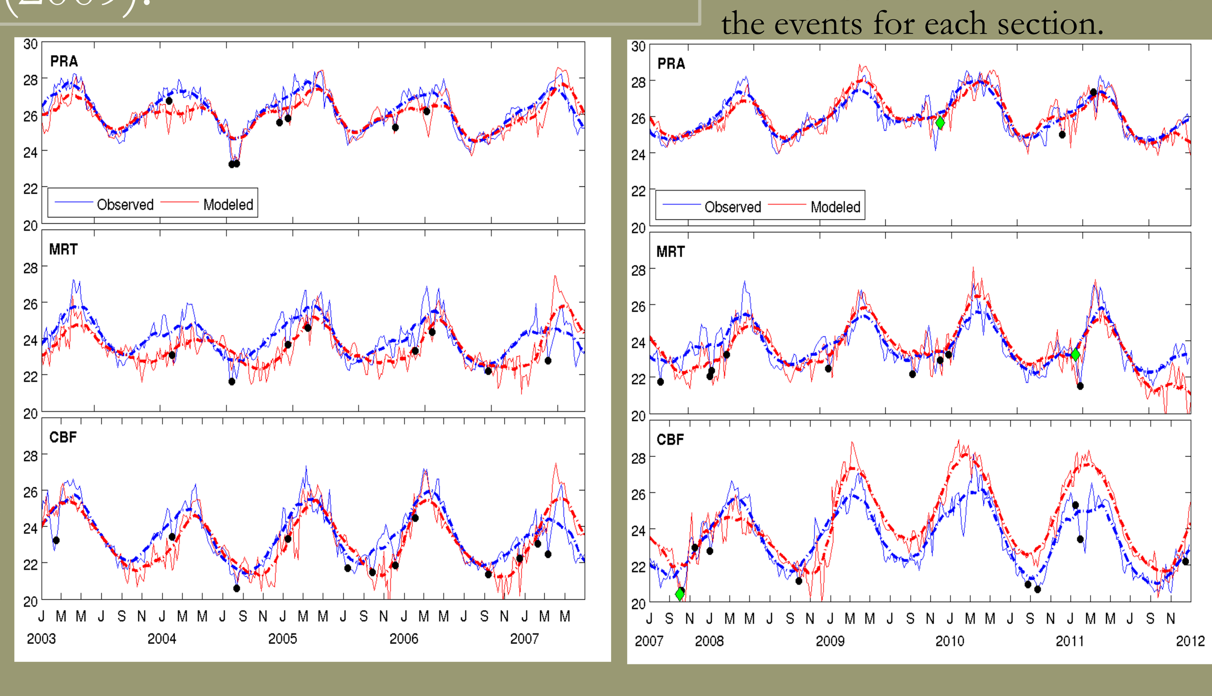

Figure 3: Time series of the observed (blue) and modeled (red) SST at the coastal region of PRA (upper panel), MRT (middle panel) and CBF (lower panel). The solid line (dashed line) represents a 5 day average (90 day running mean). Upwelling events are marked by black circles. The case study event is marked by a green diamond.

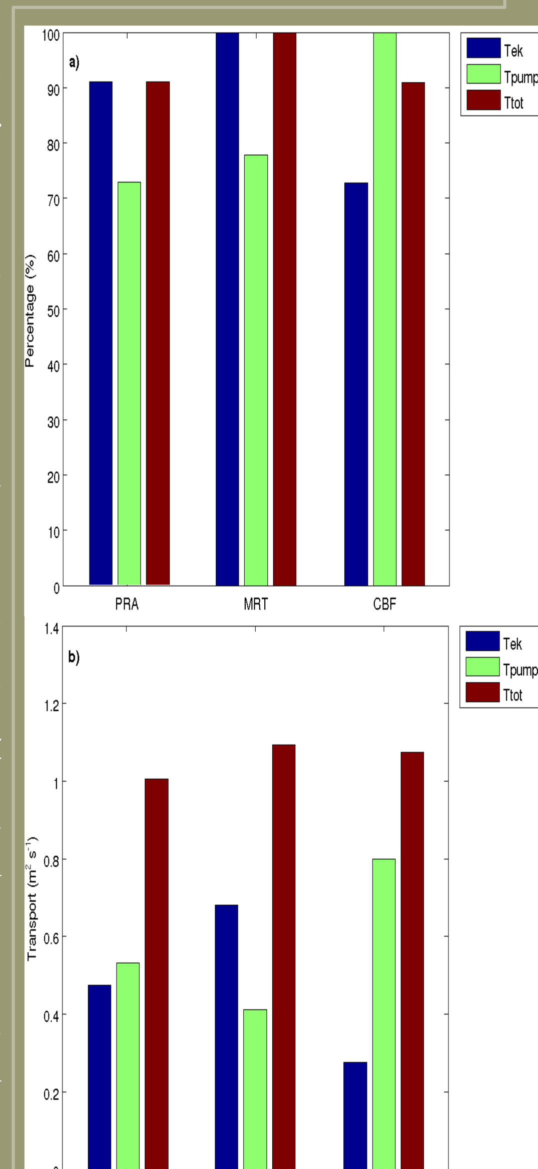

Figure 4: Wind-driven upwelling mechanisms: a) percentage of influence on the events and b) average transport (m^2/s) during the events for each section.

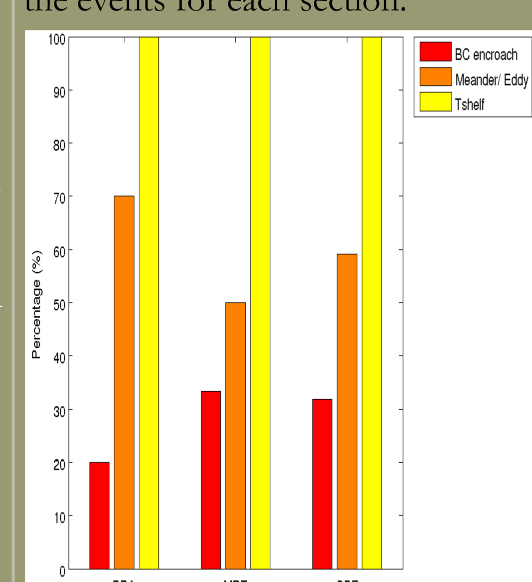

Figure 5: Percentage of influence of the current-driven upwelling mechanisms during the events for each section.

4 – Case study

Upwelling favorable northeast wind field (Figure 6a) and the presence of a cyclonic eddy (Figure 6b) are noticed during the event. Figure 6 (c,d) shows 3 stages for the upwelling occurred in 20th January 2011. In 31st December 2010, a shelf-break upwelling is taking place. The isotherm of 20°C reaches the depth of 50 m. In 7th January 2011, the South Atlantic Central Water (SACW) occupies the inner shelf and, finally, outcrops to the surface at 20th January 2011. With regard to the current-driven upwelling, the BC speed increases up to 0.8 m/s and the cyclonic eddy grows while moving onshore as the upwelling evolves to its peak stage.

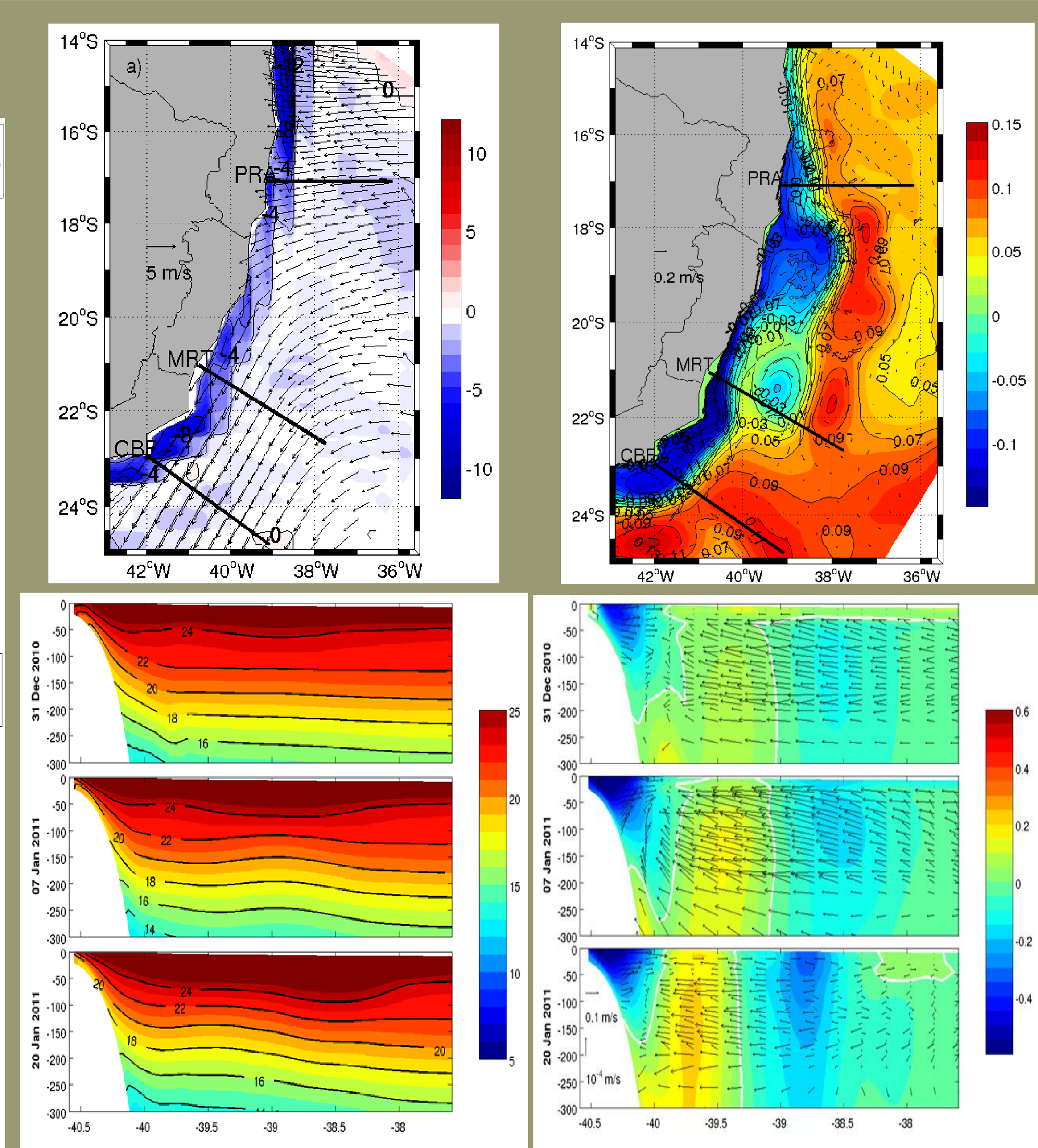

Figure 6: a)Wind and b) Sea Surface Height during the peak stage of the case study upwelling event. The interval between isolines is a) 0.5 m/s and b) 0.02 m. Cross-shore section of the c) temperature and d) velocity during the a previous (above), intermediate (center) and a peak (below) stages of the case study upwelling event along the MRT section. The interval between isolines is c) 2°C and d) 0.05 m/s.

5 – Conclusion

Concerning wind-driven upwelling mechanisms, Ekman transport is predominant along the northern portion of the ACR, while Ekman pumping tends to prevail in the south portion of the ACR, where changes in the coastline orientation are more noticeable. As a complementary part of the process, our results show the main role of the topographically induced upwelling among the current-driven mechanisms in the ACR.

References

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