WIND STRESS DIVERGENCE OVER THE COASTAL OCEAN OFF RIO DE JANEIRO

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ABSTRACT

Time and spatial variability of along-shelf wind stress divergence are investigated for the first time off Cabo Frio upwelling region, Brazil. Orographic effects and the passage of frontal systems seem to introduce the observed mesoscale variability of wind stress along the coast, which in turn may have important outcomes on the coastal ocean circulation and dynamics. Over 5 years of wind stress data from both *in situ* and remote sensing platforms are analyzed in time, space and frequency domains.

Keywords: *Cabo Frio, coastal upwelling, wind stress divergence*.

1 INTRODUCTION

Considering that wind stress is one of the major low-frequency forcing mechanisms to the coastal ocean circulation, understanding its dynamics is a fundamental task to clarify most of the three-dimensional oceanic flow responses. Derivatives of the wind field such as the wind stress curl and divergence aids on characterizing the state and behavior of wind spatial variability. Wind stress curl is an important mechanism on triggering vertical velocities in the ocean by Ekman pumping, while divergence may also play an important role, creating horizontal shear of ocean currents, and imprinting either divergence or convergence states on sea surface flow while setting spatial sea surface height variability. In coastal regions where significant continental topographic features are present and large scale atmospheric systems dominate regional dynamics, wind stress curl and divergence are recurrent and may play a significant role in regional coastal ocean circulation (Figure 1).

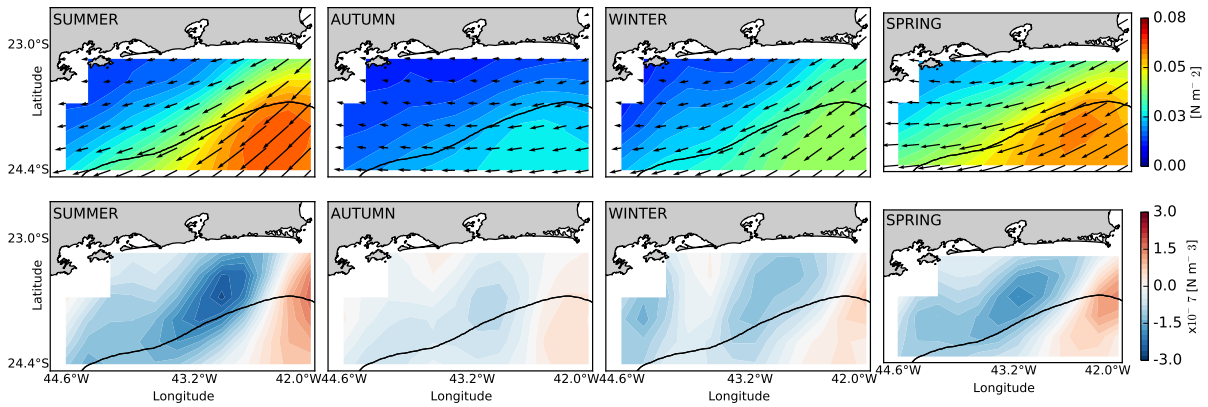

Figure 1: Seasonally-averaged zonal wind stress magnitude overlaid by wind stress vectors (upper panel) and zonal wind stress divergence field (lower panel). The black line represents the 200 m isobath, derived from Brazilian Navy digitized nautical charts, denoting shelf break limits

Castelão and Barth (2006) investigated the role of wind stress curl off Cabo Frio (RJ) and found that it enhances the coastal upwelling. On the other hand, wind stress temporal and spatial variability are responsible for the attenuation of coastal upwelling either by downwelling dynamics associated with frontal atmospheric systems [*Carbonel, 2003*] or by remotely forced warm water intrusions at the upwelling site during upwelling-favorable wind events [*Couto and Soutelino*, 2014]. The latter suggests that zonal variability in the wind field may control sub-inertial sea surface height variability and remote flow responses at the inner continental shelf waters off the south coast of Rio de Janeiro.

2 OBJECTIVES

The objective of the present study is to quantify upwelling-favorable zonal wind stress divergence field and its time variability off Rio de Janeiro.

3 METHODOLOGY

Two distinct datasets are used.

- A 6-year (2008-2014) hourly time series of *in situ* data from three meteorological stations along the coast of Rio de Janeiro: Marambaia, Forte de Copacabana and Arraial do Cabo, obtained from the INMET (Instituto Nacional de Meteorologia);

- a 5-year (2008-2013) gridded daily-averaged wind stress obtained from IFREMER (The Institut français de recherche pour l'exploitation de la mer). The wind stress product has a spatial resolution of 0.25°, and was obtained by combining ASCAT (Advanced SCATterometer) observations and ECMWF (European Center for Medium range Weather Forecasting) analyses.

Monthly climatology of zonal wind stress and zonal wind stress divergence were quantified. Frequency-domain analysis for each station were done by estimating the Power Spectral Density (PSD) for zonal wind stress and divergence, using Welch's method. Zonal wind stress divergence was estimated from Arraial do Cabo and Rio de Janeiro data.

4 RESULTS

Alongshore variability of wind stress magnitude between the three stations are evident (Figure 2). Monthly-averaged wind stress magnitude at Arraial do Cabo are much higher than those observed west at Rio de Janeiro and Marambaia stations for each month. Following that pattern, wind stress divergence presented negative values, indicating zonal convergence of the wind stress.

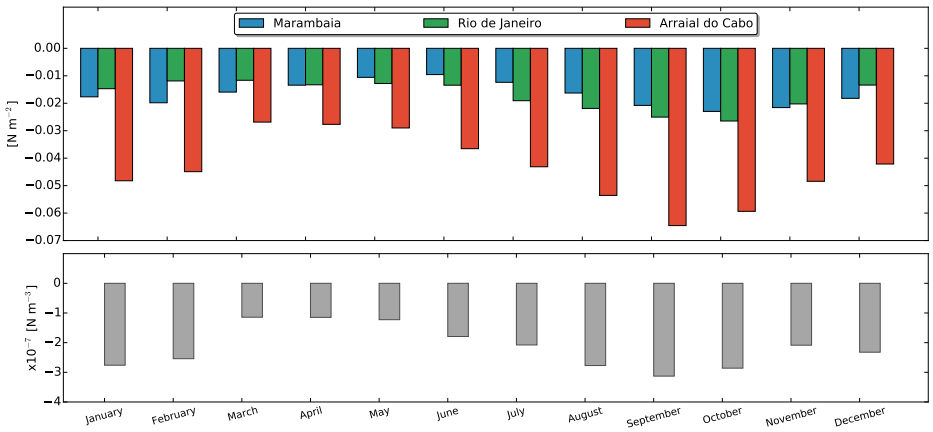

Figure 2: Monthly-averaged zonal wind stress magnitude (upper panel) and zonal wind stress divergence (lower panel) estimated from Arraial do Cabo and Rio de Janeiro time series.

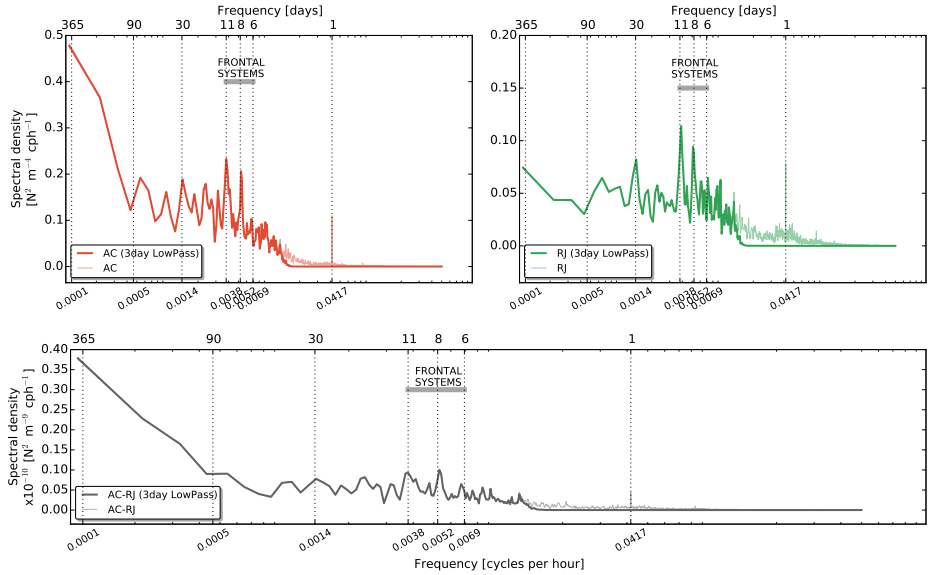

Figure 3: Power spectrum density of zonal wind stress timeseries at Arraial do Cabo (AC, red) and Rio de Janeiro (RJ, green) are shown at left and right upper panel, respectively. Wind stress divergence (AC - RJ, grey) is shown at lower panel. Frontal systems frequency band are the same observed by *Stech and Lorenzzetti* (1992)

Four main peaks can be seen from the PSD on Figure 3. Major oscillations are due to sea breeze effects (1 day) and frontal systems passage (6-11 days). Major peaks for the divergence spectrum are also centered on the daily and 6-11 days bands.

5 CONCLUSIONS

Wind stress convergence seems to predominate over the shelf off Arraial do Cabo, showing a gradual decay of upwelling-favorable wind stress magnitude towards West. Positive values are noted mostly upwind the cape, suggesting that zonal wind stress intensifies as it bends through the cape. Further studies will investigate the role of wind stress divergence on continental shelf flow responses through semi-idealized numerical experiments using the Regional Ocean Modeling System (ROMS).

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