Interannual variability of the Brazil Current assessed using observations and model simulations

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1. Summary

The Brazil Current (BC) is the only western boundary current in the South Atlantic Ocean, and carries the warm and salty upper South Atlantic water southward. Therefore, its variability has a large influence on the South Atlantic meridional overturning circulation (SAMOC). Although the BC is the South Atlantic counterpart of the Gulf Stream, it is much weaker than the Gulf Stream due to the opposing northward flow of the SAMOC. Nevertheless, the BC displays strong variability at interannual and longer time scales. Here, we use XBT and altimetry data to present new daily estimates of the BC in the shelf and the deep ocean region along 22°S for the 1992-2015 periods **(Figures 1 and 2)**. There is a good agreement between the reconstructed and observed BC transport **(Figure 3)**. In the summer of 2009-2010, the persistent anticyclonic wind anomalies over the subtropical South Atlantic strengthened the subtropical gyre and thus the BC current **(Figure 4)**. The strengthen BC current in turn carried the warm SST anomalies southward from ~20°S to 34°S along the Brazil coast, and also increased the upwelling near the coast **(Figures 4 and 5)**. The wind pattern and associated upwelling are captured in the high resolution coupled simulations, but not well simulated in the low-resolution simulation **(Figure 6 and 9)**. The warm SST anomalies in the western subtropical South Atlantic associated with the increased subtropical gyre and the BC current are closely linked to the summer precipitation in the Southeast Brazil **(Figures 7 and 8),** and also associated with remote teleconnections**.** Currently, we are analyzing four global ocean model experiments that are forced with either climatological or historical surface forcing fields in different ocean basins **(Table 1 and Figure 10)**. To analyze the local and remote forcing of the BC variability. Preliminary results show the link between the gyre and BC strength (**Figure 11**), and potentially remote influences from the Pacific.

2.1 BC across 22°S using an XBT transect

A reconstruction of the Brazil Current (BC) from 1993 to 2015 at 22°S is performed using 51 realizations of the AX97 transect (Rio de Janeiro to Trindade Island; Fig. 1) and daily, gridded altimetric sea surface height from AVISO (http://marine.copernicus.edu).

There is good agreement between the absolute dynamic height derived from XBTs and the sea surface height from altimetry.

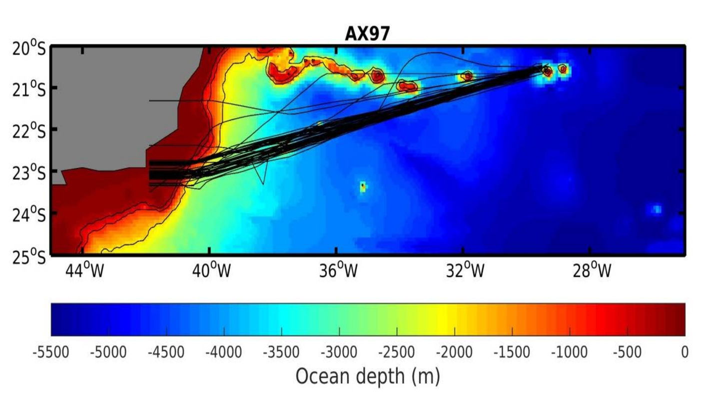


Figure 1: Location of the AX97 transects overlaid at regional bathymetry.

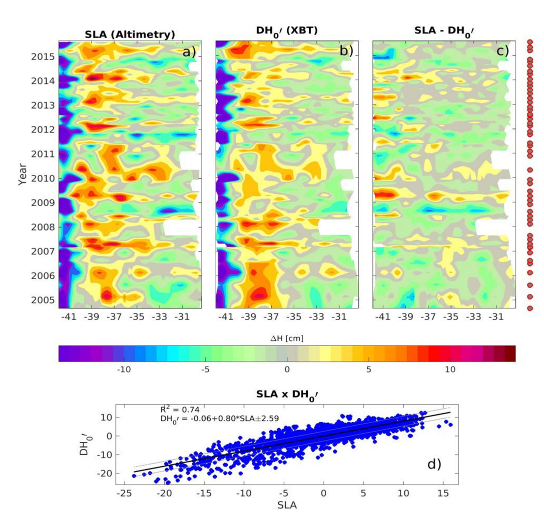
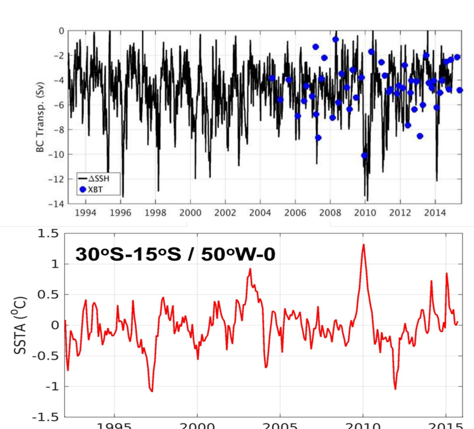


Figure 2: Comparison between sea level anomalies from altimetry and absolute dynamic height from XBTs.

2.2 BC variability from observations

Figure 3: There is good agreement between the reconstruction and the XBT transport estimates and the BC transport seasonal cycle. One event of 2009-2010 is studied, and the BC dynamics is associated with the strong SST anomaly in the region, which could impact the summer precipitation in the Southeast Brazil.



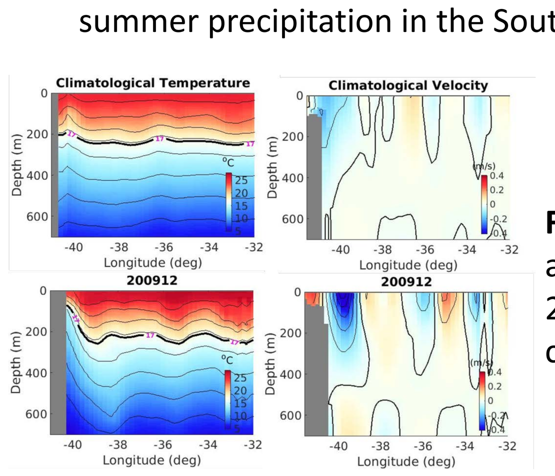


Figure 4: Comparison of DJF climatology of temperature and meridional velocity from XBT with the December 2009 section. There is a strengthening of the BC and coastal upwelling during the 2009-2010 event.

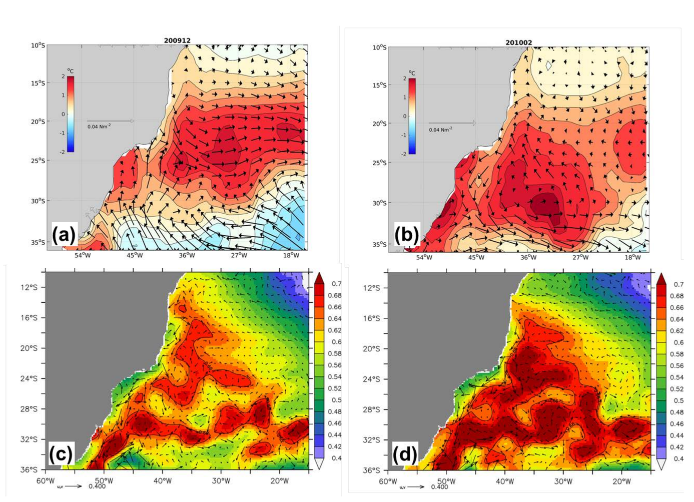


Figure 5: (top) SSTA and Tau anomalies for Dec 2009 and Feb 2010. (bottom) SSA and upper ocean velocities for the same period. The warm anomalies propagated from ~20°S to 34°S during a 2 month period. Wind anomalies are anticyclonic around the SSTA in Feb 2010. There is a strengthening of the whole subtropical gyre during that period.

3.1 Air-sea interaction in a high-res model

To study the air-sea interaction in the western South Atlantic, two simulations are examined using the National Center for Atmospheric Research (NCAR) Community Climate System Model (CCSM4), consisting of atmosphere, ocean, land, and sea ice components in a fully coupled configuration. The atmospheric model is configured at a 0.5° latitude × 0.625° longitude horizontal grid, and the ocean component is based on the POP2 model with 42 vertical levels. The simulations are:

- **LR:** is a present-day global climate simulation using a coarse 1° resolution ocean (Kirtman et al., 2012).
- **HR:** present-day global climate simulation using a high-resolution 0.1° ocean and sea ice component models (Bryan et al., 2010; Kirtman et al., 2012; Siqueira and Kirtman, 2016).

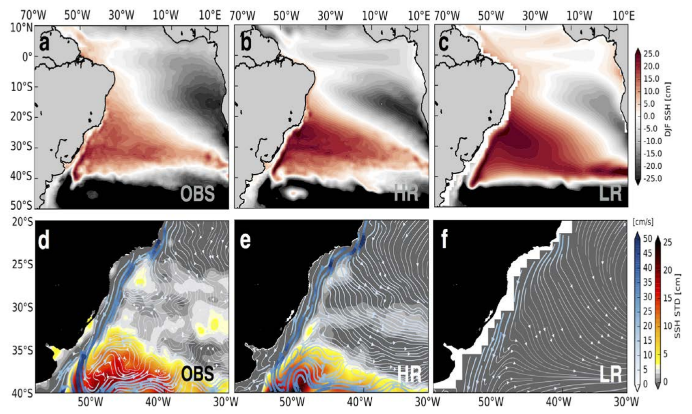


Figure 6: Top: South Atlantic DJF sea surface height climatology of **(a)** AVISO and drifter observations, **(b)** HR model, and **(c)** LR model. Bottom: WSSA DJF ocean velocities climatology and sea surface height variability of **(a)** AVISO and drifter observations, **(b)** HR model, and **(c)** LR model.

3.2 Warm SST composite and air-sea interaction in DJF

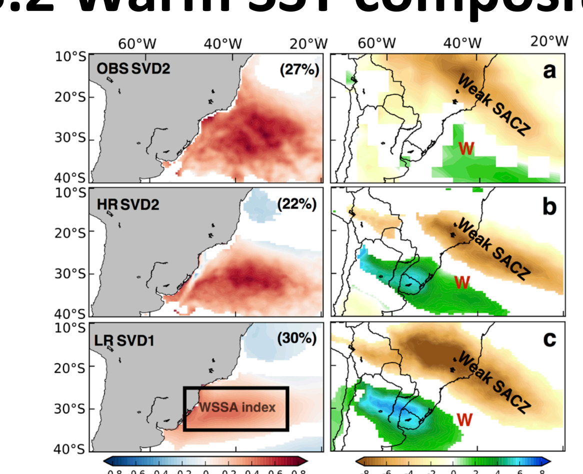


Figure 7: The second SVD mode in the observations (27%, Fig. 5a), agrees with the second mode in HR (22% SCF; Fig 5b), and the first mode in LR (30% of SCF; Fig 5c). This mode is associated with a north-south SACZ seesaw and cold-warm SSTAs in the western subtropical South Atlantic. This coupled mode has its strongest SST variance over the South Atlantic subtropical gyre, roughly centered at 25°S in the observational estimates (Fig.5a), while it appears at about 30°S in the HR and LR simulations (Fig.5b-c). The associated high cloud fraction pattern shows a clear dipole structure, with opposite values over SESA and over central-eastern Brazil near the mean axis of the convective activity in the SACZ (Fig.5a-c).

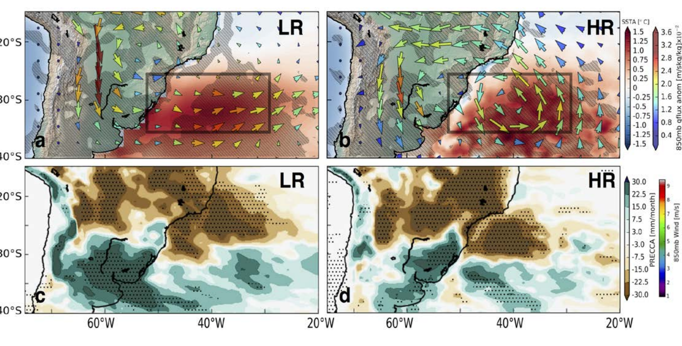


Figure 8: The warm WSSA composite is characterized by anomalous positive PRECC over the SESA region and negative PRECC anomalies over central and southeastern Brazil (Fig. 8c-d). Both LR and HR models show an anomalous low-level anticyclonic circulation that does not support the SACZ in its northward position, as indicated by the negative PRECC anomalies (Fig. 8c-d). The coastal upwelling in HR appears to be driven by more favorable southwestward anomalous atmospheric flow in HR (Fig. 8b).

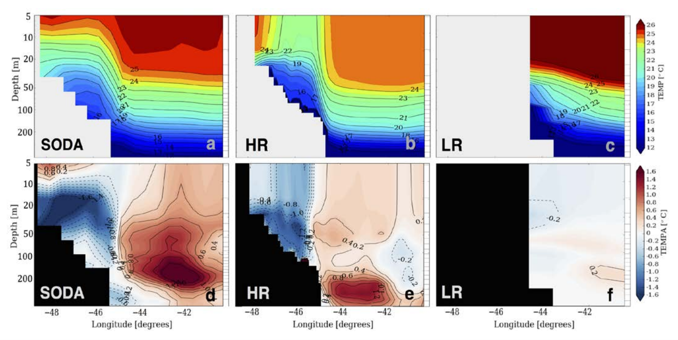


Figure 9: DJF climatological zonal temperature cross-section off the Brazilian continental shelf at 25°S for (a) SODA, (b) HR and (c) LR model, and respective warm composite anomalies (d-f). There is contrast in near-coastal dynamics between the two models and reanalysis. The LR model cannot resolve the Brazilian shelf waters and displays anomalously warm water all the way onto the coast. Both SODA and the HR model show cooler SACW along the shelf and upwelling near the coast. This upwelling appears to be driven by more favorable southwestward anomalous atmospheric flow in HR (Fig. 8) band and coastal bathymetry .

4.1 Ocean teleconnections using global model experiments

Experiment Name	Description
Spinup experiment (SPINUP)	Temperature and salinity initialized with World Ocean Atlas 2013; Forced with yearly randomized ERA Interim surface flux (1979-1996) over the global ocean.
Control experiment(CNTR)	Forced with historical ERA Interim surface fluxes (1979-2015) over the global ocean after the spinup experiment.
South Atlantic forcing experiment (SATL)	Historical surface forcing is applied only within the South Atlantic while the other regions are forced with climatology.
South Indian and Pacific forcing experiment(SIDP)	Historical surface forcing is applied only within the South Indian and Pacific while the other regions are forced with climatology.
North Atlantic forcing experiment (NATL)	Historical surface forcing is applied only within the North Atlantic while the other regions are forced with climatology.

Table 1: MOM5 ocean model experiments designed to study the ocean teleconnections to the BC variability.

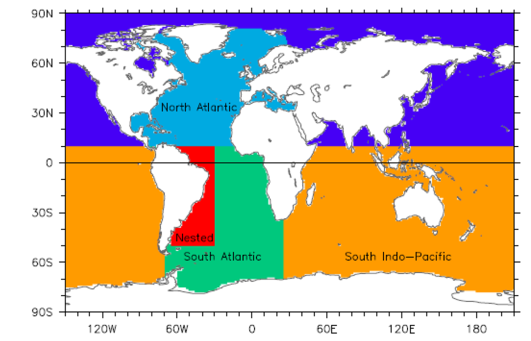
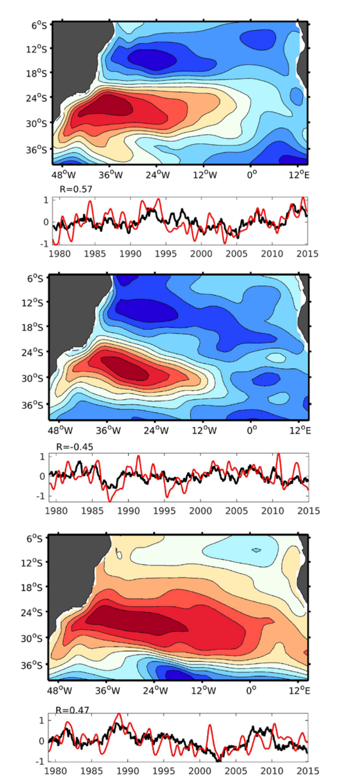


Figure 10: *Global ocean model domain and the distributions of basin sub-domains where either the historical or climatological surface fluxes will be applied in the forced experiments (see Table 1). The nested area (red) represents the west South Atlantic, the domain of the nested model.*

4.2 Basin teleconnections to the BC



NATL

SATL

SINDP

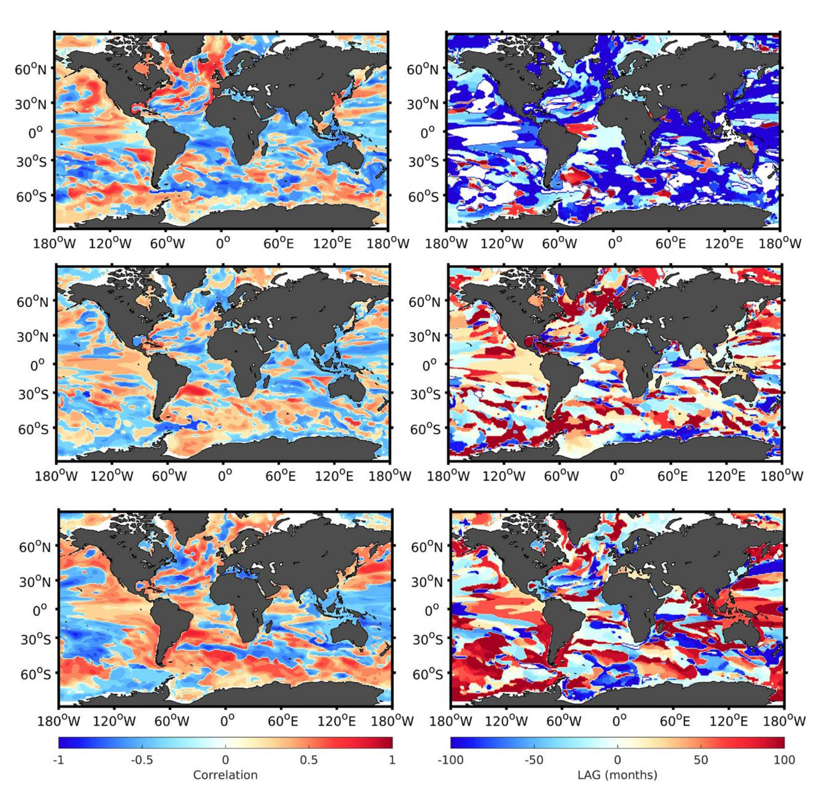


Figure 11: Sea surface height REOFs of the two EOFs that maximize correlation with the BC transport at 27S. Note that the variability of the timeseries of the BC (red) and REOFs (black) differ because of the randomized forcing in each experiment.

Figure 12: Magnitude and LAG of the maximum correlation of the SSH REOF timeseries from each experiment showing the potential ocean teleconnections from each basin to the BC. There is evidence of Pacific-Atlantic propagation of SSH anomalies in the SIDP simulation.