Ocean Forecast and Analysis Systems evaluation based on the NOAA AX97 High-Density XBT transect

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Introduction

The Western Boundary Currents (WBC) can be described as intense, narrow, and well-defined currents that flow along the continental margins. Found in all major oceanic gyres they are especially important for the oceanic transport of volume and heat; they also have a strong influence on regional climate. The Brazil Current (BC) is characterized as a superficial, warm, and saline flow, which extends to approximately 500 m depth, being the WBC that closes the South Atlantic Subtropical Gyre. The BC is particularly important for transporting heat, mass, and nutrients to high latitude regions along the South American continental margin.

The longest sustained monitoring system of the BC active today is the NOAA AX97 High Density XBT transect (hereafter NOAA AX97), characterized by an average bimonthly sampling at the 22ºS since 2004 (Fig. 1). Strong interaction of the flow with bathymetric features, coastal upwelling, eddy variability and recirculation gyres are some of the important features that influence the BC at this latitude.

The main goal of this work is to assess the structure, location, and variability of the BC in both eddy permitting and eddy resolving Ocean Forecast ans Analysis Systems (OFAS).

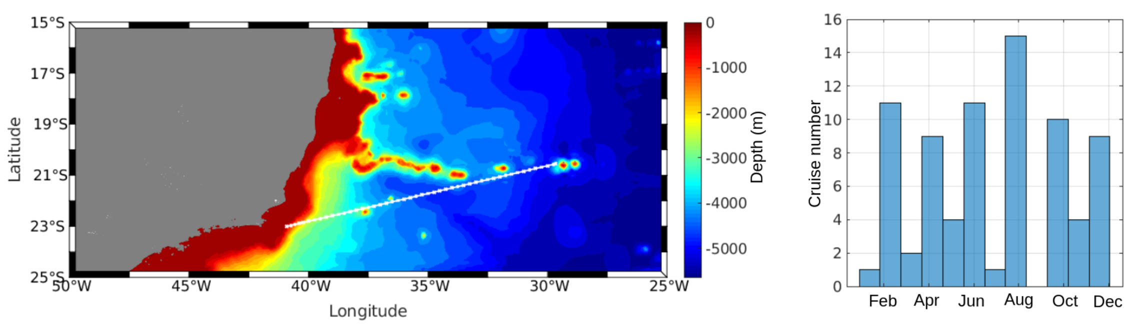

Figure 1: (a) NOAA AX97 region showing the reference transect overlaid on the contours of the local bathymetry (m). (b) Cruise distribution over the year.

Methodology

To estimate geostrophic velocities along the NOAA AX97 XBT transect, the salinity is estimated using historical T-S relationships for the region. In addition, the absolute dynamic height is calculated by imposing the Argo-based monthly climatology value of absolute dynamic topography at the reference depth (z = 500 m), which is approximately the interface between the Central and Intermediate waters (Lima et al., 2016). Finally, the absolute geostrophic velocities are calculated using the thermal wind relation. This methodology was the same used by Goes et al. (2019). Fig. 2 shows the mean current velocity of the whole period (2004- 2019). The data was extrapolated to longitudes west of 41ºW by extending the closest horizontal gradients of temperature and dynamic height onto the shelf. The mean velocities from WOA13 climatology are shown below 1000 m for comparison purposes only.

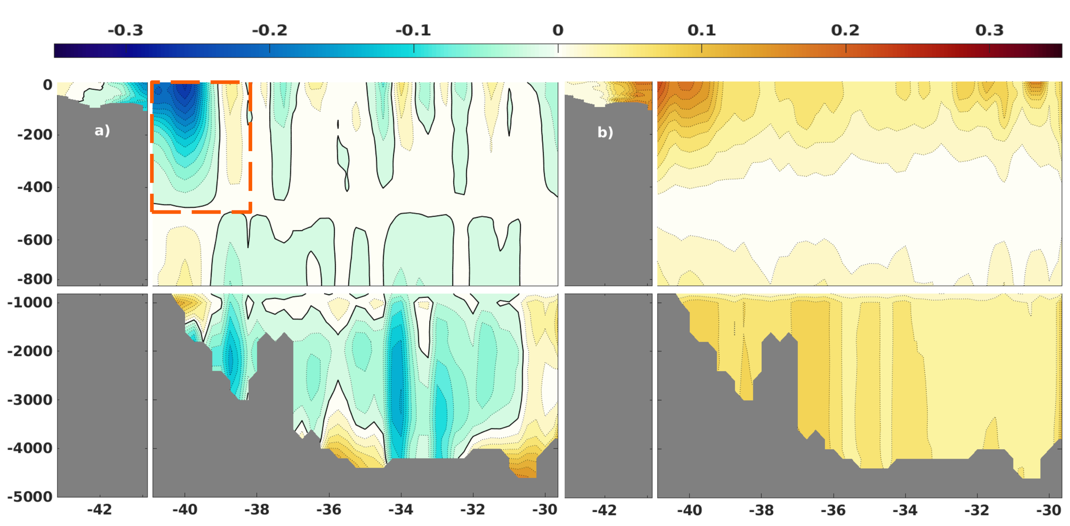

Figure 2: (a) The mean velocity derived from XBT data along the NOAA-AX97 reference transect. The red dashed line indicates the area where the volume transport was calculated. (b) The associated standard deviation.

Ocean Forecast and Analysis Systems

Ocean Forecasting and Analysis Systems (OFAS) are increasingly being used for ocean and weather forecasts along the Brazilian continental margin. In this work, over 70 NOAA-AX97 XBT transects are evaluated against nine OFAS reanalysis datasets: i) the HYCOM/NCODA GOFS3.1; ii) the Mercator GLORYS12V1; iii) the CSIRO BRAN2020 iv) the Mercator GLORYS2v4; v) the ECMWF ORAS5; vi) the CMCC C-GLORSv5; vii) the AOSC/U. Maryland SODA3; viii) the JPL/Nasa ECCO2 and ix) the UK MetOffice GloSea5. Table 1 summarizes the main features these OFAS. In Fig. 3 we can see the mean velocity and their associated standard deviation of BC along the AX97 reference transect calculated with the OFAS outputs considering the whole period of availability shown in Table 1.

OFAS	GOFS3.1	GLORYS12v1C	BRAN2020	ORAS5	GloSea5	C-GLORSv5	GLORYS2v4	ECCO2	SODA3
Origin	HYCOM/ NCODA	Mercator Ocean	CSIRO	ECMWF	UK Met Office	CMCC	Mercator Ocean	JPL/ Nasa	AOSC U. Maryland
Vertical Resolution	41 levels	50 levels	50 levels	75 levels	75 levels	75 levels	75 levels	50 levels	50 levels
Horizontal Resolution	1/12.5°	1/12º	1/10º	1/4°	1/4°	1/4°	1/4°	1/4°	1/4º
Temporal Resolution	daily	daily	daily	daily	daily	daily	daily	3 days mean	5 days mean
Availability	1994 to 2019	1993 to 2018	1993 to 2019	1993 to 2018	1993 to 2018	1993 to 2018	1993 to 2018	1992 a 2019	1991 to 2018

Table 1: Summary of all OFAS used in this study and their main characteristics.

Current Velocity

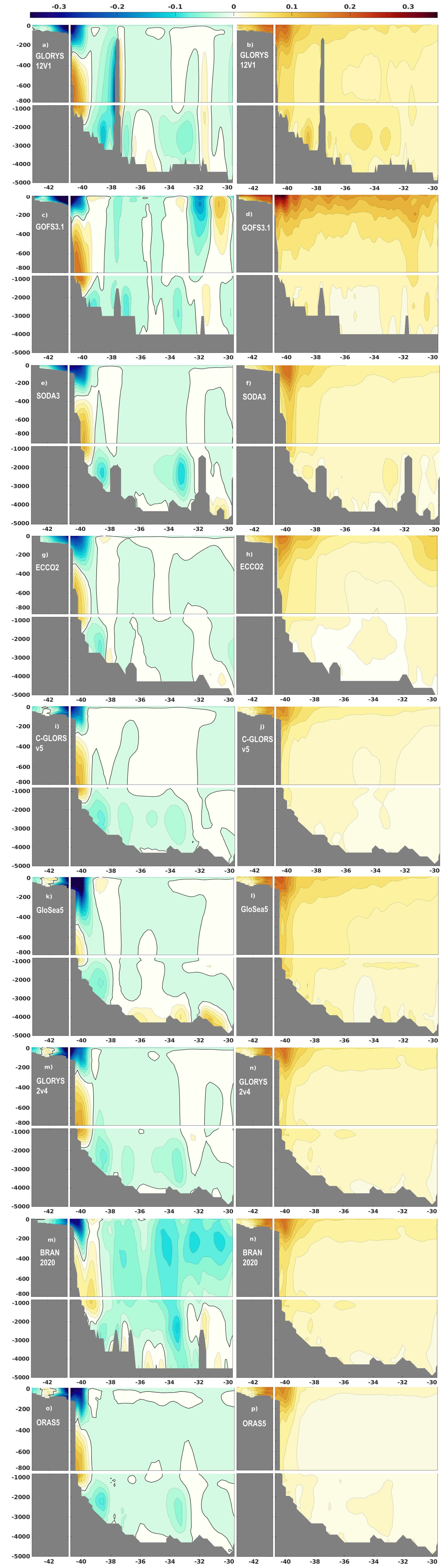

Figure 3: Mean velocity (left) and associated standard deviation (right) along the NOAA AX97 transect for the (a-b) Mercator GLORYS12V1; (c-d) HYCOM/NCODA GOFS3.1; (e-f) AOSC/U. Maryland SODA3; g-h) JPL/Nasa ECCO2; (i-j) CMCC C-GLORSv5; k-l) UK MetOffice GloSea5; (m-n) Mercator GLORYS2v4; (o-p) CSIRO BRAN2020; and (r-s) ECMWF ORAS5.

Volume Transport

The NOAA AX97 total volume transport was estimated firstly calculating the geostrophic contribution: the southward geostrophic velocity was integrated between the sea surface and a depth of 500 m and between the longitudes of 41° W and 39° W, the region where the observed flow is concentrated. Secondly, to include the ageostrophic component, the Ekman transport was calculated from the wind speed components (using ERA-5 reanalysis) at a height of 10 m from the sea surface, where the wind speed components were transformed into wind stress components, using the drag coefficient (Large and Pond, 1981). Finally, the ageostrophic contribution was added the the geostrophic in order to obtain the total volume transport. The OFAS volume transport was calculated simply by integrating the output velocities toward the south between the same limits of integration: from the sea surface to 500 m depth and from 41° W to 39° W, whereas the models already have both geostrophic and ageostrophic components. Fig. 4 presents the volume transport time series, considering only the cruise dates.

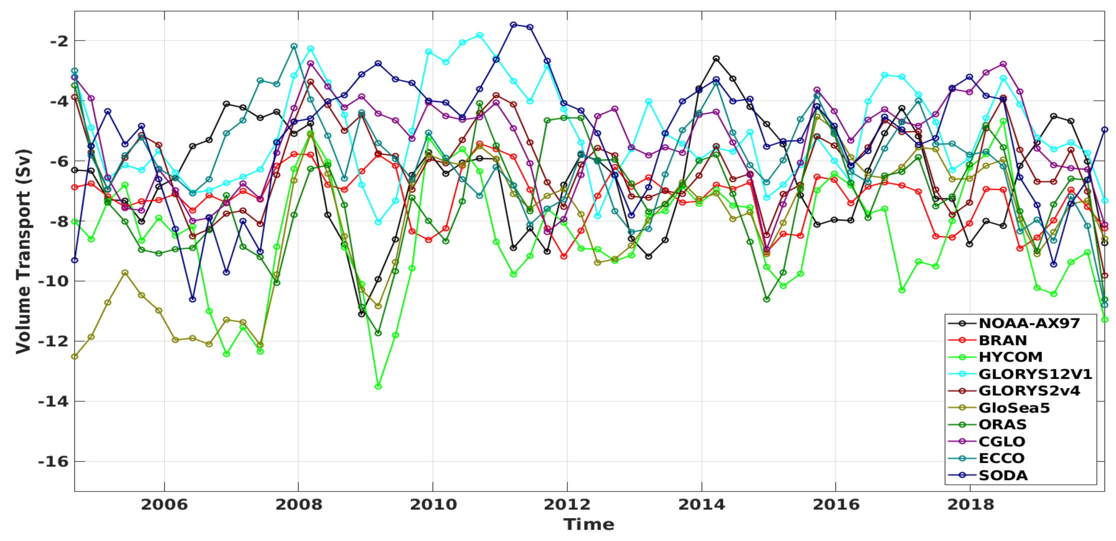

Figure 4: Time series of the BC volume transport for the NOAA AX97 XBT transect and the nine OFAS considering only the cruise dates (indicated with circles) between 2004 and 2019. Fig 2a indicates the region where the volume transport is calculated.

Conclusions and Future perspectives

After analyzing the BC main structure and assessing the OFAS against the observations along the NOAA AX97 XBT reference transect we concluded that the HYCOM and the GloSea5 overestimate the BC transport by approximately 35%, while BRAN2020 and ORAS5 overestimate the BC transport by about 22%. The GLORYS12V1 returned the least intense transport, and HYCOM had the higher variability. Table 1 shows the mean volume transport and the maximum core velocity calculated for each of the OFAS, along with their standard deviation.

OFAS	Mean volume transport (Sv)	Mean core velocity (m/s)
NOAA AX97	-5.92 ± 2.67	-0.37 ± 0.26
CSIRO BRAN2020	-7.21 ± 2.69	-0.38 ± 0.21
HYCOM/NCODA GOFS3.1	-8.43 ± 3.35	-0.54 ± 0.28
Mercator GLORYS12V1	-5.11 ± 2.46	-0.45 ± 0.23
Mercator GLORYS2V4	-6.11 ± 2.12	-0.44 ± 0.19
UK MetOffice GloSea5	-8.06 ± 2.75	-0.52 ± 0.23
ECMWF ORAS5	-7.25 ± 2.76	-0.39 ± 0.16
CMCC C-GLORSv5	-5.37 ± 2.30	-0.34 ± 0.17
JPL/Nasa ECCO2	-5.98 ± 2.48	-0.31 ± 0.15
AOSC/U. Maryland SODA3	-5.16 ± 2.87	-0.35 ± 0.13

Table 2: Mean transport and standard deviation of the BC for the NOAA AX97 transect, and all the OFAS considering only the cruise dates. The mean maximum core velocity in southward direction and its associated variability is also indicated.

This study is part of a long-term strategy to improve the knowledge about the dynamics and impacts of the oceans along the Brazilian continental margin. Our goal is to use the framework of GODAE Oceanview to assess and evaluate all available forecasts and reanalysis for the AX97 and analyze their ability to capture mesoscale extreme events.

Relevant references

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