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Ocean Science Discussions

Interactive comment on "Salinity-induced mixed and barrier layers in the southwestern tropical Atlantic Ocean off the northeast of Brazil" *by* M. Araujo et al.

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1. It is claimed that it is the intrusion of subtropical SMW brought by the SEC that is the major process contributing to the seasonal BL formation. I would argue that this is not really demonstrated. Some obscure T/S diagram more or less demonstrate the origin of water masses (see specific comments on these figures below), and only 1 sentence in the text refers to this mechanism using the phrase "... can only be due...". I expect (i) a more convincing argumentation behind this "can only be due" (see suggestions below on the figures etc) and (ii) a discussion of the temperature effect associated to this mechanism: a barrier layer is not only characterized by a marked halocline but also

by the lack of temperature gradient associated to this halocline so that the so called isothermal layer is indeed deeper. What is the temperature of the salinity cores arising from the penetration of the SEC?

R: Six new figures were added in the new version of the paper. These figures show transect distributions of the Temperature (Figs. 3c to 3h) for both seasonal periods. The temperature values of the salinity cores range from 24 to 26°C.

For what reason would it be similar to that of the surface waters of the region? In other words, why should the isothermal layer be so?

R: The temperature of ZT is not equal to that at surface waters. In fact, there is a lack between the salinity and temperature gradients. In later winter, at latitudes between 14° and 5° S, trade winds increase ZT while salty waters flow northward in the subsurface (100 m depth), forced by sSEC/NBUC system, when salinity core is located more to southward. In the summer, the SEC divergence positioned northward pushes the high salinity core to north, while heat and fresh water fluxes change values of temperature and salinity near surface. We suggest that the presence of subsurface SMW, due to SEC divergence in the summer, contributes to the formation of BLT at lower latitudes (between 5°S and 2°S) in the REVIZEE figures, contributing on changes of ZT and ZM depths.

2. de Boyer et al. (2007) and Mignot et al. (2007) recently proposed a global climatology of barrier layer thickness with the corresponding data set online. I expect at least a comparison of the results of this study to theirs. In the southwestern tropical Atlantic ocean off the northeast of Brazil, they reported primarily BLs in austral winter equatorward of the subtropical gyre. Does this correspond to the BLs of 90m deep reported in the "southernmost offshore portion of the area of the study" (p.565 l. 8-10)? What about the BLs thicker than 30m observed all over the region in austral summer? Is this a new feature that was not in de Boyer & Mignot et al data set because of a lack of specific data?

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R: The BLT seasonality found by de Boyer Montégut et al. (2007) and Mignot et al. (2007) is also observed in this study. Here, a more refined analysis was done from 0.5° N to 13° S, and local mechanisms biasing BLTs could be better noticed as Salinity Maximum Water. This refinement could not be observed by the authors above due to their global climatological analysis, which used large grids such as in the ARGO database, with 2° by 2° resolution. The BLs found by Mignot et al. (2007), equatorward of the subtropical gyre, may be the ones found in this study. However, it is not possible to confirm this because of the different BL formulation criteria used in each study. De Boyer Montégut et al. (2007) and Mignot et al. (2007) defined the BLT as the difference of two depths: one depth whose temperature has decreased by 0.2°C (reference depth of 10 m), and one whose potential density has increased from the reference depth by a density threshold equivalent to the same temperature change 0.2°C at constant salinity. In the current study, instead of 0.2°C, we considered a reference depth of 5 m, and a temperature decrease of 0.5°C, that may cause differences between our results and theirs.. The great contribution of this study is the observation concerning the influence of the western boundary current (North Brazil Current - NBC) over the BLT. This current carries salty and warm waters equatorward, increasing the thickness of the BL. This conclusion was also obtained by Silva et al. (2005) for the northern area of Brazil. Zeng et al. (2009) also noticed it at the southeast of Vietnam. The authors observed the importance of the western boundary current for the maintenance of the shallow halocline, once it caused the advection of fresh water from the Mekong River mouth, forming a thick BL.

3. This summer BL is the only one for which a mechanism si approximately proposed (p.564 l.20-end). However, the hydrographic analysis of section 3.1 "concluded" to the influence of SEC transporting SAW south of 6_S. In section 3.2, the same argument is used to justify the fact that "high BL values...not only concentrated in the southernmost part of the study area... but also present from 1_ to 10_S". Isn't this inconsistent? Or at least, it should be much more documented and clarified! Abstract and conclusion argue that this mechanism linked to the SEC was demonstrated for both season. I see

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indeed a discussion of the origin of subsurface salty waters in both seasons in section 3.1 (see general comment 1. above on this point). But I do not see any discussion of the formation mechanism of winter BLs.

R: The formation mechanism of BL observed in this study was also observed by Mignot et al. (2007). It involves wind seasonality, oceanic circulation, local climatology and geography. The annual north-south displacement of the marine Inter-Tropical Convergence Zone (ITCZ) leads to a variability in the amplitude of local wind stress curl, as well as a change in depth of the thermocline in the sSEC bifurcation region (Rodrigues et al., 2007). Such aforementioned process influences the BLT indirectly, once it is affected by ZT. During the late winter, southeastern trade winds are more intense, and surface salinity values low, because of the ITCZ precipitations at the equator. Meanwhile, subsurface salinity values are relatively high due to the presence of NBUC, whose equatorward transport increases during this period, as stated by Rodrigues et al. (2007). For this reason, as proposed by Sato et al. (2006), the ZT and ZM deepen, allowing the development of thicker BLs (although it happens locally in southern study area). In the summer, as observed by Rodrigues et al. (2007), sSEC bifurcation occurs at lower latitudes, and maximum NBUC transport happens at 6° S, which brings it within the SMW. In this period, evaporation overcomes precipitation, causing saltier waters at the surface/subsurface layers. In addition, northeasterly winds are present once ITCZ moves southward. Consequently, ZT and ZM become shallower, and the presence of SMW in the NBUC leads to the occurrence of BLs with an equal spatial distribution. This horizontal homogeneity, found during the summer period, suggests a strong influence from the South Atlantic western boundary current. This was not observed by other authors (Sato et al., 2006; de Boyer Montégut et al., 2007; Mignot et al., 2007) due to the wide grid used in their study, as its goal was the BLT around the global oceans.

4. The language in this paper needs to be improved significantly. In the present state, the reading of the paper is strongly perturbed by the language issue and it is thus dif-

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ficult to focus on the science. I understand that none of the authors are native english, and I hope that they can find an english speaker around them to help improve the language. Given my overall opinion of the manuscript, I don't think it is necessary at this point that I propose a detailed correction on this point. In general, I advise the authors to use shorter sentences.

R: Ok. After major revisions suggested by the referees, the manuscript was submitted and revised by the American Journal Experts (http://www.journalexperts.com/).

Specific points

Fig. 1a: more data are collected in the north and there seems to be focus on topography. Please comment on the reasons and the possible effects of the BLT that are presented. R: At Section 1, there is a brief description of the consequences of the BL. Concerning its thickness, it would increase the main property of this layer, which is to affect the ocean heat budget and its exchanges with the atmosphere.

Fig. 1b & c: Need more information: where do the diagrams for the reference water masses come from? R: The T/S references used to identify the water masses were taken from Wilson et al. (1994) and Bourlès et al. (1999), as mentioned at the first paragraph of Section 3.1.

What is the exact location of this "typical" diagram (the black one I guess?)? R: The actual Fig. 2a (old Fig. 1b) is located at longitude 34.500° W and latitude 12.505° S. The actual Fig. 2c (old Fig. 1c) is located at longitude 37.957° W and latitude 1.674° S. The representative stations are shown in the T/S diagram as a black asterisk.

Why not showing all diagrams of easternmost stations between the specified latitudes? R: We did not show T/S diagrams from all stations, because it would represent more than 30 additional figures. We decided to show only the diagrams representative of the main water mass signatures (EAW and SAW).

Or is it an average of all easternmost stations between the specified latitudes? R: No,

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it is not an average of all easternmost stations. The T/S diagrams shown are from stations that represent the water masses from north and south of the easternmost stations. Please see, also, the answer above.

Given the topic and the following of the manuscript, some discussion would also be needed on the sensitivity of such diagram to the season. What about NAW waters? R: We cannot find NAW water masses in the present REVIZEE-NE data because the CTD profiles reached only the first 500 m depth.

Were they not present in the data? Why? R: Please see the answer above.

I understand that in Fig. 1a & b and Fig. 2, only easternmost stations are used in order to focus on the entrance of water masses in the study area. If true, this argument should be specified in the text to be more convincing. R: This argument is specified at the beginning of the second paragraph of Section 3.1.

p. 561 l. 19-20: It is stated that thresholds to limit the isothermal layer vary from 0.5 to 0.8 degC in the literature. De Boyer Montegut et al. (2004) give a review of studies with criteria varying from 0.1 to 1 degC at least. R: We agree with the reviewer. The text was corrected in the new version of the manuscript.

There is an inconsistency in the definition of ZT and ZM: they are defined as layers in the abstract and as depths (in m) through equation (1). Please clarify and change the text accordingly (ex. p.564 l. 9, "Zm depths" is not appropriate I think). R: This inconsistency was removed in the new version of the manuscript. Throughout the text, ZT and ZM are defined as depths of the isothermal and mixed layers, BL as barrier layer and BLT as barrier layer thickness.

p.563 l.10: abbreviation SMW should be specified in the text and not only in the title of the section. R: Please see that SMW is specified in the fifth paragraph of Section 1.

How are these waters defined? R: The SMW definition is now specifically described in Section 1, according to Defant (1936), and Lambert and Sturges (1977).

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p.563 l.14 "this" boundary: what do you refer to? The previous sentences do not refer to any boundary R: The boundary referenced here is the easternmost boundary of the hydrographic stations (seen in Fig. 1), which is referenced at the beginning of the previous paragraph. It is also specified now in the referred paragraph.

p.563 l.24-27: This paragraph is crucial for the conclusions of the papers and can not thus simply be based on a "can only be due". See general comment 1. above. At least illustrate the circulation on one of the figures. R: :The text corresponding to this paragraph was totally rewritten discussing new results. Following suggestion from the reviewer, we present new figures of circulation at 110 m with the salinity and transport distribution (Figure 4a-b). These figures results from a Mercator-Coriolis product explained in Section 2.1.

p.564 l.6: the word "distribution" is misleading here since the spatial distribution is in fact described in the following paragraph. R: We agree with the reviewer. The word “distribution” was removed.

p.564 l.6 "lower". Comment that the thickness range is lower but the median higher? Or at least indicate that you will below. R: During the summer period, the highest median and lowest BLT are justified by the highest frequency occurrence, which was observed in 7.5% more CTD stations than it was during the winter.

p.564 l.9 "while ZM depths reached 135m in winter". I don’t see from the figure where this depth is reached. So at least ass the word "locally". And perhaps give a value that is more representative of Fig. 3b. R: Ok. The word “locally” was added to the text. More representative values of Fig 3b (now Figure 6a) were given.

p.564 l.10: The comparison of ZT range is not very convincing. I suggest you rather compare maximum values or the median? In addition, an explanation for the depth of the isothermal layer in each seasons is critically missing (see major comment 2 above). R: Ok. The depth values of isothermal and mixed layers are now presented by median values. Also, the discussion for both seasons was inserted.

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Note that I would also expect an explanation of the depth of ZM in winter. In fact, only ZM in summer is commented l.23-25. R: Ok the reviewer is correct, we improved the text adding comments about ZM in late winter season. Please see the previous answer.

End of the section: the link with the previous section is unclear and confusing. See major comments above. R: Ok, the text was completely rewritten.

p.565 l.11: "also": what else? This is the only mechanism that you "discussed" here. R: Ok, the word was removed from the text.

p.565 l.14-19: "these results suggest...". I don't really see the link between this sentence and the following and the results of this paper. R: Ok, after the reviewer's suggestion, the manuscript was improved with new figures and comments, which in our perception confirms the influence of sSEC over subduction of salty water, as well as in the BLT formation.

p.565 l. 19 "Nonetheless": there is no opposition with the previous idea. Omit. R: Ok, the word was suppressed from the text.

The authors thank the Reviewer for comments and suggestions, which helped us to improve our manuscript.

Please also note the Supplement to this comment.

Interactive comment on Ocean Sci. Discuss., 6, 557, 2009.

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Interactive Comment

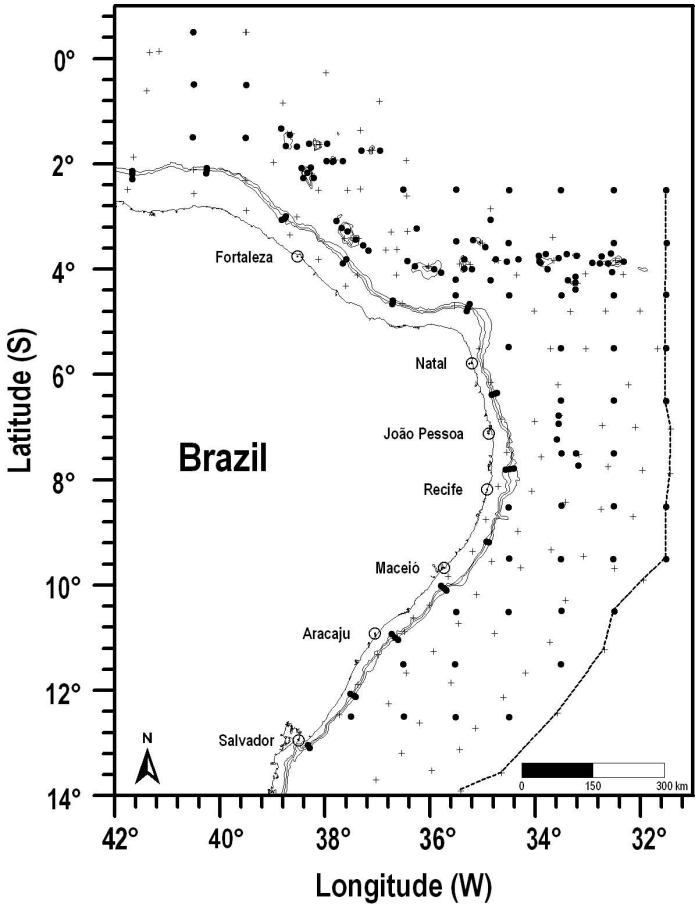

Fig. 1. Figure 1

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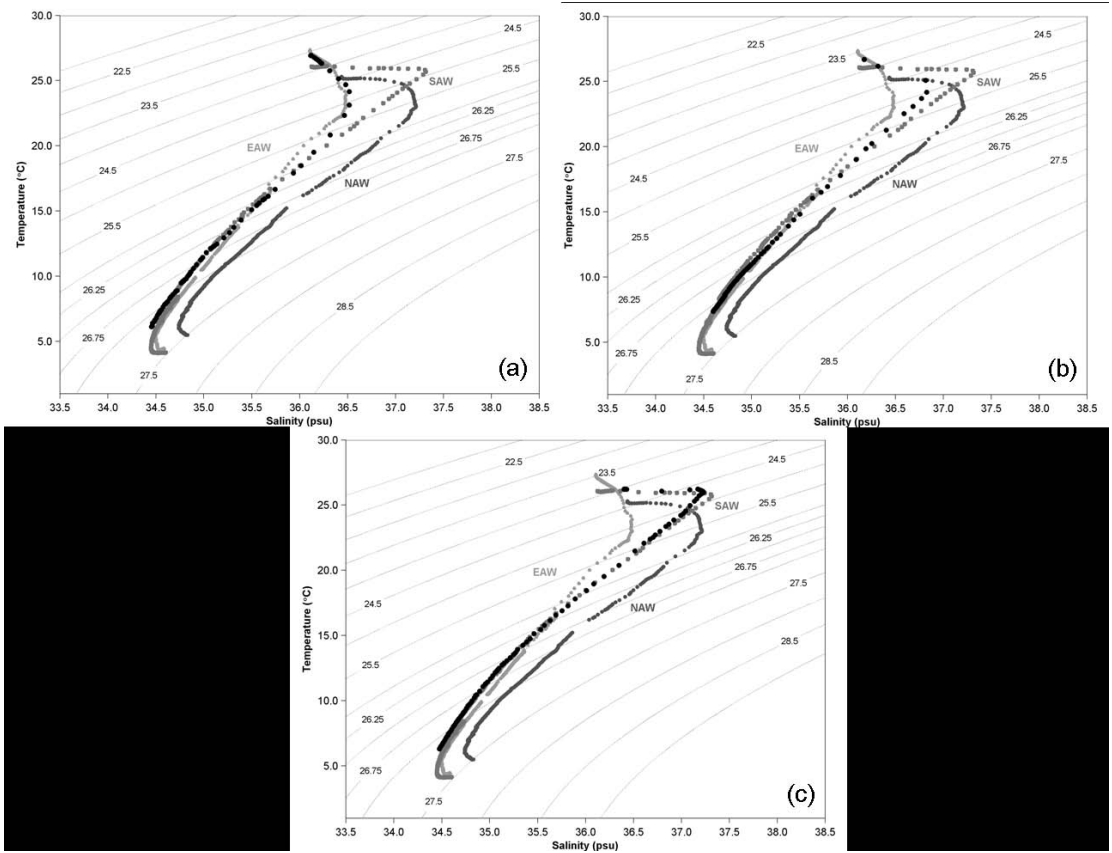

Fig. 2. Figure 2_abc

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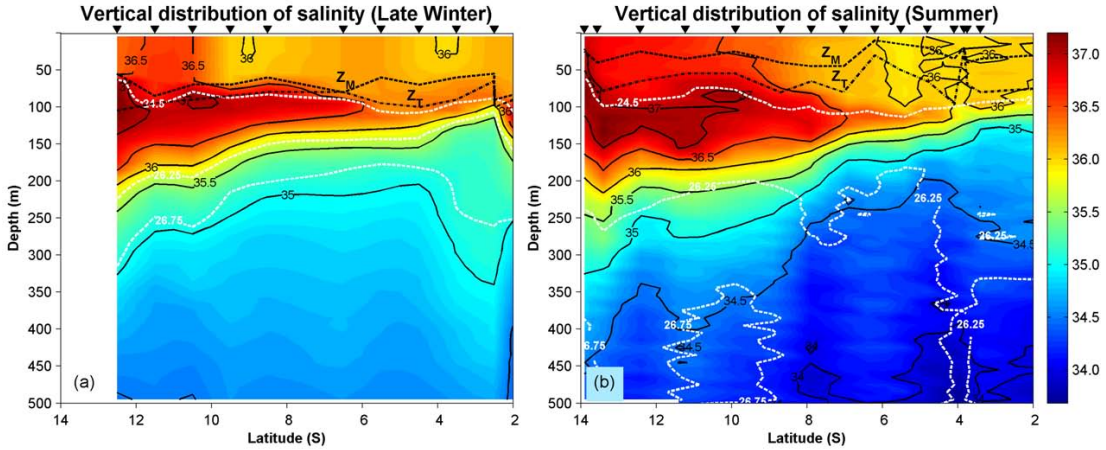

Fig. 3. Figure 3_ab

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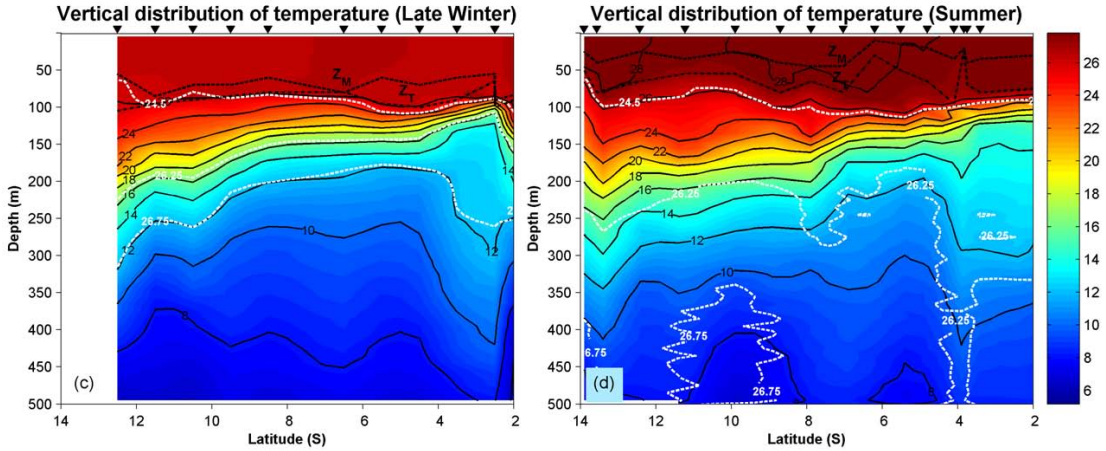

Fig. 4. Figure 3_cd

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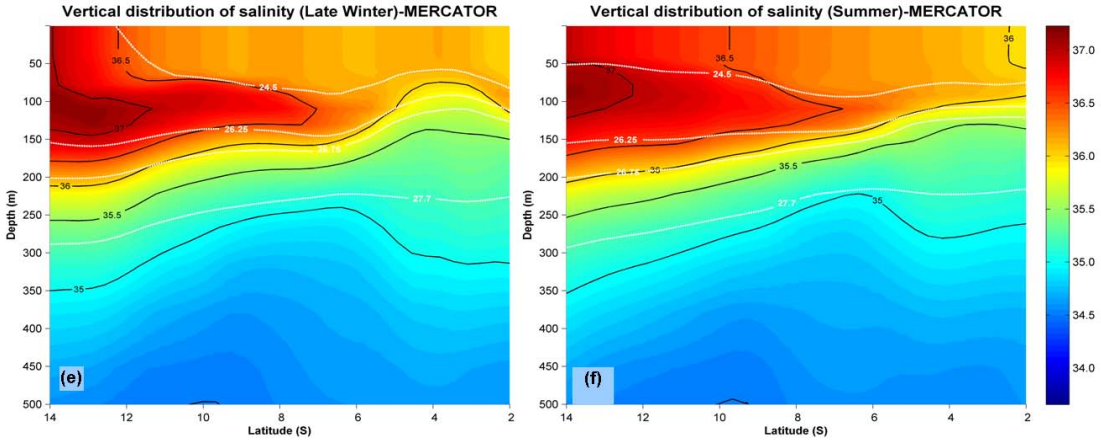

Fig. 5. Figure 3_ef

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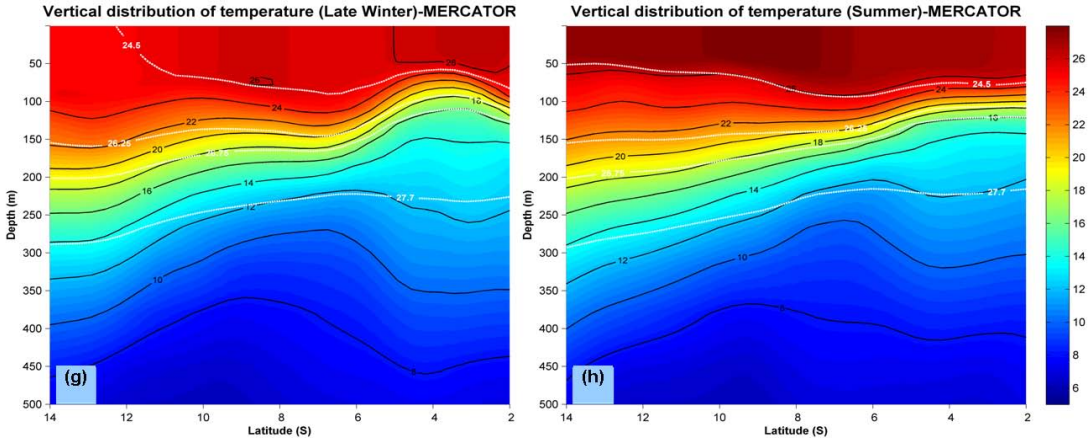

Fig. 6. Figure 3_gh

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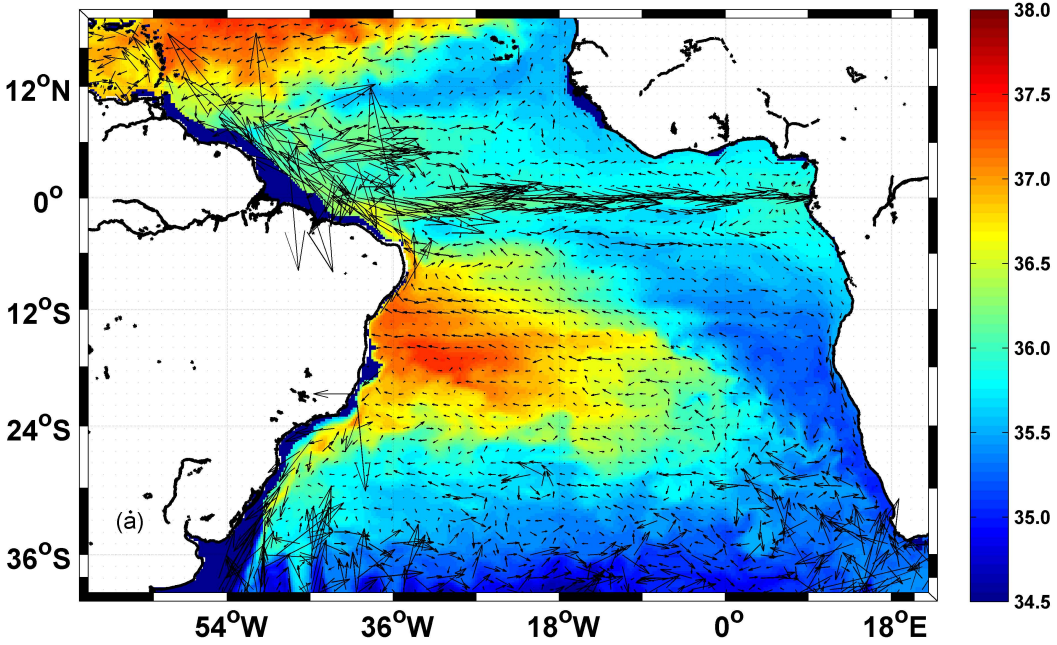

Fig. 7. Figure 4_a

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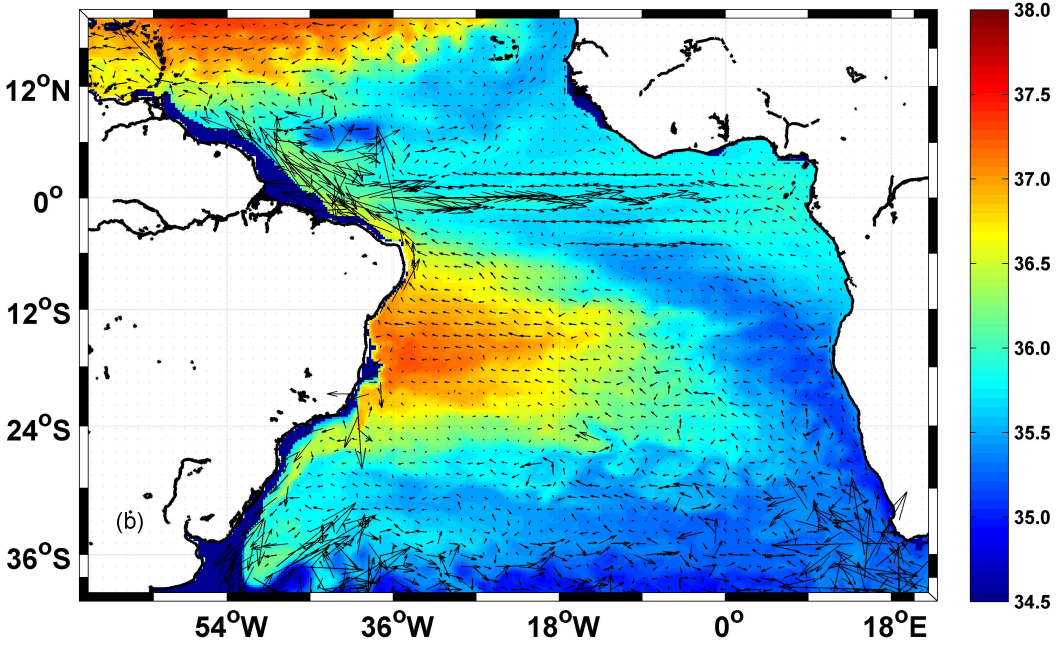

Fig. 8. Figure 4_b

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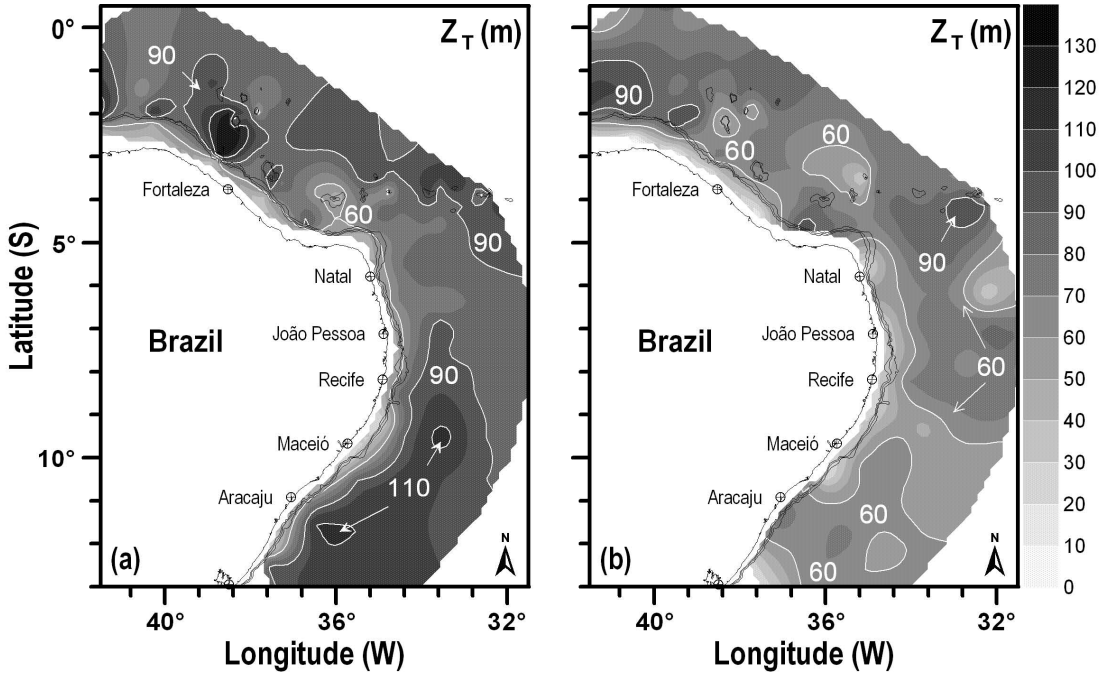

Fig. 9. Figure 5_ab

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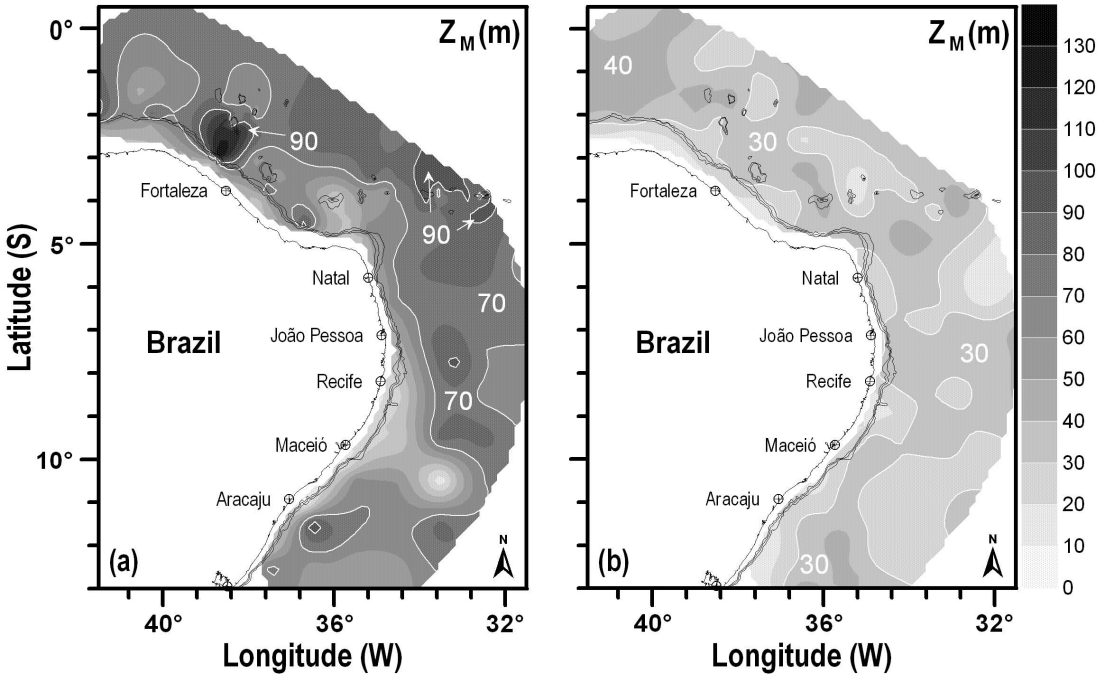

Fig. 10. Figure 6_ab

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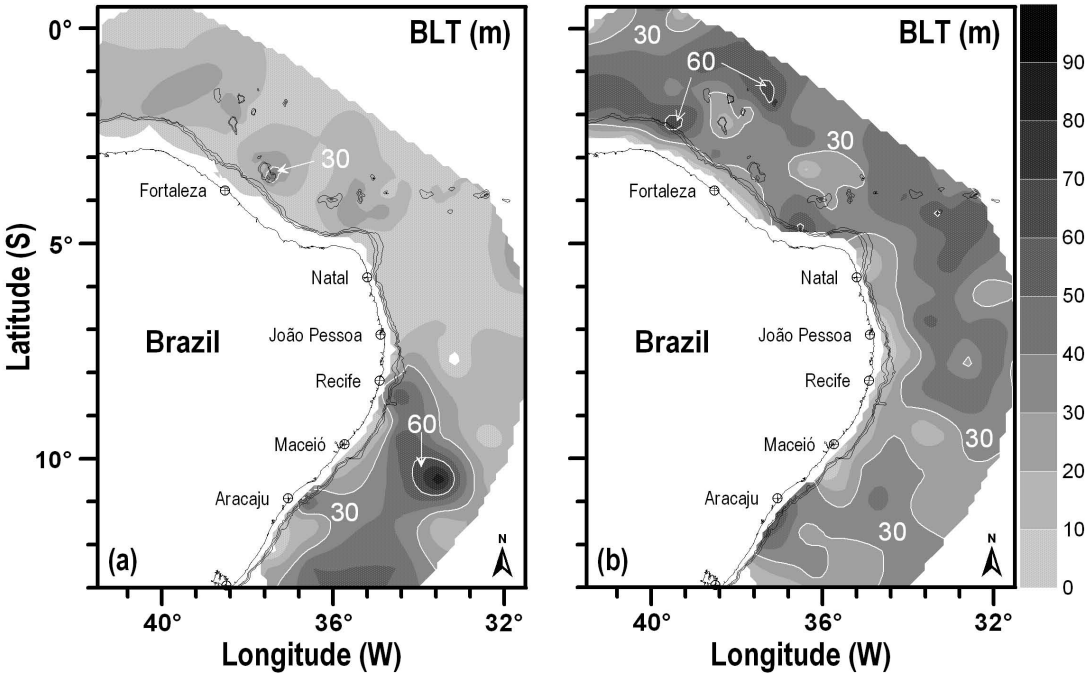

Fig. 11. Figure 7_ab

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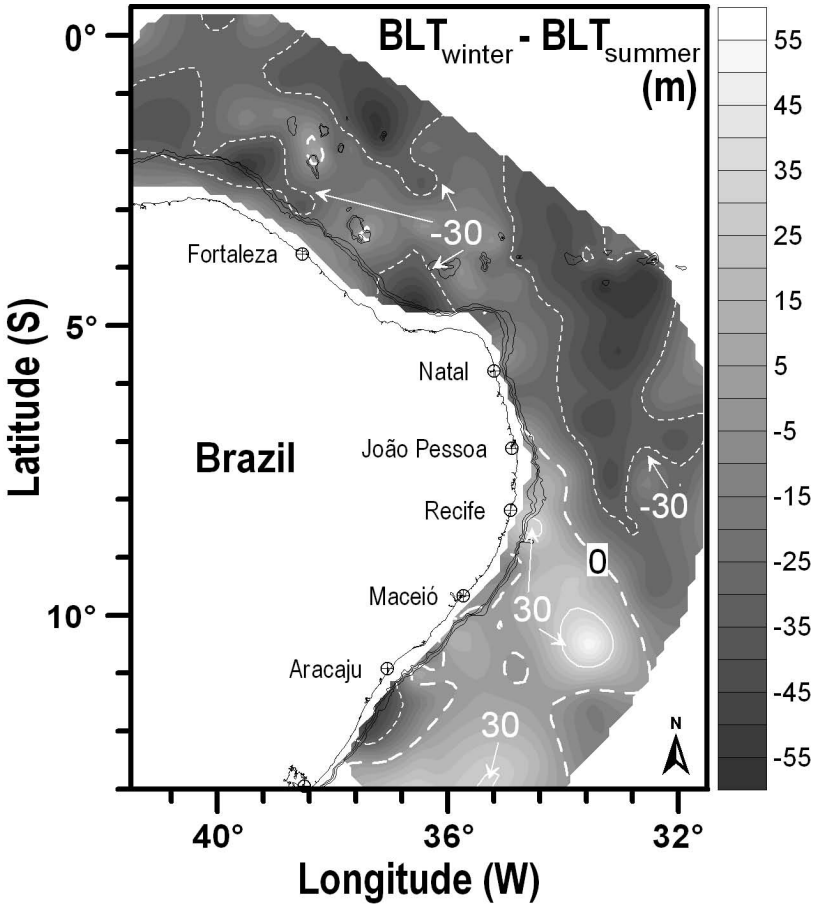

Fig. 12. Figure 8

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