The Impact of XBTs data into HYCOM+RODAS in the Metarea V

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Introduction

The present work has as main scope the inclusion and evaluation of the impacts of XBT data in the ocean data assimilation system constructed by the Oceanographic Modeling and Observation Network (REMO) which employs the Hybrid Coordinate Ocean Model (HYCOM) and an Ensemble Optimal Interpolation (EnOI) scheme. This system, called HYCOM+RODAS, is able to assimilate sea surface temperature (SST), along-track or gridded sea level anomaly (SLA) and vertical profiles of temperature (T) and salinity (S) from Argo. In order to assimilate Argo data, RODAS employs the approach presented in Thacker & Esenkov (2002) and Xie and Zhu (2010) in which Argo T/S profiles are projected into the model isopycnic layers and pseudo-observed model layer thicknesses are also assimilated. Today HYCOM+RODAS is unable to assimilate vertical profiles of T without the companion S. To overcome this limitation, an effort was realized to produce synthetic salinity profiles to accompany XBT data or any other T profile in a region of great interest to REMO and the brazilian oil industry, the so-called METAREA V (36°S-7°N, west of 20°W until the Brazilan coast).

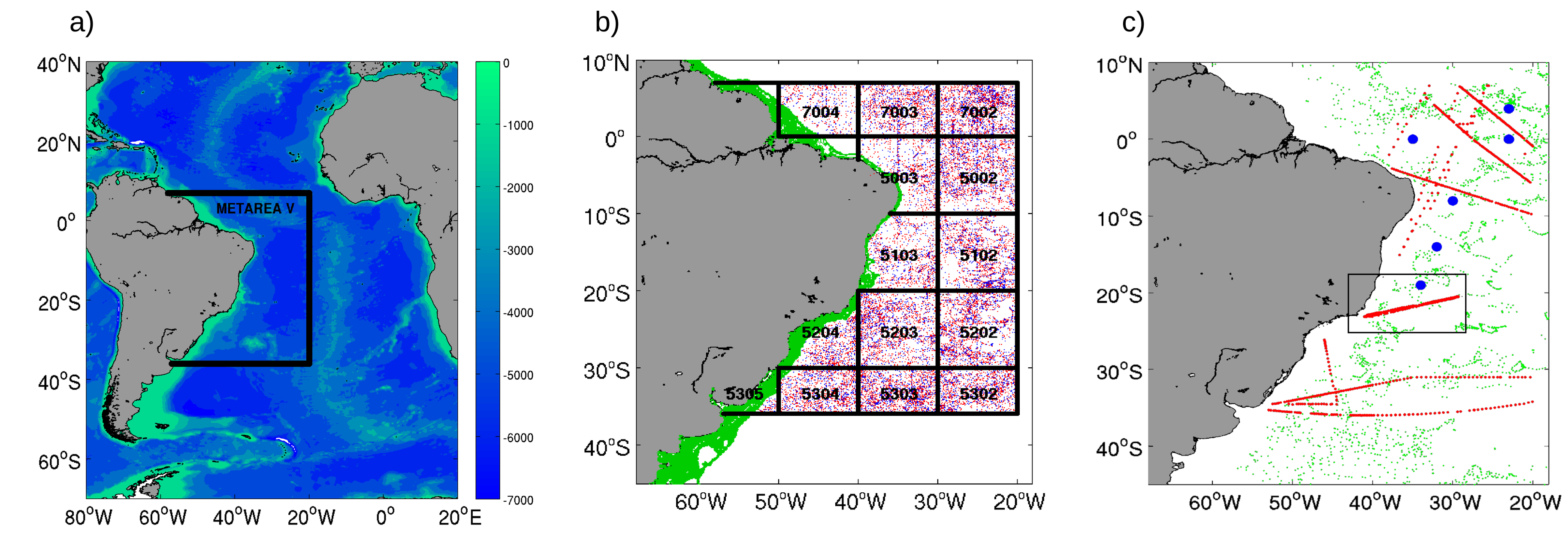

Figure 1. a) The METAREA V and b) Its delimitation in 14 subregions to better estimate salinity. Red (blue) dots denote elaboration (verification) set. In green the isobath of 200 m. c) XBT (red) and Argo (green) profiles utilized in assimilation experiments and PIRATA buoys (blue) utilized for verification and competence of the method. The black square points to AX97 sampling area. Both b) and c) maps show HYCOM 's 1/12° domain.

Salinity Estimates

Fourteen subregions were selected based on World Ocean Database areas (Fig. 1b). The data were separated into two groups: Elaboration and Verification sets. The synthetic salinity was estimated for each subregion by interpolation of monthly climatological averages (World Ocean Atlas 13) and by nonlinear regression using T of Elaboration set as predictor in a least squares scheme (Fig 2a). The best-fit curve was performed with polynomials of degree 5 (P5). The RMSD was calculated against salinity of the independent data of Verification set (Fig. 1b and Fig. 2b).

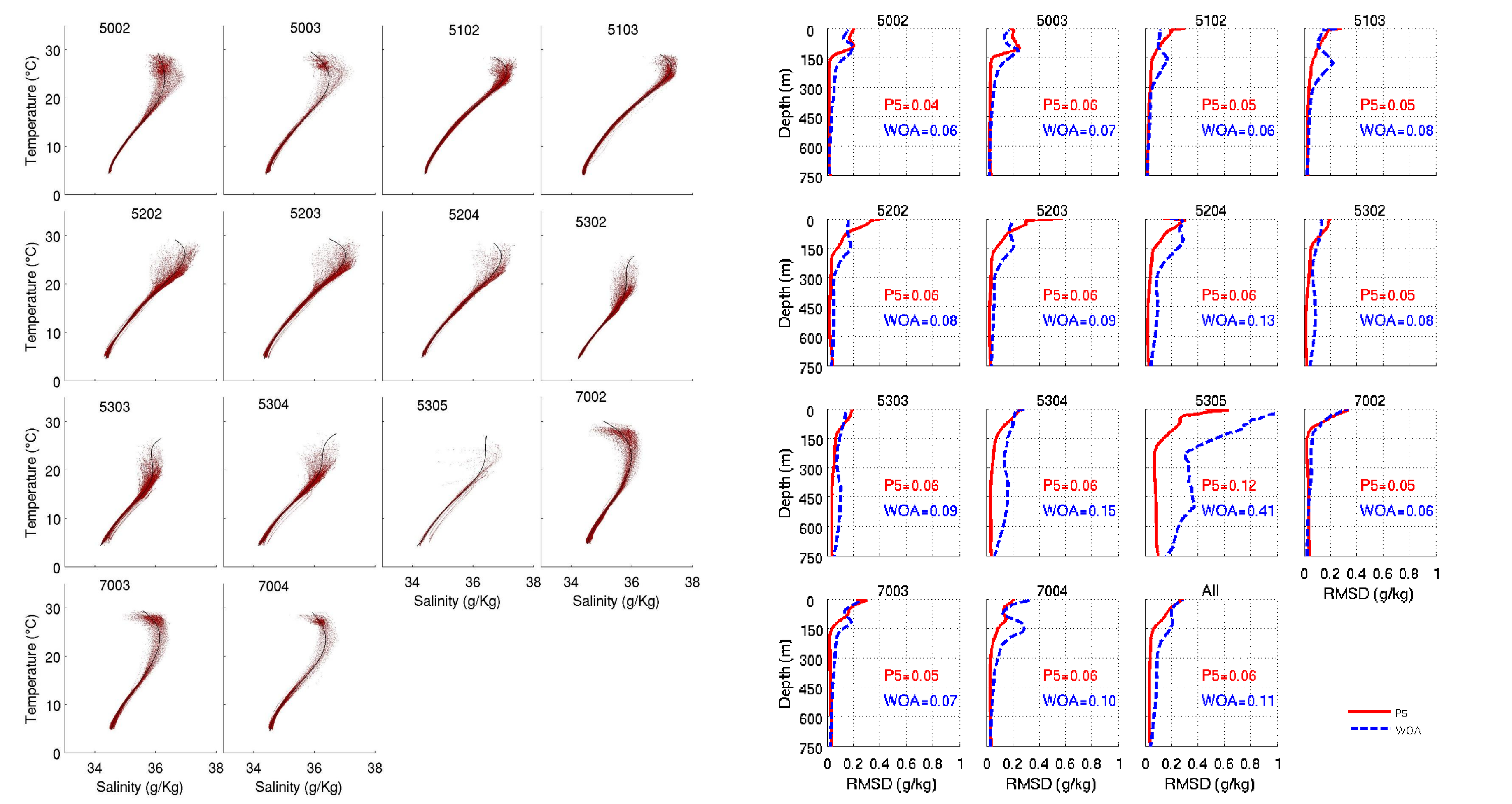

Figure 2. a) Polynomials best-fit curves and b) Root mean square deviation of fourteen subregions calculated against true salinity of Verification set, for P5 (solid red) and climatology from WOA13 (dashed blue).

In most of the studied region, the climatology tended to better represent the salinity in the first meters of the water column, while the best-fit curve of P5 gained strength at higher depths. Thus, the salinity that would accompany the temperature from XBTs probes were generated considering climatology in the first meters and the 5-degree polynomial below up to 750 m, normally, XBT's maximum depth (Fig. 3).

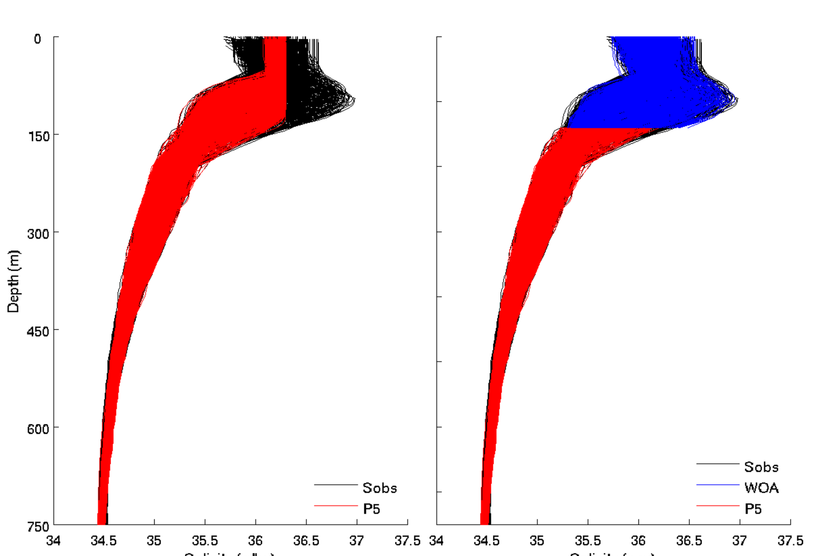

Figure 3 *Left)* Observed salinity from Verification set (black) in subregion 5002 and estimated from XBT temperature by P5 (red). *Right*) Salinity estimated from interpolation of WOA13 (blue) and by P5 (red) .Their conjoint use responds for the 'Both estimate'.

Table 1. Coefficients for the polynomials of type S(T) = $b_0 + b_1.T^1 + b_2.T^2 + b_3.T^3 + b_4.T^4 + b_5.T^5$ obtained through non-linear regression for each subregion of METAREA V. Root mean square error and determination coefficient are also shown.

ZONA	b0	b1	b2	b3	b4	$b5.10^{-5}$	RMSE	R^2 adj
5002	34,0994	0,1168	- 0,0164	0,0020	- 0,0001	0,1028	0,0772	0,9830
5003	33,9053	0,1861	- 0,0250	0,0023	- 0,0001	0,0811	0,0987	0,9790
5102	34,4784	- 0,1035	0,0283	- 0,0023	0,0001	- 0,8048	0,0635	0,9950
5103	34,6987	- 0,2123	0,0458	- 0,0035	0,0001	0,2207	0,0674	0,9960
5202	34,5490	- 0,1552	0,0337	- 0,0023	0,0001	- 0,1385	0,0885	0,9860
5203	34,6865	- 0,2405	0,0503	- 0,0037	0,0001	- 0,2122	0,0924	0,9860
5204	34,1675	- 0,0356	0,0176	- 0,0012	0,0001	- 0,0939	0,0884	0,9860
5302	33,4289	0,3367	- 0,0585	0,0062	- 0,0003	0,4328	0,0662	0,9800
5303	32,8202	0,6175	- 0,1065	0,0100	- 0,0004	0,6069	0,0688	0,9820
5304	32,4634	0,7440	- 0,1214	0,0105	- 0,0004	0,5523	0,0823	0,9820
5305	32,8683	0,5448	- 0,0831	0,0071	- 0,0003	0,3420	0,1500	0,9550
7002	34,9007	- 0,2232	0,0399	- 0,0022	0,0001	- 0,0778	0,0786	0,9660
7003	34,9046	- 0,2124	0,0368	- 0,0020	0,0001	- 0,0717	0,0769	0,9740
7004	34,5143	- 0,0173	0,0008	0,0009	- 0,0001	0,0589	0,0695	0,9880

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Experiments with Data Assimilation

Two assimilation experiments were idealized for one year (2012) employing a RODAS simplified version. The first containning only Argo profilers (**EXP_ARGO**) and the second containning the same Argo + 707 XBT (after application of quality control), with XBT salinity being estimated through the combnation of P5+WOA13 (Fig. 3, **EXP_BOTH**). The assimilation was realized once every 3 days. The S errors of the XBT were computed as the RMSD obtained against true observations of Fig. 2b.

To verify the impacts of the experiments, a free run with no assimilation was also performed. With this configuration, it was possible to verify the contribution of the assimilation of XBTs profiles in a system already configured with Argo profilers.

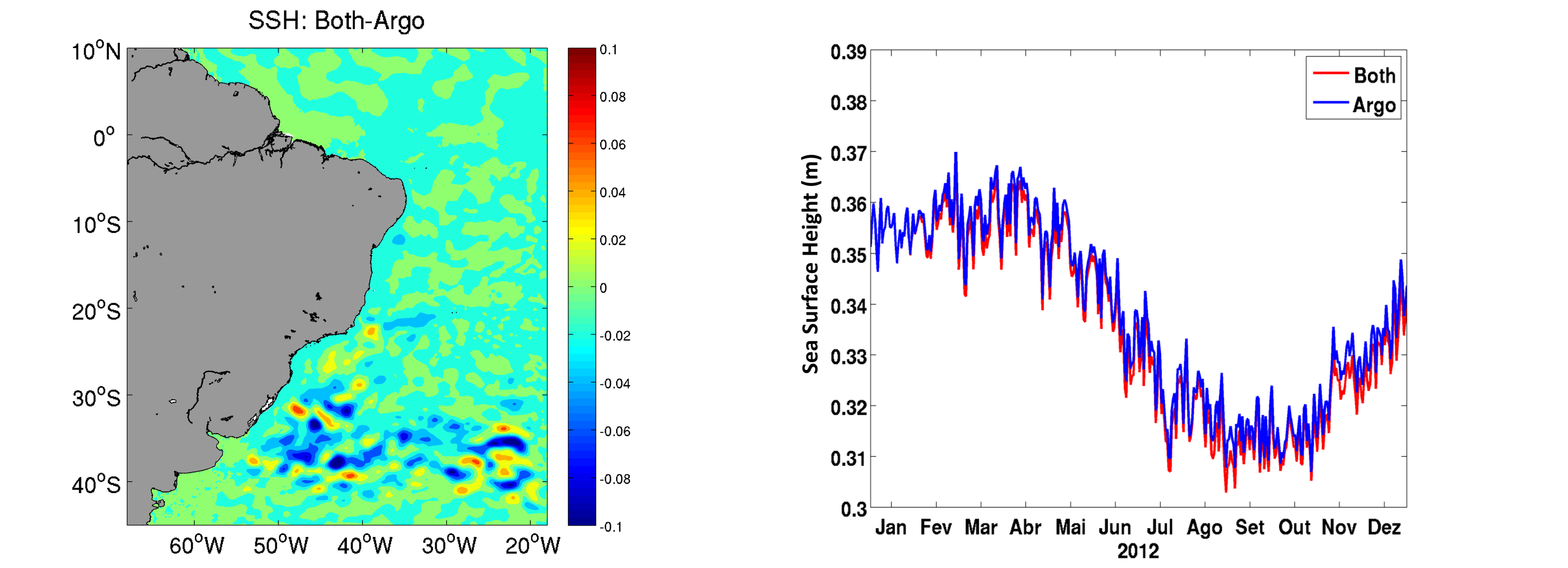

Figure 4. (*Left*) Difference between mean SSH from EXP_BOTH and EXP_ARGO from 1 January 2012 to 31 December 2012 and (*Right*) Time series of SSH for the same period.

Our free run has a strong positive bias in the SSH (and T) field. The XBTs reduced the altimetry in the whole domain. Due to the low frequency of XBTs sampling, it was not possible to find significant differences in the T and S fields for long term means. It was decided to analyze some specific regions and dates representing assimilation days. From now on, the results will be mainly focused in the AX97 area (Fig. 1c, black rectangule).

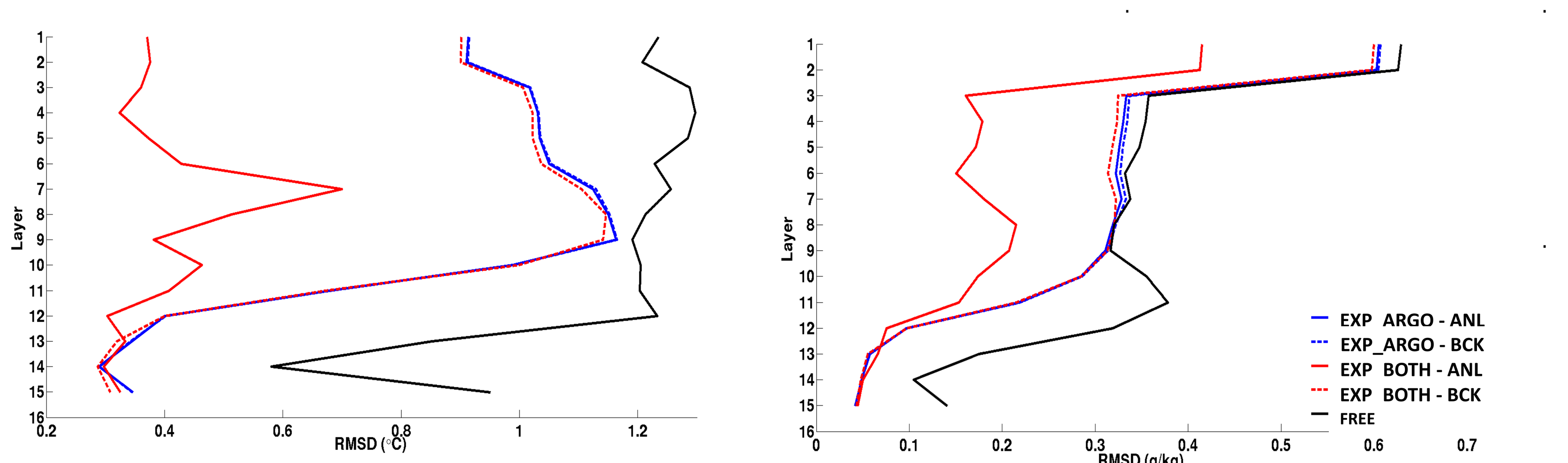

Figure 5. Root mean square deviation for each HYCOM layer against 707 XBTs that were assimilated for a) temperature and b) syntethic salinity. Dashed curves were used for background state and solid curves for analysis state. The free run is also represented in black.

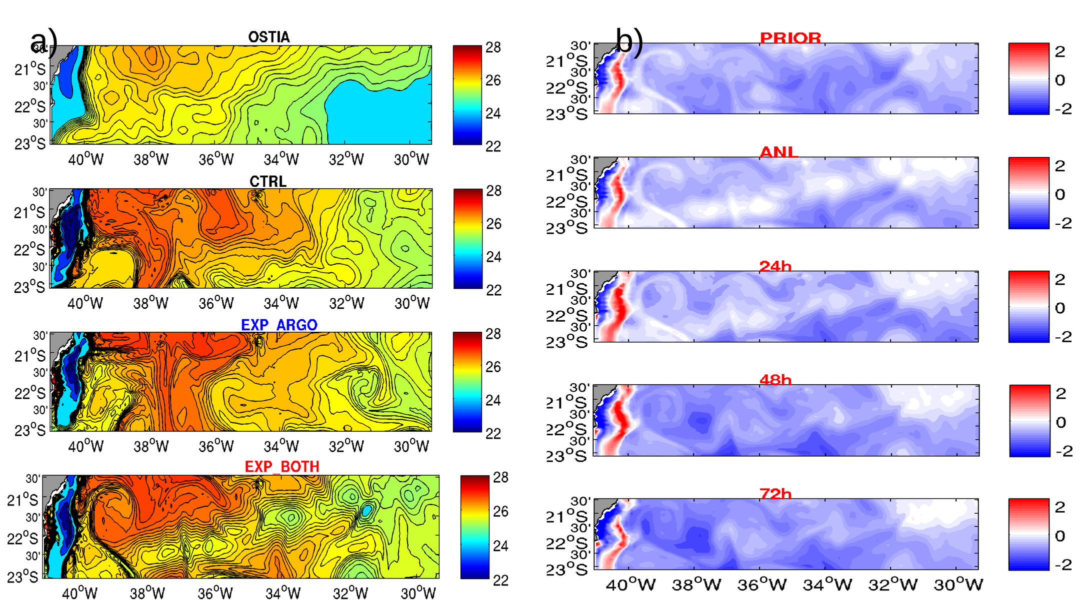

Figure 6. a) TSM from OSTIA, CTRL, EXP_ARGO and EXP_BOTH for December 8, 2012 (analysis day containing 43 XBTs). b) TSM error against OSTIA from the background state (PRIOR), analysis day (ANL - December 8, 2012) and for hindcasts of 24, 48 and 72h.

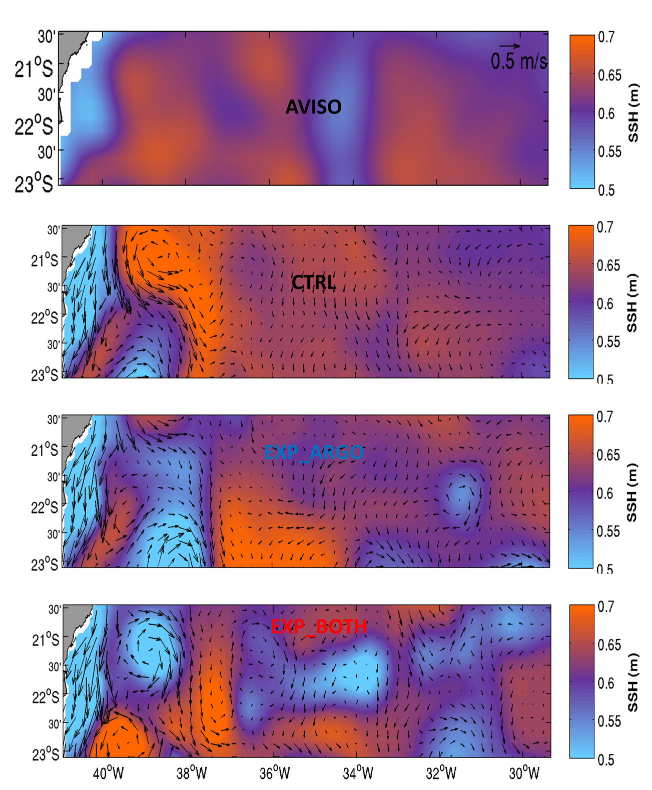

Figure 7. SSH from AVISO, CTRL, EXP_ARGO, EXP_BOTH and surface circulation for the latter three for December 8, 2012. The XBTs assimilated are those marked with a black rectangle in Fig 1c.

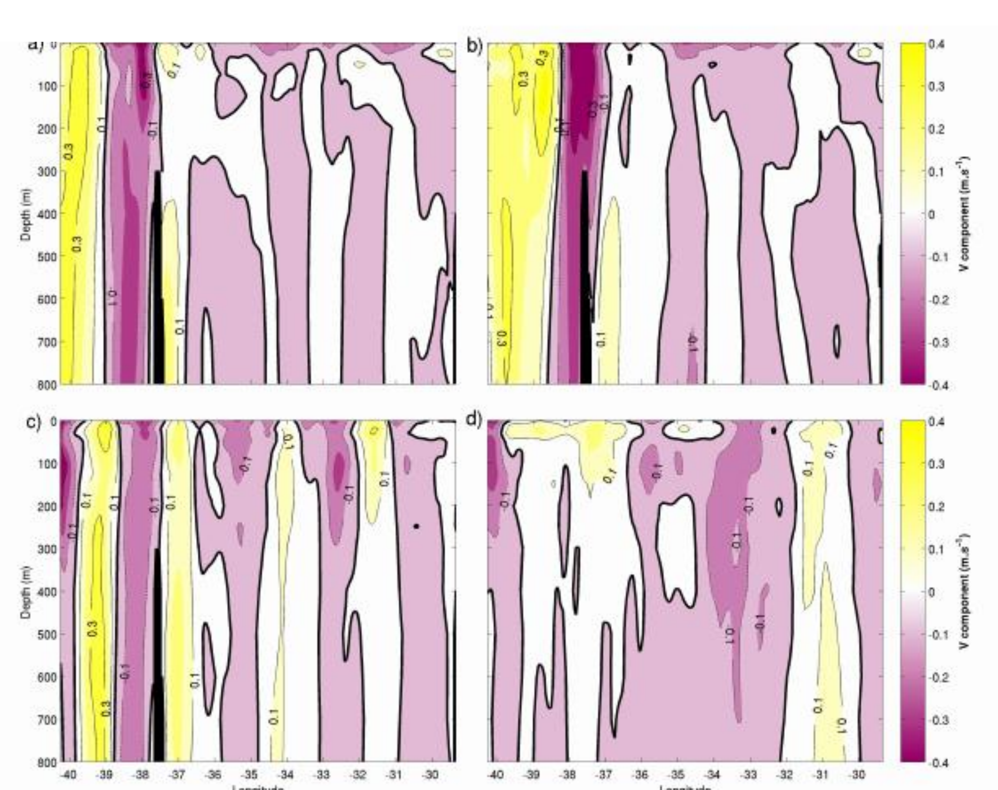

Figure 8. Meridional component of velocity at AX97 region for a) CTRL, b) EXP_ARGO, c) EXP_BOTH and d) HYCOM+NCODA system for December 8, 2012. The XBTs assimilated are those marked with a black rectangle in Fig 1c.

Conclusions

- It was possible to develop a method for estimating salinity with minors errors than WOA13. This method consisted in a combination of both, climatological data and obtained through regression. With this approach we succeeded in assimilating XBTs profiles into HYCOM with EnOI scheme.
- The assimilation of XBTs brought positive local impacts in T and sometimes in S but without a mecanism to constrain SSH, like the SSH assimilation itself, the mass field and consequently the currents disagreed with what was expected.
- The XBTs profiles were able to present impacts even in systems already configured with Argo floats. These impacts were local and had a good memory range.
- The experiment with XBTs showed the best results against both, XBT and Argo (independent) data. Also, it was able to correct the direction of the Brazil Current.
- The XBTs profiles of many sources will now be inserted into a full assimilation run of HYCOM+RODAS with all previous parameters in addition of temperature and estimated salinity (with the developed method) from PIRATA.