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Interactive comment on "Detailed temperature–salinity distribution in the Northeast Atlantic from ship and Argo vertical casts" *by* I. Bashmachnikov et al.

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We would like to thank Referee 1 for comments and suggestions which helped to improve the manuscript. The responses to the comments and the changes introduced are listed below.

Main comments: The filtering out of some of the data: the filtering out of meddies and nearby areas could result in lowering artificially the average S away from continental slope areas, thus increasing the horizontal gradients in the slope region. Could this be quantified? What percentage of profiles is removed that way and can the effect be quantified? Response: We consider that eddies do not form a part of the mean

state of the ocean, therefore we tended to exclude the related anomalies from the climatology. Meddies are the most prominent anomalous warm and salty bulbs in the region, which can have local salinity anomaly of 1 and temperature anomaly of 4oC. If not removed, this will introduce a bias into climatology. Meddies are identified using Richardson's criterion (Richardson et al., 1991), which proved to reliably identify at least strong meddies. In total, by removing profiles in meddies, we removed 2091 profiles or less than 4% of the data-set.

Eliminating the sum of T and S deviations in the 1500 and 2000m for OSD profiles originating from XCTDs. This is interesting: a reference on depth estimation for XCTDs should be provided (I did not know that they were reaching so often below 1500m). Response: Unfortunately NODC data-set does not provide the information about depth estimation algorithm for XCTD casts: the algorithm used is the choice of the data supplier. Therefore we may expect that in some cases original manufacturer algorithms were used, which induces errors in computed depths of the probes. But since we are not certain about the algorithm used for each particular cast, we prefered removing the deviating profiles, instead of correcting them.

What does close to zero refers to (be more quantitative?) Response: We extended the paragraph to give more information on the filtering procedure: "Further experiments showed that OSD profiles along some of XCTD routes evidence a consistent rise of temperature and salinity relative to WOA09 climatic profiles, especially noticeable below the 1500-m level. This was not observed for CTD or PFL profiles and was presumably due to incorrect estimation of the instrument depth for XCTD instruments (Levitus et al., 2008). To eliminate the effect, the sum of temperature and salinity deviations of the OSD profiles from WOA09 between 1500 and 2000 m were computed. The sum of the deviations should be around zero within the limits 1.96*std/sqrt(n), where n is number of data-points and std is the typical standard deviation, which is 0.5 for salinity and 1oC for temperature. Taking the typical number of casts around each of the mesh points (30x30 km square) the to be 30 and the critical deviation of the sum to be five times the error of the sum, we excluded the XCTD casts in the areas where the sum of deviations from WOA09 exceed 1 in salinity and 4oC in temperature."

Removing PFL profiles due to salinity sensor drift. I suggest to use for Argo the Coriolis data base (also the way the corrections are applied in Coriolis should avoid artificial shifts of S by the correction methods which seems the case in the Argo DAC). At least compare the two (does the sorting out of the data has some effect)? Response: In Figures 1 and 2 (attached) the gridding results using PFL (only), obtained from Coriolis data-set (meddies are filtered) and from NODC data-set (after full filtering, described in the manuscript). The number of "valid" profiles in Coriolis data-bas was higher 29000 vs. 22000 in NODC (although this difference will be smaller reduce after full filtering is applied of Coriolis data-set, as it has been applied to the NODC data). Below the results for 1500m level are presented. In general the spatial distributions are very similar, but in the NW side of the region Coriolis data set shows "spots" of higher salinity, filtered from the NODC data. In average standard deviation of difference between the two data-set from surface to 1900-m level was temperature 0.1 and for salinity 0.03, and the mean difference is one order less. Thus we conclude that, after the filtering applied, the NODC PFL data-set do not degrade the accuracy of the climatology as compared to Coriolis data-set.

Figure 1: Gridded map (function "griddata") from NODC PFL after full filtering.

Figure 2: Gridded map (function "griddata") from Coriolis PFL after removing meddies.

A lot of effort has been done to develop the adjusted beta-effect automatic sorting. This is interesting; how smooth needs the bathymetry be for the algorithm to work? Response: We agree that his information needs to be reported in the manuscript. The degree of bathymetry smoothing should be related to the size of the gridding window, but it is a bit subjective. In this study we used the bathymetry interpolated to about 1/2 of the minimum gridding window (30x30 km). This information is now added to in Section 2 of the manuscript (p.9). The effect of the bathymetry on distribution of the

weights in a gridding window is presented in Fig. 2.

on page 1485, line 19, two modes in R are commented, but the following discussion only focuses on the larger of the two. What about the smaller one? (I also noticed that in the later choices, even near the surface where data density is rather high, R retained is larger) Response: The obtained bi-modal structure of the eddy radii is certainly a very interesting result for regional eddy dynamics, but this is outside of the scope of this paper. Here eddy radii were estimated exclusively to justify the choice of the gridding window radius that should be large enough to reduce possible eddy-related bias. The final radius of the gridding window was chosen to comply with two requirements: a) to have sufficient data-points within each of the gridding areas (at least 30); b) to securely remove eddy-related anomalies (noise) from climatology (otherwise a densely sampled eddy may induce a local bias in climatology). To comply with the latter requirement the gridding radius was taken to be larger than the maximum eddy radius (Fig. 4). At the same time, there are less densely sampled areas (in the west of the region), where the first condition (on the minimum number of casts) is limiting the radius (Fig. 3c). Here the radius used is larger than the one, allowed by size of eddies. In some places, where the data density strongly varies in space (Fig. 3a-b), the window radius is chosen, orienting on the areas with lower data density.

Minor comments: A few minor comments In the title of the paper, I suggest to drop 'Detailed' Response: The title is changed accordingly.

p. 1490 l. 2: I am not sure I understand where and how the reference level is chosen. Is it the same for the different climatologies? What is the spatial pattern of this layer? The comparison might not be a proof, as the mean circulation is to some extent reconstructed from hydrography assuming a reference level (and also drifter data; depending on the version with different characteristics, in particular for inclusion of Gravimetric mission data). Response: The reference level has been positioned at 1900 m depth, and it is the same for all the climatologies (p. 1489-1490). The paragraph is changed to: "Fig. 11 shows geostrophic currents referred to the

1900-m level, computed from the MEDTRANS, WOA13 and MIMOC climatologies. Currents from WOA09 climatology are not presented since they are strongly oversmoothed even compared to MIMOC climatology. The 1900-m level is chosen as the reference one, since in the surrounding depth layer the smallest variations of isopycnal depths over the study region is observed. The reference-level currents in the study region, derived from Argo floats, are of order of 1 cm s-1 (T.Calheiros, personal communication), which can be taken as the error in computation of the upper ocean current velocities using dynamic method." In fact, our recent studies of the currents using Argo floats (unpublished) suggest that the climatic currents at those depths are typically below 1 cm s-1, and do not exceed 1-1.5 cm s-1 (except for some very limited areas along steep bottom slopes of the MAR, where the current may reach 2 cm s-1). So 1 cm s-1 is close to the upper estimate with the 1900 m reference level over the most of the region. For AVISO altimetry MDT we used the latest release of CNES-CLS09_v1.1 (http://www.aviso.altimetry.fr/en/data/products/auxiliary-products/mdt/comparison-of-global-mdt.html). The reference is added to the text (p. 16, line 6). We agree with the referee that MDT used in AVISO altimetry is not perfect. Still it combines mean altimetry sea-level, gravimetric data, drifter data and hydrography, and the surface currents computed from the MDT are the most representative for the moment, which. So we use AVISO results as the reference.

p. 1490, l. 20: for quasi-stationary meanders of Azores Current, when mentioning where they are, it would be good to check if they are positioned in same place in AVISO product. Are these real features or resulting of inappropriate sampling of varying meanders... (we see afterwards that it was only present in winter season for Medtrans; is it similar in Aviso?). Also, here I gather that geostrophy and not cyclostrophy is used. The discussion of bottom of page 1490 and top 1491 is interesting (agestrophy), but it would be useful in that case to estimate directly the cyclostrophic currents. Response: In AVISO the meanders are also observed. Now it is mentioned in the text. We are grateful to the Referee for pointing out this discrepancy in explanation of the results of the computations. To roughly evaluate the correction factor, related to the effect of

the inertial force, we applied the expression DU=Uˆ2/(f*Rcurvature), where U is the geostrophic current at the sea-surface and Rcurvature is the radius of the curvature (Cushman-Roisin, 2010). The correction DU never exceeded 1% of the module of current velocity. This is not surprising, since half-wavelength of the meanders is around 500 km, and at those scales the inertial forces are much less than Coriolis and pressure gradient forces. Therefore, this term can be omitted in estimation of current velocity. The explanation of current de-intensification, as it turns north and intensification, as it turns south, in spite of qualitative agreement with the results of Cushman-Roisin, should be rather related with continuity. On another hand, a cumulative effect of the inertial force, even a small one, may result in inflows/outflows from/to the current as the flow turns north or south. Below we present the modified version of the paragraphs: "Fig. 11a shows that the AzC decelerates as it turns north in quasi-stationary meanders and accelerates as it turns south. This is also registered in AVISO results (Fig. 11b), but is absent in WOA13 results (Fig. 11c). The most intensive meander is situated at 22o W (AVISO data – at 23o W), while the second one – around 16-17o W (the same in AVISO data). Further on (Section 3.2) we will show that the meander at around 22o W is pronounced mostly during winter and nearly disappears in summer (Fig. 13 a-b). The same type of seasonal variations is also observed in AVISO altimetry currents (not shown). The observed deceleration in the AzC in the meanders, as the jet turns north, is accompanied by widening of the jet and an outflow from the jet to the north (Fig. 11a). Merging together of the streamlines and acceleration of the AzC, as the jet turns south, is accompanied by an inflow to the AzC from the north at 20, 17 and 14o W. The southward meandering of the AzC ends with the branches to the south at 32, 28, 17 and 12oW. Therefore quasi-stationary meanders in the AzC form semiclosed water circulations to the north and to the south of the jet. Those features are also missing in WOA13 or MIMOC climatologies. The abovementioned inflows/outflows to/from the AzC jet as it meanders may be a result of accumulated effect of cross-jet migrations of particles under the inertial forces (Cushman-Rosin, 2010). Local inertial effects are estimated to be within 1% of the computed geostrophic current velocities."

p. 1492, l. 9 and later, ‘African coast’ is a bit vague. It would be good to add latitude ranges. Bottom p. 1492. It would be interesting to know how much the currents at 700m are influenced by reference level. 1600m is also presented (which is even stranger/less reliable) for seasonal cycle. Response: The phrase is changed to better specify the locations: “Along the western coast of the Iberian Peninsular and the northwestern coast of Africa (from the Canary islands to the Gulf of Cadiz), water at 200 m depth is fresher (Fig. 12 c) and colder (not shown) during the warm season” Following a comment above on the independent studies of Argo drifters, we assume the possible error of 1 cm s-1. This is now mentioned above (p. 16). At 1600 m we did not evaluate seasonality in currents, but only the T-S distributions. We changed the phrase, which, in the context, was misleading and added the missing information: “Though the weak currents computed at those depths are influenced by the non-zero flows at the reference level (of around 1 cm s-1), existence of the pattern is supported by stronger westward penetration of MW during summer (Fig. 12, d-f). Temperature-salinity maps at 1600 m depth suggest that seasonality here is very weak (Fig. 12, g-i).”

p. 1496, l. 9 ‘to the northwest’ (instead of ‘to the northeast’) Response: Thank you, this is corrected.

Throughout the text quite a few geographic or bathimetric features are cited, which would require them to be reported on at least one of the figures. Response: The geographic features are now reported (Figure 3, attached).

Interactive comment on Ocean Sci. Discuss., 11, 1473, 2014.

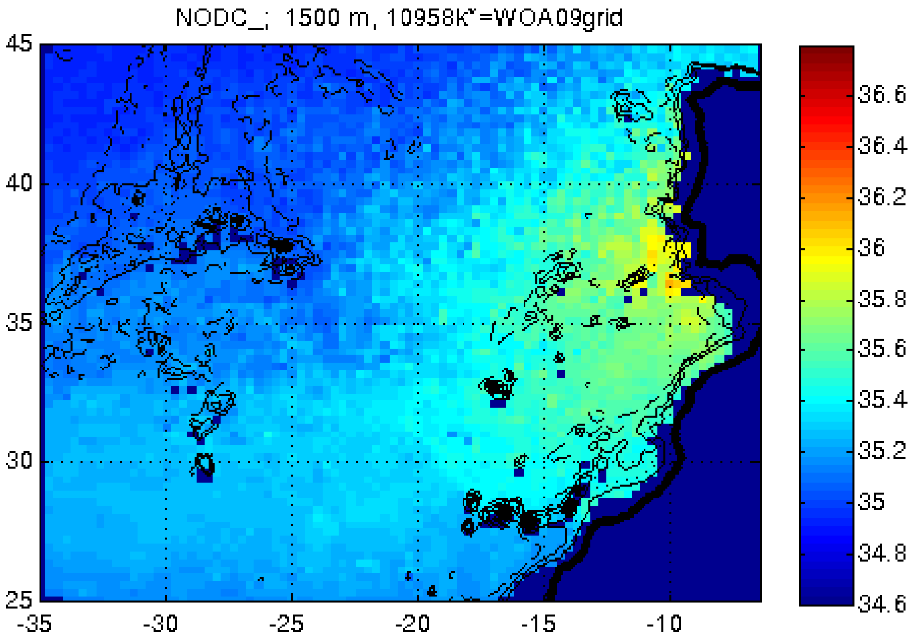

Fig. 1. Figure 1: Salinty, gridded map (function “griddata”) from NODC PFL after full filtering.

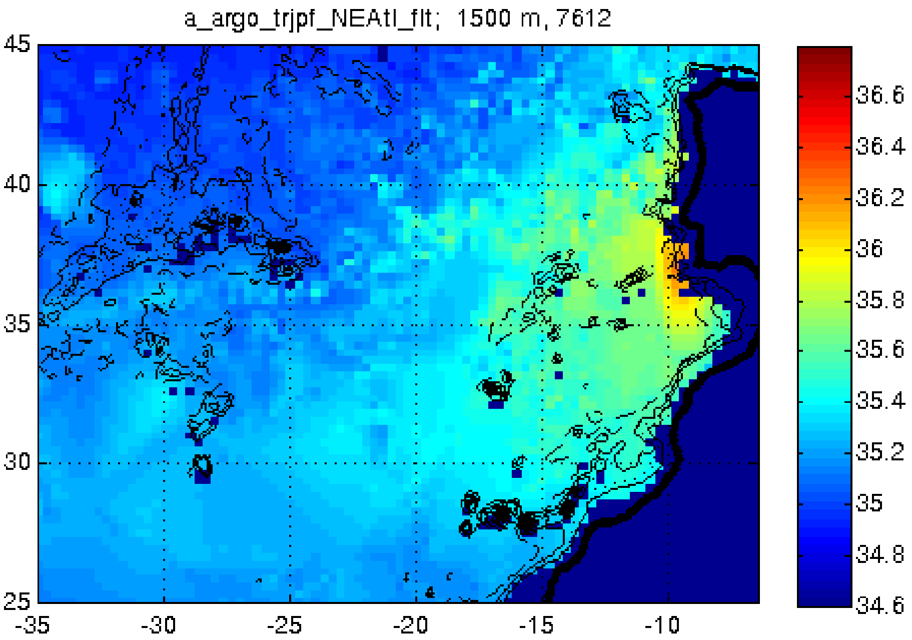

Fig. 2. Figure 2: Salinity, gridded map (function “griddata”) from Coriolis PFL after removing meddies.

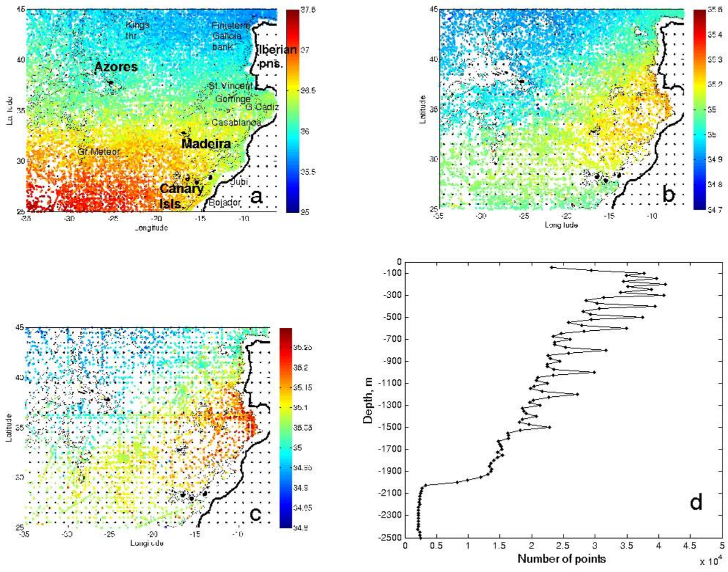

Fig. 3. Figure 3: Distribution of data-points at different depth levels