Ocean Sci. Discuss., 6, C924–C930, 2009
www.ocean-sci-discuss.net/6/C924/2009/

Ocean Science Discussions

Interactive comment on "Modal composition of the central water in the North Atlantic subtropical gyre" *by* A. Cianca et al.

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Received and published: 21 December 2009

We appreciate your constructive comments on our manuscript and we have updated the manuscript accordingly. We have addressed each of your comments in the MS as outlined below. GENERAL COMMENTS: We agree with the reviewer; the manuscript would be enhanced with the inclusion of the motivations to further characterize the NACW composition. It is true that there exists extensive literature about the NACW, and some of the papers are specifically referred to the mode water composition. We have tried to base our work on the main studies that have driven this topic, including them in the references. This work began with a temperature/salinity comparison between both sites (BATS and ESTOC) in order to establish the real differences in salinity. This objective, although less needed at present due to the increase of hy-

drographical data (e.g. Argo profilers), is considered of interest by some researchers, as the salinity is still under-sampled. The results obtained in our analysis have given us the opportunity to extend our investigation, facing another objective related to the NACW composition. Nowadays, mode waters represent one of the most important topics in oceanography and climate due to their role in the ocean ventilation process. In addition, biogeochemical effects have been recently described by Palter (2005) and Reverdin et al. (2009) as a consequence of the mode water presence. Although our objective is clearly descriptive, the presented results will improve the understanding of mode waters, by providing an exhaustive view on temperature/salinity characteristics and formation areas of the Mode Waters in the North Atlantic subtropical gyre. The new map, principally related to the eastern mode water distribution, will favour the possibility to draw up future studies focused on the estimates of ocean/atmosphere fluxes in a better context. MAJOR CONCERNS: a) Uncertainty error. It is the 1 standard deviation error estimate for each point. You can find the computer routine below: ; Only do this computation if user wants YBAND. if (haveYband) then begin z = REPLICATE(1d, n) yband = REPLICATE(covar[0,0], n) FOR p=1L,2*ndegree DO BEGIN ; compute correlated error estimates on y z *= x ; z is now xˆp sum = 0 for j=0 > (p - ndegree), ndegree<p do $ sum += covar[j,p-j] yband += sum * z ; add in all the error sources ENDFOR ; end of p loop yband *= var IF (MIN(yband) LT 0) OR (MIN(FINITE(yband)) EQ 0) THEN BEGIN status = 3 IF NOT ARG_PRESENT(status) THEN MESSAGE, $ 'Undefined (NaN) error estimate encountered.' ENDIF ELSE yband = SQRT(TEMPORARY(yband)) endif b) Why do these metrics seem to be at odds? It is true that by definition, mode waters have a low vertical density gradient; however, as mentioned in the text, ... "we are aware that making observations based on time-series results is very complex as there are no comparative data with the surrounding waters. In addition, the remoteness of the outcropping regions and the layer erosion as a consequence of the mixing processes, add more uncertainty to the observations. This process mainly affects the shallower modes on the eastern side of the gyre, where the vertical mixing is seasonally strengthened after spring due to the reinforcement of the

trade winds. In spite of this handicap, the possible presence of the minima or the expected identification of the corresponding cores can be considered as supplementary results in this analysis". The water recirculation at BATS allows a higher 18°C water time-residence, and the mode water core is easily distinguishable in the time-series. This is the reason why the low vertical density gradients were visible at BATS, whereas only a structure of three layers with different vertical density gradients was observable at ESTOC. This work uses other different resemblance criteria that this mode satisfies compared to the mode waters already referenced. c) Is there actually more variability in the T-S relationship at ESTOC than at BATS? The supplementary figure shows the seasonally averaged curves for each station were subtracted from the yearly mean curves at temperature increments of 0.1 °C. At BATS a very low seasonal variability is seen (< 0.01 of salinity) and standard deviations do not vary much (near 0.012) whereas variations are larger and change from season to season at ESTOC. Standard deviations are lower (around 0.025) in spring and fall, showing higher differences at higher temperatures (0.025 and 0.05 of salinity, respectively). Summer solution shows the higher standard deviation (0.060) and the estimated difference presents a constant value (near 0.015 of salinity) from upper to lower temperatures. The seasonal changes at ESTOC are related to the close-by upwelling area off West Africa and are a consequence of motions in the baroclinic structure. We have updated the manuscript and a new Figure 1 has been included as supplementary material. d) Troubles with several aspects of the Figures 4 and 5. Figure 4 represents the pycnostads in surface during winter (January to March). These pycnostads were obtained using the standard deviation from the time-series data (WOD2005). The low standard deviations represent more stability referred to peculiar densities. As the analysis has been made for winter-time data, we suppose that the surface layer is homogenous as a consequence of the convective mixing. We reached this supposition after estimating the mixed layer depth and calculating the average of the density in the depth range for each profile (the density values were very similar). Once each profile had its representative density value for the surface layer, we then estimated the mean and standard deviation

by square. Thus, low standard deviations provided us the temporal stability in density (Pycnostad). Figure 5 is the same as Figure 4, including the yearly isotherms of the surface temperature minima, over-plotted. The isotherms were obtained using sea surface temperature data from the Ocean Pathfinder Program (OPP). The yearly surface temperature minima correspond to the winter-time in the area and represent the characteristic temperature layer to be subducted at the end of winter (it is an approach). The temperature minima above the pycnostads offer information on the temperature of each pycnostad. Thus, the coincidence of the temperatures on the pycnostads with the referenced temperatures for the mode waters, approaches the outcropping regions. The weakest pycnostad signature of the 18°C water is most likely a consequence of the higher inter-annual variability that this water has in relation to the eastern mode waters along time-series MINOR COMMENTS. a) Page 2489, paragraph 2. Worthington (1959) defined its potential temperature as 17.9° C $\pm$ 0.3°C b) Page 2489, paragraph 3. We agree with the reviewer; the term "deep waters" into the parenthetical is a mistake. The ENAW is composed of the higher density SPMWs southward flowing in the Eastern North Atlantic region. Harvey (1982) described these mode waters as part of the intermediate waters in the temperature range from 4°C to 12°C. It has been updated in the manuscript. c) Page 2490, last paragraph. As suggested by the reviewer, it could be a different approach to the subject. However, from our point of view, the hypothesis was proposed because other authors have mentioned the probable presence of this mode water. We have confirmed the hypothesis and characterized the mode. d) Page 2493, last full paragraph. This statement was tested using the WOD 2005. We chose the squares from WOD2005, which were located between the latitudes 30 and 40 N and the longitudes 10 and 70 W, where both stations are more spatially representatives. The BATS and ESTOC standard curves are included in all of the Figures. The Figures that represent the western characteristics of NACW showed higher variability due to fluctuations of Gulf Stream meanders and mixing with SAIW. The central subtropical gyre showed lower variability and was flanked by both standard TS curves below 14°C, with a maximum difference between each other near 0.2 in salinity. Above this temperature a lower salinity is observed, similar to the western squares. The eastern side showed higher salinity due to the influence of MOW. Below 14°C, two MOW salinity maxima are seen. Above this temperature, the BATS standard curve limits the salinity to low values. We include Figure 2 as supplementary material e) Page 2495. We agree with the reviewer. Joyce and Robbins (1996) is a better reference. We have proceeded to change it in the manuscript. f) Page 2494, bottom paragraph. Once again we agree with the reviewer; the conservative tracer is the isopycnic potential vorticity, and in our case, f is fixed (as mentioned by the reviewer). We have updated the manuscript following the reviewer's proposal.

Interactive comment on Ocean Sci. Discuss., 6, 2487, 2009.

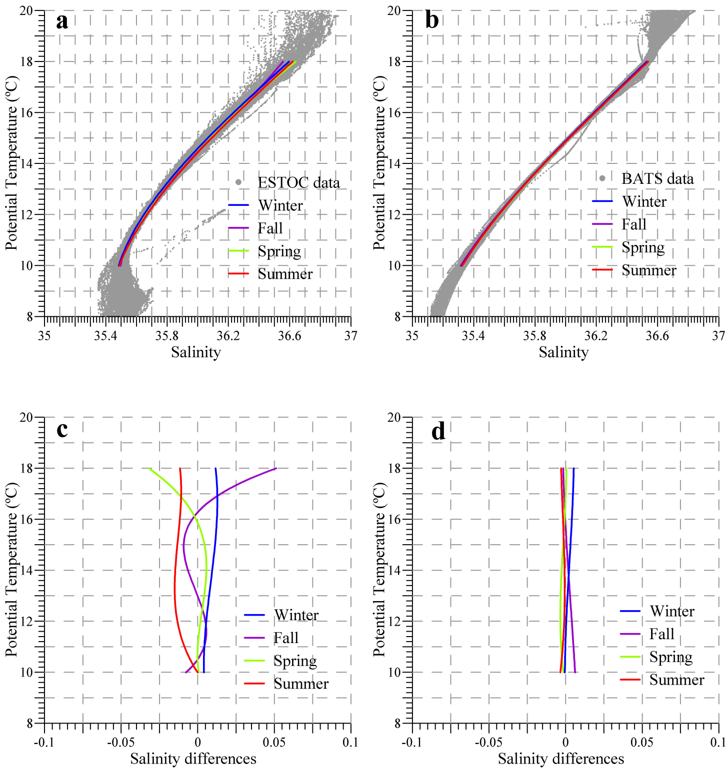

Fig. 1. (a) TS-distribution from ESTOC data (grey dots) and seasonal mean curves, (b) same for BATS, (c) salinity differences between seasonal and overall mean curves from ESTOC, (d) same for BATS.

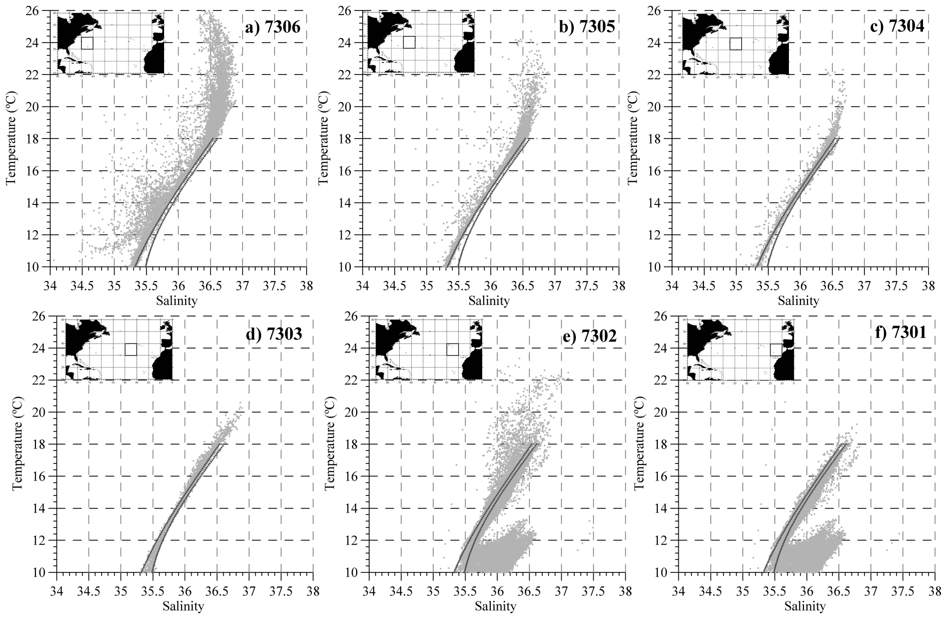

Fig. 2. Temperature and salinity distributions extracted from WOD 2005 for squares neighboring the time series stations with the standard curves for BATS and ESTOC.