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Ocean Science Discussions

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

Anonymous Referee #2

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Review of os-2009-75 "Modal composition of the Central Water in the North Atlantic subtropical gyre" submitted for publication in Ocean Science by Cianca et al.

This manuscript analyzes interior ocean hydrographic data from BATS and ESTOC along with near-surface data from WOD2005 and satellite SST. It attempts to identify a new mode water through various analyses, but does not succeed. It should be rejected for publication for the major reasons (A, B, and C) given below. While there are other minor flaws in the manuscript, only the severe flaws in the manuscript are addressed in this review, because the manuscript is not really a starting point for a publication-worthy document.

A. Two central assertions of this manuscript are that the structure in the uncertainties of the polynomial fits to theta-salinity (T-S) data from BATS and ESTOC (Fig. 2b) as

a function of theta relate to the local (as a function of theta) variance in the spread of the T-S relation and furthermore that these minima in variance are somehow related to mode waters. Both of these assertions are incorrect, as detailed below under "Firstly" and "secondly".

Firstly, the local variance of salinity around theta has nothing to do with the shape of the uncertainty curve, except as it contributes to the standard deviation of the residual. This fact directly contradicts a central assertion of the manuscript. Actually, for any polynomial fit higher than 0 order (a mean), the amplitude and shape of the uncertainty curve for the fit is governed by a combination of these three factors:

1. The standard deviation of the residual between data and the model (the polynomial fit to the data). All else being equal, the larger this value the large the size of the uncertainty curve. This factor is why the red curve has lower values than the blue curve in Fig. 2b.

2. The model (polynomial fit) used. For a data set that is evenly distributed as a function of theta (a histogram of number of data points in uniform theta bins being flat) the uncertainty curves will generally increase towards the edges (warmer and colder waters). They will also be symmetric around the mean value of theta for the data set used. Superimposed on this tendency toward increases in uncertainty towards the edges of the regime will be local minima equal in number to the order of the polynomial used. A second order polynomial fit will result in three minima, and a seventh order polynomial fit seven minima, and so on.

3. The distribution of the data points as a function of the independent variable. If there are many more data taken around 18 deg. C than elsewhere, the uncertainty will tend to be smaller near that temperature (modulating the wiggles whose number is dictated by the order of the polynomial used as described just above). This factor is why the red curve in Fig. 2b has its absolute minimum near 18 deg. C and why the blue curve has its absolute minimum near 11 deg. C. There are more BATS data near 18 deg.

C than elsewhere and more ESTOC data near 11 deg. C the elsewhere. Here the fact that both curves have three wiggles is presumably mostly owing to the order of the polynomial used, and not differences in the number of data points as a function of theta.

Thus If what one is interested in is the local variance in salinity about the T-S curve, one should compute that quantity. However, secondly, while a minimum in that local variance may be associated with a mode water, that characteristic is in no way the primary definition. That low variance may in fact be due to a number of factors (including double-diffusive mixing - e.g. Schmidt (1990, Journal of Physical Oceanography, vol. 20, no. 6, pages 900-906)) that are unrelated to mode waters. Mode waters must be associated with a pycnostad, with supporting evidence of recent ventilation also being desirable.

B. The quantity plotted in Fig. 3 can certainly be used to identify mode waters. Mode waters are characterized by a thermostad, a pycnostad, or occasionally a halostad. According to Seitz (1967, Journal of Marine Research, vol. 25, no. 2, page 203) oceanographic nouns with the suffix "stad" denote "a layer of water in which there is a relative minimum of the absolute value of the vertical gradient" in the parameter being studied. The customary measure of vertical stratification is the buoyancy frequency squared (N2 = -g/rho * drho/dz) with rho being locally referenced to central the depth around which the vertical gradient is estimated. However, the parameter displayed will do for the purposes of this review.

In the top panel of Fig. 3 the NASTMW is clearly visible as a local vertical density minimum, or pycnostad, with no other mode waters visible, so that is in accord with the discussion. However, in contrast, there is only one mode water distinguishable in the bottom panel of Fig. 3 is the NASPMW (although the discussion incorrectly asserts that no modes are visible there, see lines 13-14 on page 2495). Neither the discussion of this panel nor the panel itself in any way support the reputed presence of MMW or ? Mode Water (later dubbed Azores Mode Water).

C. The location of so called "pycnostads" in the WOD2005 and satellite SST data sets (Fig. 4 and associate discussion) is odd. Finding geographic minima in temporal variance of winter-time surface mixed layer densities is not related to finding pycnostads as defined above, so labeling these regions as pycnostads is wrong.

Locations where the winter mixed layer is deep are often associated with mode water formation regions, as are locations where the horizontal gradients of mixed layer density are weak. In order for the mode water to become part of the central water, it must be subducted below the base of the seasonal pycnocline. Thus one might find a mode water by detecting a pycnostad in the portion of the water column denser than the local maximum winter mixed layer density, and then tracing that pycnostad upstream to a location with a deep and laterally homogenous winter mixed layer of the same density as that pycnostad. The planetary potential vorticity (Q = f/rho * drho/dz) should be conserved along streamlines of flow, but generally it will be lowest in amplitude within a mode water near the formation region and then increase with distance downstream from this formation region.

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