Peer review report on “Characteristics of Water Masses in the Atlantic Ocean based on GLODAPv2 dataset” by Mian Liu and Toste Tanhua

1) Overview and general recommendation:

Understanding the formation, transformation, and circulation of water masses has been a hot topic in oceanography since its start. Many ways of tangling this oceanography field have been developed, from the mere description of hydrographic properties to statistical and numerical models. This manuscript presents the water mass structure of the Atlantic Ocean resulting from an Optimum Multiparameter (OMP) analysis.

Although the intention of the manuscript is honorable, trying to facilitate the interpretation of biogeochemical results, the findings of the manuscript do not add any new information to the community. I would consider reducing the extension of this work and merging it with the companion paper. In the case the work would have to stand from itself, a much deep discussion of the results would be needed. Besides, the reliability of the OMP results has not be proven, by, for example, analyzing the residuals.

The manuscript needs a very careful proofreading and the number of figures/subplots in the main text needs to be reduced.

2) General comments:

1. After previous reviewers highlighted the need of a careful proofread of the manuscript, the manuscript still presents grammatical errors and misspellings. To highlight some:
   a. There are still two appearances of STW instead of SWT (lines 325 and 355).
   b. The term "sea water type" still appears in the manuscript instead of "source water type" (line 160 and Table 4 caption).
   c. There are inconsistencies in units. For example, sometimes density units are written as kg m^{-3} and others as kg/m^3.
   d. Sloppy proofread can be seen, for example, on lines 181 (“…is that he water masses…”), 306 (“…our analysi.The region…”), 423-424 (“…being important to distinguishe AAIW from Central Waters…”), and 536 (“vintages” of LSW exitst), to enumerate some. Besides, there are grammatical errors, such as those on lines 49 (“there are gradual transformation between them”, where “transformation” should be plural), and 52-53 (“Also important is the concepts”, it should be either “important is the concept” or “important are the concepts”); and sentences that are unfinished, such as the one on line 126 (“…water masses, since this product is.”).
   e. One citation is not correctly spelled in the text (line 68, should be Jacobsen (1927)). There are also few references not cited in the text, such as Clarke et al. (1990); Ishii et al. (2011); Key et al. (2010); Lacan and Jeandel (2004); to enumerate some.
2. To solve the OMP for the whole Atlantic Ocean, the authors split the water column into different regions and layers (as summarized in Table 1), called OMP runs. Some suggested improvements for the OMP analysis:
   a. After changing the description of the Central Waters by using two SWTs, the two SWTs defining each Central Water are not allowed to mix between them between 40N and the Equator (#5 upper and lower), so the transition between the different properties of the Central Waters observed in the ocean cannot be represented by the OMP. Besides, in Table 1 there is no

specification of which of the two SWTs (or if the two SWTs) representing each one Central Waters they use that when solving the OMP system, such as in #6 and #8, for example. Please specify to avoid confusion.

b. Lines 205-206: If the SWTs allowed to mix in each of the OMP runs have a coherent lateral and vertical distribution not such "step-like" features should appear. Each run should share at least one SWT with the adjacent OMP runs to avoid that issue, which seems to be the case according to Table 1. However, drastic disappearances/appearances of water masses can be observed in the top panels of Figure 19, highlighting the lack of a "transitional water mass" between AABW and NEADW.
c. Lines 207-214: There is no figure supporting what is discussed there, and what is 100% is the mass conservation itself not the residual, the residual should be 10% or 20% (same for line 36-37). Besides, if all the required SWTs are defined and the weighting of the OMP equations is well performed, an error in the mass conservation of 20%, even 10% should not happen.
d. There is no discussion about the residuals of the OMP analysis. The residuals of the least square method constrained to non-negative solutions used for an OMP analysis give insights about the reliability of the proposed mixing model, and indicate the quality of the solution.
e. Figure 6 shows high percentages of ENACW along the Gulf Stream. That highlights the fact that that water mass is formed in the intergyre region (Pollard et al., 1996) and not close to the Iberian Peninsula. Changing the formation region for ENACW would result in a wider temperature and salinity range for ENACW than the one considered in this work.
f. Figures 7 (WSACW) and 14 (ISOW) show water masses outside the range they should appear. Fig. 7 shows WSACW below σ_θ = 27.00 kg m^3, which should not appear according to Table 1 (below that density, OMP run #8 should be applied, which does not include WSACW). In Fig. 14, ISOW seems to extend to surface with percentages around 10% (guessing from the color scale), where it is not allowed according to Table 1. These two facts question how the OMP runs were applied to the dataset.
g. Both reviewers highlighted the fact that some samples are not accounted by any water type, and no change has been made to solve this issue. This is clearly seen in Fig. 2 (previously Fig. 22).

3. There is a good explanation on how the regions of water mass formation where selected to determine the SWT properties, but the discussion of the OMP results, i.e., the water mass distributions comparing them against previous works is almost inexistent. If this works wants to stand by itself, it needs a better discussion of the results, presenting what novelties have been found. Some of the information to discuss with is already in the sections describing the formation regions of the water masses.

3) Minor comments:

4. Line 26 and elsewhere: Once the MOW has overflowed the Strait of Gibraltar and has mixed with Atlantic Waters, it is no longer MOW but Mediterranean Water (MW) (see, for example, Carracedo et al., 2016). As in this work the depicted area of formation of MOW west of the Strait of Gibraltar (Fig. 9), please change MOW to MW here and elsewhere.
5. Introduction: New information has been added to the introduction, but a careful re-organization and summarization needs to be done in this section. The information is presented in a chaotic order, being some information repeated.

6. Lines 156-158: This sentence is confusing. Consider rephrasing something like: “Some WMs need more than one SWT to be defined (Tomczak, 1999), for example Central Waters present a linear temperature-salinity relationship that requires two SWTs for a complete description.”.
7. There is still a misuse of the terminologies water mass vs. source water type. For example, on lines 162 and 164 it is used the term WM instead of SWT, as it is correctly used on line 176. For an OMP analysis what is defined are the properties of the SWTs and not of the WMs.
8. On lines 189-191 it is stated that the mixed layer was not considered, but on lines 192-194 it is stated that all the Atlantic data present in Glodapv2 was analyzed. That creates confusion, please merge both sentences.
9. Line 195: to a reader not familiar with OMP it is not that clear why solving the fractions of 6 SWTs is an excessive number. Please clarify that the number of SWT fractions must be lower than the number of properties defining the SWTs in order to solve an overdetermined system of equations.
10. Lines 241-251: as already pointed out by van Heuven, only key figures should be maintained in the main manuscript and the rest should be placed in the supmat. As a guidance, I would leave one of the figures referred in these lines (Figs. 5, 8, 11, 12, 16 and 17) in the main text as an example and move the others to the supplementary material.
11. Line 318: Salinity should be specified as a dimensionless quantity (Unesco, 1986).
12. Lines 726 and 730: should it be “6-dimensional” and “Six often measured” according to the number of properties defining each SWT?
13. Both reviewers rightly point to the fact samples near 34.8 salinity and -1^{o}C temperature are not represented by the SWTs used in this work. van Heuven and the authors themselves determine that those samples are located in the Norwegian Sea, therefore those samples should not be considered in this work that focusses in the Atlantic Ocean. Therefore, those data points and those of the mix layer that were not being solved by the OMP analysis performed in this work should be removed from Figs. 2, 5, 8, 11, 12, 16, and 17.
14. Figures: Pressure units should be dbar not db.
15. Figure 2: I would recommend adding all the SWTs to the plots, and not only the central points in case of the Central Waters. Adding the two extremes of the TS-relationship would help the reader to know which samples are “enveloped” by the defined SWTs.
16. Figures representing along section properties (Fig. 1) and waters mass distributions (Figs. 7, 8, 10, 14, 15, 19 and 20) will benefit from map insets (as Fig. 3) to avoid the reader to go back and forth to Fig. 2 to know where the section is located. In case such map insets are not added, please state that the cruise tracks are represented in Fig. 2.
17. Please, consider changing the color scale of Figs. 1, 3, 6-10, 12-15 and 18-20 to a colorblind-friendly one, such as the ones in the cmocean package: https://github.com/kthyng/cmocean-odv.

4) References

Carracedo, L.I., Pardo, P.C., Flecha, S., and Pérez, F.F.: On the Mediterranean Water Composition. J Phys Oceanogr., 46, 1339–1358, 2016.

Pollard, R.T., Griffttths, M.J., Cunningham, S.A., Read, J.F., Pérez, F.F., Ríos, A.F.: Vivaldi 1991 – a study of the formation, circulation and ventilation of Eastern North Atlantic Central Water. Progress in Oceanography 37, 167–192, 1996.

Unesco: Progress on oceanographic tables and standards 1983–1986: Work and recommendations of the Unesco/SCOR/ICES/IAPSO Joint Panel. Chapter 7.1: Practical Salinity. Unesco Technical Papers in Marine Science 50, p. 9, 1986.