

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

This paper is an attempt to provide a very thorough analyses of water masses in the Atlantic Ocean. The authors have clearly done a lot of work, both in analyses, figures and text. Their objective seems to be, to provide some sort of look-up table on Atlantic Water masses that can be used for both physical and biogeochemical community in order to understand the formation and spread of water masses. This in itself is certainly useful, and in that regard, I think this paper is worthy of publication. However, this paper is not *ready* for publication.

It is not a lack of effort that is the problem. The authors have done a substantial job. It is because it is too much and yet too little. Too much because 1) a lot of the text can be shortened and 2) in the sense that they try and cover a lot of water-masses and therefore have to cover a lot of literature. On the other hand, too little because 1) a lot of the method and the science is not well explained or clearly laid out, and 2) they don't cover all the literature for all the WM because that is perhaps impossible.

So, to me, there are two issues: 1) science, 2) presentation and text. The first requires a lot of work, as explained below. Even to just make this work reproducible by others. The second, I'm not sure what is the best option, but currently I think it may be too long and maybe still incomplete. Overall, I think this paper can be reduced to at least 75% of its current length just by being more precise, concise and to the point. Because this paper is already long, this is important. Some comments are also provided below.

The science

It is unclear which salinity is used. I assume Practical Salinity. These days we do not use potential temperature and “salinity”. We use Conservative Temperature and Absolute Salinity. These can easily be obtained using the TEOS-10 gsw software. Please use these or provide clear arguments why you do not use those variables.

Section 2.2 and 2.3. Line 136 to 174. What exactly is the message of all this text? Basically, I read; “it's difficult to define water masses, but Tomczak did a good job and we use his method”. If so, I think this can be a lot shorter. This would free up some space to then properly explain the method. You provide one equation (L175), with little explanation. It is not clear where and how source waters are defined and how the related **G**-matrix would look like and what kind of numbers go into that matrix. Then it is unclear which data go's into **d** and it is also unclear which method is used to find a minimum for **R**. Is this a least-squares inversion? If so, have you looked at the sensitivity to choices in the input parameters, such as how water masses are defined, and how much variables are used? Is any weighting used for the solution? These are all unanswered question that are important for reproducibility of the results.

L181-184 This paragraph is unclear. Please provide numbers. What are “short” transport times, and how “close” is close enough and how to these numbers influence your results.

Section 2.3 and beyond. Nitrate and phosphate seem to have a very similar distribution. Using them both may not add that much information. In line 181-191 you then say you use them to construct a conserved variable. So, are you then using 5 instead of 6 variables? If so, this should be made very clear in the manuscript. Also, for the conclusion section you talk about 7-dimensional space. Is it still if you combined tracers into one? On top of that, what do you do with Oxygen, as that is also non-conservative and, in these lines, you mention this could be a problem.

Because the explanation of L185-L214 is not always clear and the manner by which numbers are obtained is not well explained, I don't understand L207-214. In addition, the authors talk about something in A16 in L208-209, but do not refer to where we can see this.

You define 4 vertical layers based on surface-referenced potential density. First of all, how is this calculated? Do you use the TEOS-10 software? Second, why surface referenced potential density. This is not accurate beyond 500 meters depth for WM analyses. Please use Neutral Density, which is perhaps the best we currently have.

L261-278 Is this about figure 5 and beyond. It is not clear what the message of this paragraph is and where it belongs. Either remove it or clarify what the purpose is.

The writing and presentation

The authors have provided many figures with a lot of information. A lot of work has been done to do this properly. Still some improvements can be made. Overall, I think that the text needs to be written more concise, precise and to the point and can reduce to 75% of its current length.

Introduction: The authors attempt to write a little bit of history on the subject. It seems incomplete and maybe not necessary to the extent done here. It is partly a matter of style, but partly also a matter of being precise, concise and to the point. So, I think the introduction can shrink at least 25% and still convey the same information. Perhaps consider reading Groeskamp et al 2019, it provides a history on WM analyses and WM transformation.

Section 4,5,6,7

Each WM is introduced with some literature background. That is great. However, because so many WMs are considered, this of course requires a lot of literature study. I think the current references are all pretty old and some new insights can be included, from more recent studies. I can give one example of a WM which I'm more familiar with. For AAIW. Consider these papers: Over all

- Saenko, O. A., and A. J. Weaver (2001), Importance of wind-driven sea ice motion for the formation of antarctic intermediate water in a global climate model, *Geophys. Res. Lett.*, 28(21), 4147–4150, doi:10.1029/2001GL013632.
- Saltee, J.-B., K. Speer, S. Rintoul, and S. Wijffels (2010), Southern Ocean thermocline ventilation, *J. Phys. Ocean.*, 40(3), 509–529, doi:10.1175/2009JPO4291.1.
- Nycander, J., M. Hieronymus, and F. Roquet (2015), The nonlinear equation of state of sea water and the global water mass distribution, *Geophys. Res. Lett.*, 42(18), 7714–7721, doi:10.1002/2015GL065525.
- Abernathey, R. P., I. Cerovecki, P. R. Holland, E. Newsom, M. Mazloff, and L. D. Talley (2016), Water-mass transformation by sea ice in the upper branch of the southern ocean overturning, *Nat. Geosci.*, 9, 596–601, doi:10.1038/ngeo2749.
- Groeskamp, S., R. P. Abernathey, A. Klocker (2016), Water Mass Transformation by Cabbeling and Thermobaricity. *Geophysical Research Letters*

I'm sure such additional work could be done for most WMs considered here. Now I'm not sure how much of this work you need to do to provide a reasonable background. Eventually, I'll leave it up to the authors to decide if the current version is good enough or needs more work on that.

Line 115-134 can be merged into one brief paragraph half the size.

L181 - What is internally consistent? I don't think this is a useful description.

L241 – During the narrative of each water mass. What does that mean?

L244 – which colour coding?

L256-260 – Good point, but not very clearly explained. Please try again.

Figure 2: When Figure 2 is first mentioned in text, SWT is not yet defined. But it is used in the caption. That should be clarified. It is unclear where the colours stand for. Please provide link to abbreviations in caption, they have not been discussed yet. Please provide in caption, the clarification that the middle panel is a zoom of the box in the left panel. The letters in the light blue can't be read.

A few examples of incomplete, misspelled, or weird sentences. This needs work:

- L181 that the
- L194 . .
- L211 weird sentence
- Where is section 8?