Reply to the comments by Reviewer 1, Matthias Tomczek

The paper uses the most comprehensive ocean database to objectively define source water types for the Atlantic Ocean.
The paper is put sloppily together and will require a careful reading by someone not too close to the original manuscript to iron out the many grammatical errors and other inconsistencies.

We have now rewritten the manuscript and did careful reading to iron out the many language errors.

I do not consider it the role of the reviewer to do that, but here are a few pointers as to what has to be done:
a) The reference "Schaffer, A.J., JACOBSEN, A.W., Mikulicz's syndrome: a report of ten cases. American Journal of Diseases of Children 34, 327-346, 1927" has no place in an oceanography paper. I assume that, in an effort to be as comprehensive on the history of water mass analysis as possible, the author meant "Jacobsen, J P. (1927) Eine graphische Methode zur Bestimmung des Vermischungskoeffizienten im Meer. Gerlands Beiträge zur Geophysik, 16, 404-412" and went astray in his Google search.

Thanks for pointing this error out. Reference now removed.

b) "The ocean is thus composed a large number of water masses" misses the word "of", and similar with many sentences.

Corrected (line 41)

c) "Source water type" is sometimes abbreviated as SWT, sometimes as STW.

We went through the manuscript and corrected to it now is always "SWT".

d) "Based on the work of (Pollard and Pu, 1985)" should be "Based on the work of Pollard and Pu (1985)", and similar with many citations.

We went through the manuscript and corrected the citations. (line 276)

Turning to the scientific content of the paper, it may be noted that there are basically two approaches to derive objective definitions of water masses and their source water types. Assuming no knowledge of the situation under study one might try cluster analysis and discover the relevant source water types from that. If, on the other hand, sufficient information is available to predict the source water regions with certainty one might proceed with an analysis of the parameter distributions in the preselected source water regions and derive the source water types from that. Given the large amount of information available for the Atlantic Ocean the paper rightly proceeds along the second path.

We agree with this assessment, and the intention of our work was not to redefine the water masses in the Atlantic Ocean, but rather to use the information already available and base the work on that. In several instances, water masses has in the past been differently defined and/or named so we tried to put this information in the paper as well.

Unfortunately, the paper does not fully grasp one of the basics of water mass theory, namely the distinction between water masses formed by subduction and water masses formed by winter-time deep convection. The water masses of the deep ocean are mostly formed by winter-time deep convection.

Source water types of the latter variety represent the conditions in their source regions during winter and can therefore be mathematically described by a single point in parameter space, with an associated variance representing interanual changes during water mass formation. The variable values given in Table 3 for the lower three layers can thus bee seen as a listing of the SWTs for the corresponding water masses, which are defined through single points in parameter space.
The water masses of the upper ocean (known as Central Waters), on the other hand, are formed by subduction over extensive ocean regions of the subtropics and therefore characterized not by points in parameter space but by usually nearly linear parameter relationships. This is clearly seen in Figure 3, where the TS-relationship of ENACW stretches from 10 to 15_C and 35.2 to 36.2 in salinity, or in Figures 5 and 6, which show similar TS-relationships for WSACW and ESACW. (This is even occasionally acknowledged in the text, for example in section 3.1.1.) To define these Central Waters through source water types requires two SWTs for each Central Water to define a linear parameter relationship, one at the lower end of the parameter relationship and one at the upper end. The principle is demonstrated in detail in Figure 2 of Tomczak (1999). The paper states "In this paper we use the concepts and definitions of water masses as given by Tomczak (1999)" but it does not appear to follow this through in full logic. It states when introducing the water masses of the upper layers: "The Upper Layer is occupied by four SWTs called central waters that are known to be formed by subducted [sic] into the thermocline (Sprintall and Tomczak, 1993; Tomczak and Godfrey, 2013) into the interior of the ocean (Pollard et al., 1996). Figure 2 illustrate [sic] a schematic of the main currents in this layer and the main formation regions of the central waters in the Atlantic Ocean. Water masses or SWTs in this layer can be easily recognized by their linear T-S relationship."

There is complete confusion between water masses and SWTs here. The correct description would read: "The Upper Layer is occupied by four water masses called Central Waters that are known to be formed by subduction into the thermocline (Sprintall and Tomczak, 1993; Tomczak and Godfrey, 2013). Figure 2 illustrates a schematic of the main currents in this layer and the main formation regions of the Central Waters in the Atlantic Ocean. Water masses in this layer can be easily recognized by their linear T-S relationship, and each water mass requires two SWTs to represent this relationship for a complete description."

Thank you for helping us out here with a clear path forward.

In the revised version, we made amendments to this aspect. **Central Waters** are redefined by their **upper** and **lower boundaries** by following the suggestions:

In the Section 3.1, distinctions between Central Waters and other deeper SWTs are pointed out. The most significant feature of the Central Water is that the characteristics cover a relative larger range and cannot be consider as a point value. As a result, upper and lower boundaries are set for each property of Central Waters and the values between them are all considered as SWTs of Central Waters in the further OMP analysis.
Take the potential temperature (θ) of ENACW as the example. After confirming the formation area (15°W—25°W, 39°N—48°N and 100 — 500 db), and the criteria (σ_θ between 26.50 and 27.30 kg/m^3), a relationship between potential temperature and density (potential density as the reference/independent parameter, detail in section 3.0) is plotted (blue dots) in Fig. 3 with linear fit (red line). The upper and lower boundaries in potential temperature of ENACW are finally determined by the choice of our own fit ranges (https://omp.geomar.de/), 14.60 °C as the upper boundary and 9.80 °C as the lower boundary. All the other properties are done with the same method and the boundaries are listed in Table 3.

In the figure plots for other deeper water masses (for example Fig. 9 for AAIW) statistics are done for all the data in the selected regions with selected criteria. For the Central Waters, statistics are done, considering all **the data between upper and lower boundaries**, and then, all the data between the boundaries are considered as one Central Water Mass and plotted in the following figures (for example Fig. 4 for ENACW). In the figure plots, Central Water, for example ENACW, is still plotted as **one water mass**. The reason we plot figures in this way is hoping to show the reader that one Central Water, although the properties cover certain ranges and have upper and lower boundaries, is still **one water mass** instead of two.

The problem of the Central Waters continues right through the paper. If the criteria used to define ENACW pick up all data points along the linear parameter relationship of Figure 2, what is the meaning of the variable values given for ENACW in Table 3?
Those values do not describe a parameter relationship but a single parameter point in space not representative of Central Water. The representation of the Central Waters in Figure 22 also does not correspond to the definition ranges shown in Figures 2, 5 and 6. Central Waters should show up in Figure 22 as TS-lines, not TS-points. (As an aside, I assume that "F ISOW" in the figure caption should read "K ISOW".)

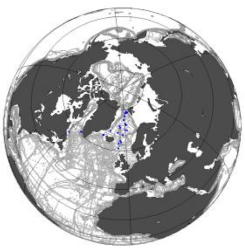
However, in the further OMP analysis, one Central Water **occupies two positions** of SWTs (upper and lower boundary respectively). In other words, upper and lower ENACW for example are considered two independent SWTs in the calculation of OMP analysis, but the final output in the figure plots (for example, in Fig. 4 for ENACW) is still **one water mass**, which means that all the data within the range are considered to be this central water mass.

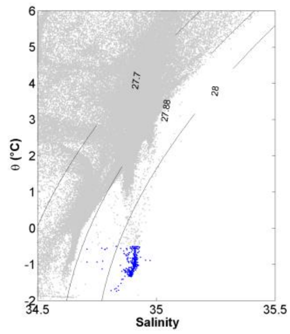
To summarize the review up to this point, the paper has to address the description of Central Waters afresh and make a clear distinction between subducted water masses and water masses formed by deep convection.

We hope that the above modifications we have made can avoid the previous mistakes and also avoid the misunderstandings or confusions to the readers, and also conform to our original intention of quoting the literature for example, Tomczak (1999).

There are other points of a minor nature that nevertheless require attention. Figure 22 shows a sequence of data points near 34.8 salinity reaching down to temperatures as low as -1.5_C. Such data points cannot be produced by mixing between any of the SWTs shown, so they represent an additional SWT. At least a remark is required what these data points stand for and why they are not considered further.

Thanks for pointing out this detail that we overlooked in previous version. This water mass indeed cannot be explained by the mixing of any above listed original water masses. So a new SWT should be defined. By analyzing of their distributions (blue dots in the left figure) on the map and their depth (between 2000 and 4000m), and also combining with temperature and salinity data (right plot). The properties are closer to Eurasian Basin Deep Water (e.g. Bönisch and Schlosser, 1995; Schauer et al., 2014). As a result, we preliminarily determined this water mass as from the deep Arctic (Eurasian Basin). Since this water mass originate from the Arctic Ocean, and the amount of data is too small (only 600 samples), and further there is not much interaction with other listed water masses, we did not list it as an independent water mass in this paper and also no SWT is defined so far. Thanks again for pointing out this point and also provides guidance for our next work. We explain this point in the new manuscript.





The paper states "Mode Waters, on the other â˘A´lhand, are considered as the precursor or the prototype of the central waters." This is not necessarily so. The quasi-linear parameter relationship of Central Water does not relate linearly to depth. Some depth ranges within the Central Waters display rapid parameter changes with depth, others show particularly uniform properties. Mode Waters are sub-regions of Central Water; they describe such layers within the Central Water range that display particularly uniform properties.
Finally, in a combined TS-diagram of data from a region SWTs are normally identified as the extreme TS-points that cannot be produced by mixing with other water masses. The definition points for AAIW in Figure 8 clearly include TS-combinations influenced by admixtures from NADW and even Central Water. A definition of AAIW based on its source region will have to concentrate on the low salinity points in the 0 to 2_C range. Some commentary is necessary to justify the selection of definition points in Figure 8.

In the previous version, Mode Water is considered as the precursor or the prototype of the Central Water. Such a statement is indeed not rigorous. Thanks for pointing out this key point and in the new version, such description is used. Mode Waters are described as **sub-regions** of Central Waters and also report the most significant characteristic of Central Waters: the linear T-S relationship.