Reply to Referee #3

We thank referee #3 for the helpful comments. We have addressed the referee's concerns as explained below.

Detailed comments

I am not familiar with the content in the much cited Zunino et al., which might limit my ability to interpret some of the findings in this manuscript.

Thank you for making us notice that we refer too much to Zunino et al. (2017) and the reader could be confused. According to your comments below, we have rewritten section 4.1, which describes and discusses the changes in the water masses between 2002-2010 and 2014. We have reduced the redundant citations to Zunino et al. (2017) and we have added more information when needed to better guide the reader.

The use of a subscript (e.g. SPMW7) for different types the otherwise well known water masses, is new to me. And this notation is not even introduced in this manuscript. I must admit that this detail hindered me in following this manuscript initially. This confusion might be caused by my lack of knowledge, but this will probably confuse other readers as well. Please give a better introduction to this, and improve the integration with the literature. E.g. how does the SPMW7 associated with the water mass descriptions given in other oceanographic papers?

We used the subscripts to denote that it is the same water mass but with slightly different temperature and salinity. In fact, the subscript indicates the temperature of the SWT. Similar notation was used in other works (e.g., Álvarez et al., 2004; van Aken and de Jong, 2012). However, García-Ibáñez et al. (2015) was the first OMP-based work to use different SPMW end-members, according to our knowledge. Therefore, there are no other works using this notation. However, we believe that the first paragraph on page 5 (copied below) that introduces the notation will help the reader to understand the notation.

"The upper waters of the GEOTRACES-GA01 section were characterised by Central Waters and SPMW. The thermohaline range of the Central Waters was solved by defining two SWTs that coincide with extremes of the θ-S line defining the East North Atlantic Central Waters (ENACW), the predominant variety of the North Atlantic Central Waters to the east of the Mid-Atlantic Ridge (Iselin, 1936): ENACW of 16ºC ($ENACW_{16}$), whose θ-S characteristics match those from the warmer central waters of Pollard et al. (1996); and ENACW of 12ºC ($ENACW_{12}$), which represents the upper limit of ENACW defined by Harvey (1982). The change in temperature of SPMW along the NAC path cannot be accounted by the OMP analysis, since it is the result of air-sea interaction (e.g., McCartney and Talley, 1982; Brambilla and Talley, 2008). This problem was solved by defining three SWTs to characterize SPMW: SPMW of 8ºC ($SPMW_8$), SPMW of 7ºC ($SPMW_7$) and SPMW of the Irminger Basin (IrSPMW). $SPMW_7$ and $SPMW_8$ characterize the thermohaline range of SPMW in the Iceland Basin, with the θ-S of $SPMW_8$ being representative of that formed within the Iceland Basin (Brambilla and Talley, 2008); and the θ-S of $SPMW_7$ to that found over the eastern flank of the Reykjanes Ridge (Thierry et al., 2008). The θ-S of IrSPMW characterize SPMW found in the Irminger Sea (Brambilla and Talley, 2008), and are close to those of the Irminger Sea Water (Krauss, 1995). The intermediate waters of the GEOTRACES-GA01 section were characterised by LSW, MW and SAIW. The thermohaline properties of LSW were chosen from the thermohaline properties of LSW formed in 2008

(LSW2008; Kieke and Yashayaev, 2015; Yashayaev and Loder, 2009, 2017), which, according to the transit times proposed by Yashayaev et al. (2007), would have reach the Irminger and Iceland basins by 2014. The properties of MW were taken from Wüst and Defant (1936) near Cape St. Vicente, where MW has its θ-S characteristics established after overflowing the Strait of Gibraltar (Ambar and Howe, 1979; Baringer and Price, 1997). The thermohaline range of SAIW (4–7ºC and S < 34.9) was represented by two SWTs: SAIW of 6ºC ($SAIW_6$) and SAIW of 4ºC ($SAIW_4$), following the descriptions of Bubnov (1968) and Harvey and Arhan (1988). Finally, the deep waters of the GEOTRACES-GA01 section were characterised by DSOW, ISOW and NEADW. The thermohaline properties of ISOW were defined as the ISOW properties after crossed the Iceland-Scotland sills defined by van Aken and Becker (1996), and were readjusted by increasing its temperature and salinity by 0.1ºC and 0.01, respectively, according to the observed changes in the overflow properties since 2002 (Hansen et al., 2016). The thermohaline characteristics chosen for DSOW were selected from those found by Tanhua et al. (2005) downstream of the Greenland-Iceland sill. We also included PIW in the analysis to take into account the dense shelf water intrusions into DSOW. The thermohaline characteristics selected for PIW are in agreement with those proposed by Malmberg (1972) and Rudels et al. (2002). NEADW was modelled by the definition of two SWTs equal to the end-points of the line defining the thermohaline properties of NEADW in the West European Basin (Saunders, 1986; Mantyla, 1994; Castro et al., 1998): upper NEADW ($NEADW_U$) and lower NEADW ($NEADW_L$)".

This work seems to use different – and maybe lower - values for the nutrient concentrations in the SWTs, compared to some other studies. The authors e.g. use a silicic acid concentration of 6.33 µM to represent the MW, while (McGrath et al., 2012) use a silicate concentration of 10-11 µM for the same water mass.

Note that the values selected as nutrient concentrations to characterize the SWTs are preformed values, that is, the values the water mass acquired when it was formed. That is the reason why the concentration of silicic acid for MW in our work differs from that reported by McGrath et al. (2012) for measurements further north from the formation area of MW.

a) Is silicic acid, Si(OH4)0, not the same as "silicate"? b) Why use both one and two decimals in Table 1? c) How sensitive is eOMP method to such different choices of the source water silicic acid concentration?

a) The notation "silicate" is commonly used instead of "silicic acid" for simplicity, but both notations denote the same. b) The number of decimals was set to show the accuracy, giving two decimals when the standard deviation was lower than 0.2. c) The importance of the silicic acid concentrations when solving the eOMP analysis is that it tracks NEADW, that is, the water masses with high silicic acid concentration. In the Irminger Basin and in the main thermocline, nitrate and oxygen are better tracers to solve the water mass distribution. We did not perform a Monte-Carlo simulation only perturbing the silicic acid values describing the SWTs to evaluate the sensitivity of the eOMP of the choice of silicic acid values for the SWTs. However, the Monte-Carlo simulation performed by perturbing all the physical and chemical properties defining the SWTs leads to an average standard deviation of distribution of SWTs lower than 12%, which indicates that the methodology is robust.

I am a bit confused by the definition and discussion of the 'Central Water'. On page 5, line 26 (p5,l26) this water mass is defined as ENACW16+ ENACW12, on p5,l29 is stated that "The distribution of the Central Waters is associated with the NAC" and on (p3,l6) is stated that the Central Waters is transported with the NAC. How can it be defined by the eastern waters, and be transported with the NAC? Please clarify.

> *Sorry for the confusion. To the east of the Mid-Atlantic Ridge in the North Atlantic, the predominant variety of the North Atlantic Central Waters (Iselin, 1936) is the East North Atlantic Central Water (ENACW) (Harvey, 1982; Pollard et al., 1996; Read, 2000), which is formed by winter convection in the intergyre region (Pollard et al., 1996). This is the reason why we chose the ENACW nomenclature to refer to the Central Waters. We added the following information when defining the water masses we used: "The thermohaline range of the Central Waters was solved by defining two SWTs **that** coincid~~eing~~ with extremes of the θ-S line defining the East North Atlantic Central Waters (ENACW)**, the predominant variety of the North Atlantic Central Waters to the east of the Mid-Atlantic Ridge (Iselin, 1936)**: (...)".*

(p5,l6): "An important assumption of the methodology is that the physical and chemical characteristics of the SWTs are considered time invariant and..." (p9,l31): "...the progressive salinization that classical LSW (our SWT) has been experiencing since its last formation event in the late 1990s..." So the eOMP method seems to be importantly dependent on the assumption of time invariability of the SWTs, and it is clear that the SWT are not time invariable. At first glance, this appears as a contradiction. Please explain.

> *We are aware that the properties of LSW and ISOW have been changing over time. To take this fact into account and following the comments of referee #1, the temperature and salinity (TS) for LSW and ISOW have been slightly modified compared to García-Ibáñez et al. (2015) to match those found in the most recent period. We have also revised the standard deviations of the properties that define the SWTs taking into account the temporal variability. The TS properties for LSW in this new run are 3.4ºC and 34.855, thermohaline properties chosen from LSW formed in 2008 (LSW_{2008}, Kieke and Yashayaev, 2015, Yashayaev and Loder, 2009, 2017), which, according to the transit times proposed by Yashayaev et al. (2007), would have reached the Irminger and Iceland basins by 2014. The TS properties for ISOW in this new run are 2.7ºC and 35, that is, an increase in temperature of 0.1ºC and an increase in salinity of 0.01, according to the changes observed in the overflow properties since 2002 (Hansen et al., 2016). We have used the results of the new OMP run as the final results of the manuscript. By making this change, we believe that the contradiction is resolved. Besides, the salinization of LSW to which we refer is due to lateral mixing of LSW with surrounding waters once formed, and not to the salinization of its source area.*

(p7,l32): "...measurements and by an overall mass balance of 1 ± 3 Sv northwards..." It is not clear what this means.

> *We have changed the text: "... and by ~~an overall mass balance~~ **a net volume transport** of 1 ± 3 Sv northwards **to ensure mass conservation**".*

(p9,l13) and below: The abbreviation SMPW is often used. I assume this should be SPMW. Section 4.1. The discussion on the water mass changes between the average 2002-2012 state, and 2014 is difficult to follow. This is partly because Fig. 6 could be improved (see comments below), and partly because the patterns are not always clear. Maybe guide the reader better to the mentioned changes (e.g. specify depths levels).

Thank you for highlighting the mistake in the acronym SPMW. We have made the replacement. Regarding the discussion about the water mass changes, we have improved Fig. 6, following your suggestions and the comments from referee #1. We have also rewritten section 4.1 to improve the message.

(p9,l27): "The negative anomalies of LSW between 1000 and 2000 dbar coincide with positive anomalies of SPMW7..." It makes sense that the cooling after 2014 was associated with a replacement of the relatively warm SPMW7 with the colder LSW. But it seems counterintuitive that the opposite occurred below 1000 dbar. Was LSW really replaced by the warmer SPMW at these deeper levels? Please explain. One result of this paper is an unexpectedly high presence of ISOW. It is known that the eOMP is sensitive to the assumption of time invariability of the SWTs, and it is clear that the ISOW SWT became more saline after 2002. Could the unexpectedly high presence of ISOW partly be a result of this uncertainty?

We are aware that the temperature and salinity (TS) of some water masses have changed over time, e.g. LSW and ISOW, and, therefore, we have performed a new OMP run with the TS properties defining LSW and ISOW slightly modified in relation to those used in García-Ibáñez et al. (2015) to match those found in the most recent period (see answer to comment on p5, L6). Even the results of the new OMP run show proportions of ISOW higher than the mean values reported in the literature. Therefore, we are confident that the higher than expected concentration of ISOW is a real feature, which is in agreement with the volume transport of ISOW observed in the OSNAP array (Johns et al., 2017; Zou et al., 2017). We have added this fact in the manuscript: "The uniform increase in ISOW is consistent with the increase in volume transport of ISOW observed in the OSNAP array (Johns et al., 2017; Zou et al., 2017)". Besides, when using the results of the new OMP run, the replacement of LSW by $SPMW_7$ below 1000 dbar disappears, being LSW replaced by ISOW, which is more consistent.

Figures

Figures 1-5 are all ok.

The NAC in Fig. 1 is located farther south than where we usually see it (in the literature). Is this because the authors suggest that the NAC is actually located this far south?

The figure represents average location of the NAC during 2002-2012 based on the OVIDE and 60°N sections (Daniault et al., 2016). The location of the NAC branches at the Mid Atlantic Ridge is from Bower and von Appen (2008) and they are locked to the Charlie–Gibbs Fracture Zone, Faraday Fracture Zone and Maxwell Fracture Zone. The location of the last two fracture zones has been added to Fig. 1.

Fig. 2d. The silicic acid values span 0-40 µM, probably in order to get the highest values near the seafloor in the eastern part represented as well. But most of the observed silicate variability is seen in the range 2-12 µM, and the figure has a low resolution in this range. Maybe consider using a non-linear color code?

Thank you for the suggestion. We have changed the color code to be non-linear.

Figure 6

The message in this figure is not clear.

a) Maybe use different software. Although ODV is well suited to scan oceanographic data, it might not be the right choice for making publishable figures. If you still want to use ODV, remove the redundant references to this software.

Thank you for the suggestion. We prefer to continue using ODV. We cannot do anything about the redundant references to the software because ODV does not allow removing the references for each plot. We have improved the figure by changing the color scale to one that has white around zero, warm colors for positive values and cool colors for negative values, as suggested by referee #1.

b) Use the y-axis label, "Pressure (dbar)" only once. The same goes for the other ODV-based figures (Figs. 2 and 4).

Thank you for the suggestion. We have performed the suggested change in Figures 2, 4 and 6.

c) What does "(on a per one basis)" really mean?

It means that the proportion of each SWT is represented ranging from 0 to 1. Following the suggestion of referee #1, we have deleted 'on a per one basis' from the figure captions.

d) Maybe add something to the text in (p9,l4) "Positive (negative) anomalies in the proportion of a water mass imply a gain (loss) in 2014 compared to 2002–2010." to the caption for Fig. 6.

Thank you for your suggestion. We have added that text to Figure 6's caption.

e) Since the patterns in this figure are quite noisy, one can doubt the usefulness of this figure. The uncertainty about the parameter shown, and the definition of the water types with that subscript (e.g. ENACW16, see comment above), it becomes difficult to follow the discussion related to this figure. Suggestions: a) Show and discuss only the clearest signals (fewer panels in the figure). Patterns with blue and red blobs might too much associated with the inherent variability, which could strongly impact a single transect along the OVIDE line. Or b), improve the figure and the explanation of its content, and integrate the discussion with this figure in a clearer way.

Thank you for your suggestions. Following your suggestion, we have reduced the number of subplots, showing only those water masses with clear patterns. We have also rewritten the section explaining this figure to improve the message.

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