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Oxygen export to the deep ocean following Labrador Sea Water formation by Koelling et al.

Ilaria Stendardo (Referee)

Referee comment on "Oxygen export to the deep ocean following Labrador Sea Water formation" by Jannes Koelling et al., Biogeosciences Discuss.,
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The paper from Koelling and colleagues investigates the ventilation of the Labrador Sea Water (LSW) and how this impacts the export of the oxygen towards the deeper limb of the ocean circulation. The analysis was done using a mooring array containing sensors for oxygen, temperature and salinity along 53°N at the outflowing boundary current in the Labrador Sea to reconstruct time series and seasonal cycles of these properties, and Argo floats to analyze the formation and export of LSW.

It is a nice paper and well written, and gives some more insight about the effect of the LSW formation and export on the oxygen concentration that is then exported from the Labrador Sea. I found the method good especially in the analysis of the seasonal cycles and in the identification of which water mass (LSW or Irminger Water) contributes to the oxygen concentration in specific months. I do have however some specific comments especially on some of the figures and on the global impact of the LSW ventilation which I am pretty sure they can be easily addressed by the authors and that might help to improve this already good paper. Thus, I recommend this paper for publication after minor revision.

Specific Comments

1) I have some technical comments about some of the figures which I will address later, but I do have a specific comment about Figure 8. Figure 8 and Figure 9a show exactly the same thing. I find unnecessary to have two figures which shows the same, considering that the paper is actually long. I am not asking to short the paper. I do not have a problem with that but reducing the number of figures is already an improvement. Everything that is described in session 3.2 can be easily and actually better follow by looking at Figure 9a. Figure 8 might look fancy but 3D figures are difficult to look on a 2D plane, there is always some part which is hidden. But I could see all the points you described much easier in Fig.9a. I then suggest to remove this figure and refer directly to

Figure 9a for the seasonal cycle in session 3.2

2) Doesn't make more sense to compare the calculated export of 1.57 Tmol instead of with the global oxygen loss of 70 Tmol year⁻¹ with the value calculated only for the deep Atlantic. I think it is an oxygen gain of about 1.7 Tmol year⁻¹ for the deep ocean according to the extended table from Schmidtko et al., 2017.

3) The calculation of the oxygen export at 53°W of 1.35 Tmol and 1.57 Tmol are of course approximations, so I think it should be mentioned. The same for the calculation of the oxygen consumption of 2.2 Tmol by organisms. Regarding this calculation specifically I do have some concern. The authors use a global value of aOUR of 0.1 μmol kg⁻¹ year⁻¹ at 1500 m from Karstensen et al., 2008. First of all, the calculation was made separately for the Pacific and Atlantic oceans, although it seems to be the same for both oceans. Nevertheless, I would indicate the value for the Atlantic. Moreover, the aOUR values are on an order of 10 μmol kg⁻¹ year⁻¹ below the euphotic zone and decay exponentially with a value assumed to be 0.1 μmol kg⁻¹ year⁻¹ at 1500 m. The authors chose this last value for their calculation, however the isopycnal range they considered "27.68 kg m⁻³ and 27.8 kg m⁻³" is not exactly at 1500 m. It is of course changing according to location, so the layer can be as deep as 1500 m but also as shallow as about 200 m or shallower so basically if you always assume that the thickness of this layer is constant (800 m, which is also an approximation because it of course not constant) then your consumption value varies from about 200 Tmol to about 2 Tmol which means the southward export of LSW might supply between 0.71% to 71% of the oxygen demand in this layer.

Technical Comments

Line 31: Irminger Water appears here the first time. You could think of define already here the acronym (IW). In the rest of the manuscript, I noticed that sometimes you write Irminger Water other time IW. I think the correct way is once the acronym is defined to stick with that. So please replace Irminger Water with IW in the text after that is defined in line 31. The same for Labrador Sea Water (LSW). Once defined it should be mentioned always as LSW. I found some of them which I highlighted further down but I might have missed some more.

Line 31: "originating in the Irminger Sea" instead of "originating in the Atlantic Ocean"

Line 83: wasn't Pickart et al., 1997 the first to define LSW at this boundary. It should be cited before Zantopp et al., 2017.

Line 123: "LSW" instead of "Labrador Sea Water"

Line 124: "LSW" instead of "Labrador Sea Water"

Line 125 until end of session 2.2: here Figure 3 should help to understand the method. But I found this paragraph a bit confusing. Figure 3 is made out of three panels (a, b and c) they should be motioned in the text and help to understand the method.

Line 140: could you give a precise range instead of bigger than 0.5?

Line 140: I do not follow the argument here. If you say that the correlation between O₂ saturation and temperature is high it should be an indication that concentration changes are due to temperature-driven solubility differences unless the correlation is lower than the one between O₂ and temperature. That's why I suggested above to give a range and not simply saying that is bigger than 0.5.

Line 154: February, March and April 2017 or 2018 or both?

Line 154 & 155: "oscillate between values typical of the months prior" what do you mean?

Line 179: It looks like you used a dataset that is not described in the data and method session. Please add a description of the dataset from Holte et al., 2017 in the data session.

Line 189: "...but are more concentrated towards the sides of the patch..." To me doesn't look like it. A lot of the red dots are in the middle of the patch. What is more concentrated on the sides are the yellow and green. Do you mean that?

Line 201: "a handful", you could quantify that with a number, 7 right?

Line 215: IW instead of Irminger Water

Line 215: LSW instead of Labrador Sea Water

Line 227: O₂ instead of O2 (twice)

Line 229: O₂ instead of O2

Line 229: What is the central O₂ bin?

Line 242: "another." Instead of "another:"

Line 246: "Oxygen concentration in the interior before January are lower than those at 53°N during March-July..." to me it doesn't look too much lower. Maybe you could quantify it? Moreover, the SeaCycler mooring has two picks in January. Could you explain why? I think this should be mentioned in the results.

Line 273: "LC" instead of "Labrador Current"

Line 279: "density." Instead of "density:"

Line 362: "salinity." Instead of "salinity:"

Line 372: "LSW." Instead of "LSW:"

In section 4.2 (line 375) you calculated a supply of oxygen for the 6 months (March to August) of 1.35 Tmol from an increase oxygen increase of 6 μmol/L. Could you specify the increase of oxygen for the whole year as well? I guess the 1.57 Tmol/year that you calculated for the whole year is determined by this value since all the other parameters stays the same (mean velocity, layer thickness and section width), otherwise it would be 2.7 Tmol/year.

Line 376: "21.2 mol m⁻²" instead of "21.2 mol m²"

Line 437: "NADW" instead of "North Atlantic Deep Water"

Figures

First of all, I think the authors did a good job with the figures, they are clear, with a good choice of the color schemes and font size. So here are just few suggestions for further improvements:

Figure 3: Figure caption is really long and the second part it looks like it belongs to the text in the session and not as caption. Moreover 27.74 kg m^{-3} should not be written in italic. Figure 3a it is a bit confusing what is displaying since it is nowhere written what is the thick green line and what are the thin white lines. Figure 3c, why the dark blue line stop at 27.75 kg m^{-3} ?

Figure 5: The reference at 600 dbar to me seems unnecessary. Moreover, the comparison with the work from Atamanchuk et al., 2020 (purple stars and ellipse) and from Pacini et al., (2020) (green symbols and ellipse) sounds interesting but I do not find it discussed in the paper. If you put that into a figure then it should be discussed, otherwise remove it. Finally, how is the anomaly calculated?

Figure 6: The blue to red colormap for absolute values is a bit confusing, especially if it has been used in the previous figure for the anomaly. Also here the reference to 600 dbar is not necessary.

Figure 7: the red dots are too small; I can hardly see them. Could you make the symbol the same size?

Figure 10: The K9 is already displayed in Figure 9a, it is a repetition. Comparison can be easily done by looking at the two figures and best if you plot K7, K8 and K10 one below each other and with the same length of K9 in figure 9a. Moreover, I would also put for the 3 other moorings the black line showing the bin with the highest number of observations.

Sincerely

Ilaria Stendardo