

Water mass transformation variability in the Weddell Sea in Ocean Reanalyses

General comments

The authors use three different ocean reanalysis products and apply a water-mass transformation framework to study the processes that affect the variability of AABW exported from the Weddell Sea. This work addresses a climatically relevant process that plays an important role in the global Meridional Overturning Circulation. To my knowledge, there have not been similar studies using ocean reanalysis and it will be useful for the community to know whether these products are simulating realistically AABW formation processes and export. Their main conclusion is that the reanalyses are not capable of consistently and faithfully capture processes involved in driving AABW production, export and variability.

The application of the WMT framework in the region is a novel idea, but I find that there must be further explanation within the manuscript of the methodology and definitions used for the study in order to interpret the results. Considerable improvements to the structure of the manuscript should also be made to facilitate reading.

Specific comments

Major comments

1. You conclude in the Discussion section that none of the reanalyses capture realistically AABW formation, export and variability due to their coarse resolution. This should be included in the abstract, before describing the loss of AABW found in SOSE, not at the end as a reason for no relationship with large-scale climate oscillations.
2. It is not clear how AABW is defined in this paper. In line 287 defines it based on TS boundaries, in line 319 it is all the waters denser than CDW (without clarifying which density this is), and in line 364 there are different density criteria for each reanalysis. Since the paper is focusing on AABW, its definition should be clearer to the reader, with supporting references if it is based on prior studies, or adequate justification if it is a new definition for the purposes of this work.
3. The study region is not defined. Defining the study region is vital for the reader to interpret the physical meaning behind inflows/outflows. For example, is the shelf region included? Is the northern boundary set by topography or an arbitrary latitude?
4. The Introduction is devoted mostly to a description of the global MOC. I suggest shifting to a more regional focus that is more relevant to the paper. For example, what is already known about water-mass transformations and inflows/outflows of AABW. Some works that could be useful on this regard are:
 - Couldrey, M. P., Jullion, L., Naveira Garabato, A. C., Rye, C., Herráiz-Borreguero, L., Brown, P. J., ... & Speer, K. L. (2013). Remotely induced warming of Antarctic Bottom Water in the eastern Weddell gyre. *Geophysical Research Letters*, 40(11), 2755-2760.
 - Meredith, M. P., Gordon, A. L., Naveira Garabato, A. C., Abrahamsen, E. P., Huber, B. A., Jullion, L., & Venables, H. J. (2011). Synchronous intensification and warming of Antarctic Bottom Water outflow from the Weddell Gyre. *Geophysical Research Letters*, 38(3).

- Jullion, L., Naveira Garabato, A. C., Meredith, M. P., Holland, P. R., Courtois, P., & King, B. A. (2013). Decadal freshening of the Antarctic Bottom Water exported from the Weddell Sea. *Journal of Climate*, 26(20), 8111-8125.

Also, there is a lack of references in the Introduction and Discussion sections, including but not limited to:

- Line 28: "... forming Antarctic Bottom Water (AABW) [reference]"
- Line 31: "The global impacts of this circulation system on biological productivity and carbon and heat uptake [reference] ..."
- Lines 32 to 35.
- Line 40: "... interior mixing [reference]"
- Line 46: "... cascading down continental boundaries [reference]"
- Line 55: "... storage of large amounts of carbon [reference]"
- Line 73: "Even if physical processes such as coastal polynyas are not always represented accurately in ocean reanalysis [reference] ..."

And finally, please double check the relevance of citations. For example:

- Line 24: Purkey and Johnson 2013, Vernet et al. 2019 are not relevant citations regarding the MOC's inter-hemispheric transport
 - Line 463: Armitage et al. 2018 don't study AABW production/export
5. In the model assessment section, in order to make a fair comparison, please select the same time periods for model/observations. Your comparison could be biased because you are comparing, for example, bottom temperatures from ECCO for the period 1992 to 2015 with WOA for the period 1981 to 2010. This applies to the entire section.
 6. It's not clear to me that bottom properties in the reanalysis products are similar to the observed. What does this mean for the reliability of AABW production and representation in reanalyses?
 7. Lines 318-325: it is confusing the grouping of CDW/WSDW. Did you mean CDW/WDW? Warm Deep Water is the local term for CDW in the Weddell region, whereas Weddell Sea Deep Water is a different water mass altogether, with a different origin and characteristics.
 8. In the same paragraph, you cite export values from Figure 5. To get export values, shouldn't you get the cumulative sum for the density range corresponding to your AABW definition? If I interpreted correctly, that minimum is the cumulative sum of export of **all** the lighter densities, and is in fact excluding export from denser waters. And how are you obtaining the transformation values afterwards?
 9. Line 326: Kerr et al (2012) obtain this value from a transect at the tip of the Antarctic Peninsula. Your calculation encompasses outflows for the entire region, so I'm not sure it is valid comparison. This comparison is repeated in other places in the text.
 10. Paragraph starting in line 330: you are describing Figure 7 and your conclusion is that both models agree with past studies. However, I look at the Figure and ECCO and SOSE look completely different. They show different water mass transformations (different signs for same density ranges). And again, how are you obtaining the precise values for transformation of bottom waters?
 11. In a couple of occasions, you mention that the salinity driven WMT is due to brine rejection, with no influence of ice melt, runoff or precip (such as line 357). How do you verify that?

12. In line 363 you define CDW as the inflowing water and AABW as the outflowing waters. There are several studies that show that there is significant inflow of AABW into the region. Have you verified how sensitive your results are on this definition?
13. Also, if I interpret your figure correctly, the time tendency in SOSE is <0 year-round. Wouldn't this mean that there is a loss of volume throughout the year? This contradicts your statement in line 368.
14. Are the correlations between terms and the correlations between climate indices significant? With what confidence level?
15. In the Discussion section you mention discrepancies with mooring records. Please cite them and describe how your analysis is different.

Minor comments (general)

- Correct figure captions throughout the text. For example: add units in Figure 1 and 2, add description of density contours in Figure 3 and 4 as well as labels for panels.
- Please use same axis for different panels. For example, Figures 5 to 8. Figure 10 is ok since it would make visualizing difficult.
- Sections 4 to 5 read a bit confusing. A suggestion for improvement is to try to make paragraphs focused on just one topic, which could be, for instance, describing one figure. Avoid one-sentence paragraphs as in line 326 and 460. Last for paragraphs in Seasonal Climatology section could be organised better: you go from describing Figure 7 for all 3 models, to a paragraph each describing ECCO and SOSE in Figure 8 and 9, back to SODA in Figure 7 for the last paragraph.
- There is no need to completely describe a figure in the text since it is already in the captions. For example, from line 310 onwards you describe all components of Figure 6 and 7, when you could limit the paragraph to (for example): "The time evolution of the cumulative water mass volume distribution is not completely balanced by the total inflow/outflows and mean transformations, indicating that the system is not in steady state balance but is subject to low frequency variability or model drift".
- Avoid subjective judgements. For example: line 359: "It is interesting to note"; line 447: "it gets worse, not better"; line 505: "take these correlations with a grain of salt".

Minor comments (line based)

- Line 13: add period where SOSE shows loss of AABW.
- Line 25: "... transported to the *northern hemisphere* ..."
- Add 1000m isobath in Figures 1 and 2 to aid in visualization.
- Consider changing salinity colorbar range or colormap to better visualize the region's bottom salinity, Figure 2.
- Add delimiting lines of AABW according to working definitions in the TS diagrams, Figures 3 and 4; as well as in Figures 5 and 6.
- Change units in all figures from [x] to (x).
- Figure 9: change colorbar label from Sverdrup (m³/s) to Transport (Sv).
- Number figures in order of appearance in the text (Figure 9 is described before than Figures 6 and 7)

- Line 275: the region you are indicating is not beneath the Filchner-Ronne Ice Shelf (I think none of these reanalyses include the FRIS).
- Line 351: why do you refer to *psi* (inflow/outflow from the region) to overturning?
- Line 383: why tertiary and not secondary?
- Line 478: change wording. For example, “there is little agreement between reanalysis products regarding variability in seasonal to interannual timescales”
- There are several syntax errors throughout the text, including but not limited to:
 - Line 438: Fig. 2 is not the one you wanted to reference right?
 - Line 439: forgot parenthesis closure
 - Line 457: and instead of AND
 - Line 465: sea-ice concentration (SIC).
 - Line 522: starts with Purkey and Johnson (2012) and ends with (Hellmer et al 2011).
- Correct citations throughout the text. For example, line 549: (e.g. Small et al. (2014); Morrison et al. (2016); Kiss et al. (2020)) should be (e.g. Small et al. 2014; Morrison et al. 2016; Kiss et al. 2020). This is probably a latex typo, please check throughout the text.
- Similar to the comment above, verify throughout the text the figures you are referencing. For example, in line 517 you reference Fig. 2, but I don’t think that is the figure you wanted to refer to. If so, I don’t see how in bottom salinity you can identify loss of AABW properties.
- Check text for unclosed parenthesis (I found several).