RESPONSE LETTER

Dear Editor,

Please find enclosed the response to reviewer #1 comments based on the OSD submission *doi:10.5194/osd-11-497-2014* and entitled "ASSESSMENT OF THE STRUCTURE AND VARIABILITY OF WEDDELL SEA WATER MASSES IN DISTINCT OCEAN REANALYSIS PRODUCTS" by T. S. Dotto et al. The manuscript has been carefully revised in response to the reviewers' comments and suggestions; detailed responses to their comments are below. Our reply is in italic font, whereas the reviewers' specific comments are not italicized. We thank the reviewers for their suggestions, which have significantly improved this m/s.

Authors Responses (AR) to Reviewers:

Referee #1:

General comments:

This manuscript evaluates the structure and variability of intermediate and deep Weddell Sea waters in five reanalysis products. The authors have thoroughly compared hydrographic properties in these products with those of observed data. I think that the material is useful for readers who analyze the reanalysis products. However, I feel that the manuscript should be improved mainly in the following two points. First, the final rating of the products should be included in Section 5 corresponding to the aim of this research stated as "to identify which reanalysis product best reproduces the main regional oceanographic features" (P. 501, L. 8-9). Although many strong and weak aspects of all the products are thoroughly described and discussed in Sections 4 and 5, the best product is not clearly stated based on all the aspects considered here. I think that it is useful for many readers to know which is the best product regarding Weddell Sea deep water masses. Second, some of the general comments in Section 4 should be carefully checked since they are not exactly correct for all the products as pointed out in the specific comments below.

AR: We thank the reviewer for his/her valuable review of our manuscript. Throughout the manuscript, we point out which product is most suitable for each aspect assessed. We agree with the reviewer that a final rating is missing. Following the reviewer's suggestions, we added a sentence to Section 5 stating more clearly a rating of the products considering all the aspects investigated. Please see the following sentence:

P. 518, L. 4. "In general, it appears that all of the reanalysis products require considerable development to improve their representation of the Weddell Sea water masses, particularly in their representation of dense-water production and overflows. The choice of the reanalysis product that best reproduces the main regional oceanographic patterns depends upon one's particular interest. For example, if the primary interest is in describing prominent oceanographic features, e.g., water mass distribution and thermohaline values, MyOcean *produces results closest to the observational data; thus, MyOcean is considered the best product for this purpose. If trends and temporal variability in the water masses are the major motivations, the choice of reanalysis product is dependent on the water mass evaluated. For WDW, SODA captured the warming, the salinity increase and the density decrease patterns that were found in the observations. For WSDW, the ECCO2 results were closer to the observational estimates, reproducing the freshening trends in WOCE SR4 and the warming in WOCE SR4 and WOCE A12. Finally, for WSBW, MyOcean and SODA were able to capture the warming pattern recorded in the dataset, although the simulated salinity increase in WOCE A12 and decrease in WOCE SR4 are not clear in the real ocean. Caution is advised regarding the anomalous periods that were seen in most of the reanalyses that were assessed."*

Specific comments:

1. P. 498, L. 11-13: The MyOcean product has the same problem as the CFSR and ECCO2 products as shown in Fig. 12.

AR: In this sentence, we mean that CFSR and ECCO2 could not represent WSBW with a neutral density ≥ 28.4 kg m^{-3}, which is used as the neutral density surface boundary between WSDW and WSBW. Part of the abstract has been rewritten for clarity. The revised material is reproduced below:

P. 498, L. 8–13. "The MyOcean UR025.4 product provided the most accurate representation of the structure and thermohaline properties of the Weddell Sea water masses when compared with observations. All the ocean reanalysis products analyzed exhibited limited capabilities in representing the surface water masses in the Weddell Sea. The CFSR and ECCO2 products were not able to represent deep water masses with a neutral density ≥ 28.40 kg m^{-3}, which was considered the WSBW upper limit throughout the simulation period."

2. P. 498, L. 15-16: This is not true for SODA as shown in Table 4.

AR: We agree that the generalization in this sentence is incorrect. We rephrased the sentence to clarify the idea that all the products showing statistically significant results produced a decrease in density. Please see the new sentence below:

P. 498, L. 15-16. "All the assessed ocean reanalyses were able to represent the decrease in the WSBW's density, exception is the SODA product in the inner Weddell Sea."

3. P. 504, L. 24-25: The authors should add a brief explanation of the normalized centered root-mean-square error. I think that some readers are not familiar with this quantity.

AR: We accept the referee's suggestion and include the following sentence explaining the centered root-mean-square error:

P. 504, L. 26. "The CRMSE is used as a measure of the difference between values predicted by a model and values that are observed, minimizing the effect of the model mean bias. Further details and equations are presented in Taylor (2001)."

4. P. 506, L. 24-26: In some results, colder and fresher difference from observations does not extend till ~1500 m.

AR: We rephrased the sentence to clarify this point in the following revision:

"In general, the majority of the ocean reanalysis products showed cold and fresh waters relative to the observations at intermediate depths (Figs. 4a and b and 5a and b). However, the ECMWF, CFSR and ECCO2 products did not appear to follow this general pattern for θ below a depth of ~1000 m."

5. P. 507, L. 6: It seems that "If the opposite occurred" means saline and warm biases. However, it is not the case for the MyOcean and ECCO2.

AR: This passage was unclear to both reviewers and does not add relevant information to the final discussion. Thus, we decided to delete the passage from the text.

6. P. 507, L. 23-24: The statement of "as shown by the underestimation of S in almost all products and sections evaluated" is not quite true for section SR4 with distinct fresh bias in 1000-2000 m only seen in the CFSR.

AR: We rephrased the sentence to clarify this point, as shown below:

"At this layer, the S field showed smaller differences than those of the whole upper structure of the water column, as demonstrated by the underestimation of S in almost all the sections by all the products, except for the WOCE SR4 section by the CFSR product (Figs. 4b and 5b)."

7. P. 509, L. 2-6: Figs. 7 and 8 show that most (not all) reanalysis products have warmer and saltier values than those in observations along A12, but this is not the case along SR4. I do not think that the first sentence here correctly states these facts. Furthermore, it is not clear to me how the second sentence explains the facts in the first sentence.

AR: We intended to state that section A12 showed WDW warmer and saltier compared with SR4 in most of the reanalysis products. The cooling and *freshening of WDW are caused by mixing processes along its pathway to the Weddell Sea (e.g., Schröder and Fahrbach, 1999). Therefore, the differences between A12 and SR4 support that most of the reanalysis products could capture the WDW modification towards the center of the gyre. The sentence was rewritten for clarity as follows:*

"Most of the reanalysis systems evaluated represented the WDW layer (28.1 ≤ γ^n < 28.27 kg m^{-3}) as warmer and saltier in WOCE A12 (Fig. 7) than in WOCE SR4 (Fig. 8). This difference occurs because WDW advection towards the inner Weddell Sea is associated with cooling and freshening of this water mass through mixing processes with upper waters (e.g., Schröder and Fahrbach, 1999). Moreover, the differences between A12 and SR4 support that the mixing processes along the WDW pathway are being captured by most of the reanalysis products."

8. P. 510, L. 26-27: Anomalous periods in ECMWF along section A12 are shown in Fig. 9, but not described in the text.

AR: Thanks for the comment. We agree and added the following sentence to the text:

"The ECMWF reanalysis product showed a stable period in the WOCE A12 section between 1987 and 2007 (Fig. 9), whereas before 1987 and after 2007, anomalous variability patterns were observed;"

9. Section 5, Discussion and conclusions: It is easier to follow discussions if relevant table or figure is cited more often.

AR: We agree with the referee's suggestion and have cited the figures and tables in Section 5, when appropriate, as shown in the revised manuscript.

10. P. 515, L. 5-8: I do not understand what is meant by the final phrase of this sentence.

AR: Kerr et al. (2012a) found that high resolution (1/12°) simulation using the OCCAM model reproduced the AABW export rates to the global ocean from the Weddell Sea relatively well, although shelf break convection was not the main source of AABW in the model. Indeed, the authors suggested that deep ocean convection is contributing to the relatively good AABW export from this area. We changed the sentence for better understanding to the following:

"Kerr et al. (2012a) investigated a high resolution (1/12°) simulation of the OCCAM model and noted that despite the absence of a dense shelf break and slope plume in the model, the presence of deep ocean convection could explain the relatively good AABW export rates to the global ocean from the Weddell Sea."

11. P. 516, L. 28 - P. 517, L. 2: Are there any possible reasons for this discrepancy?

AR: In this work, we distinguished between AABW varieties based on neutral density surfaces, whereas Fahrbach et al. (2011) used isotherm boundaries. We added the following sentence in the text to clarify this point:

P. 517, L. 2. "This discrepancy may have been caused by the different criteria used to define the AABW varieties."

12. P. 517, L. 20-26: It seems that the discussion here is limited for section A12. However, we cannot tell whether this is the case from the phrase "In the Weddell Sea" alone.

AR: We discussed the variability in bottom waters for the Weddell Sea in general, not just WOCE A12, but based only on the statistically significant results. All our significant results showed a decrease in density, but depending on the reanalysis considered, warming or freshening could be the process responsible for the less dense WSBW. We rewrote the sentence to clarify this point as follows:

"Throughout the Weddell Sea, bottom waters have been warming with no clear change in salinity (e.g., Robertson et al., 2002; Fahrbach et al., 2004, 2011; Purkey and Johnson, 2010; Azaneu et al., 2013). Considering all statistical significant results of the ocean reanalysis time series, the density of WSBW is declining, but the causes are not clear because both cooling/freshening and warming/increasing salinity were reproduced (Table 4)."

13. Table 4: It is better to write down periods for all the products used to evaluate trends in the caption. The footnotes only describe exceptions. Why are trends for WSBW in ECCO2 not listed?

AR: We agree with the referee and included a line in Table 4 with the periods considered to determine the trends for each of the water masses. The WSBW trends for ECCO2 were not listed because this reanalysis did not represent a water mass with $\gamma^n \geq 28.40$ kg m^{-3} for most of its simulation period in either section analyzed (as can be seen in Figs. 11 and 12).

14. Figs. 7-12: The authors do not clearly state what the gray curves represent. It is not clear what is meant by "The grey shading indicates the variation...".

AR: We rephrased the sentence to clarify this point. Please see the following text, which was inserted in the caption of the respective figures:

"The grey shading indicates the standard deviation due to variation caused by the different station locations in the different years of the hydrographic cruises."

Technical corrections:

1. P. 501, L. 9, 12-13: Sect. -> Section

AR: When we submitted the m/s, ‘Section’ was spelled out. This change may represent technical formatting by the Journal.

2. P. 501, L. 17: in represent -> in terms of

AR: Done.

3. P. 502, L. 1-2: The ocean model is derived from ... -> The ocean model is driven by ...

AR: Done.

4. P. 507, L. 25-26: S lower differences -> lower S differences

AR: Done.

5. P. 516, L. 9: variabilities of -> variability

AR: Done.

6. P. 516, L. 13 and 16, and P. 517, L. 5: degCyrˆ{-1} -> degC yrˆ{-1}

AR: In the submitted file, it was written degC yr^{-1}. This change may represent technical formatting by the Journal.

7. P. 518, L. 16: and to -> to

AR: Done.

8. Table 1: The degree symbols are missing in the ocean model resolution for SODA.

AR: Done.

9. Table 2: Footnote b: Only used until 2010. -> Only data in 2010 are used.

AR: Footnote b was revised to read "Only 2010 data are used."

10. Fig. 4 caption: expanded to allow for more detail → expanded to show more detail

AR: Done.

11. Figs. 4 and 5: I am afraid that the panels in these figures are too small when they are printed.

AR: We agree that the figure is too small as it is presented in OSD. However, this issue is more a technical problem that must be corrected by the journal technical staff. We previously sent a figure the size of A4 paper to be published in OSD. Thus, we kindly ask the Editor to consider enlarging this figure in the final m/s. Another option is to split the figures.

12. Fig. 6: The normalized centered root-mean-square error abbreviated as CRMSE is indicated as "CRMSD" in the figure. It may be better to label two panels as (a) and (b) and refer to them as such in P. 509.

AR: Done.