

Interactive comment on “Antarctic Bottom Water and North Atlantic Deep Water in CMIP6 models” by Céline Heuzé

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The author sincerely thanks Reviewer 1 for their really helpful comments: not only did they point out issues, they also constructively suggested solutions. The role of the reviewers has been duly acknowledged:

L.554-555: “The author thanks the two anonymous reviewers whose comments greatly improved the quality of this manuscript”

The response is organised as follows: first, the reviewer’s comment. Then, my answer. Finally, if relevant, new or modified text (with line number for additions)

1. While the 6x6 postage stamp figure format is quite useful, especially for the modelers, it may be a bit much for some readers. Please consider putting all the postage

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stamp figures into the appendix and switching the text figures to 3-panel figures (water property reference, mean or median difference of water property from reference, std deviation or interquartile range of water property difference from reference). This would keep 4 figures in the main text: Two 3x3 figures (3 panels each of reference, mean, and standard deviation for potential temperature, practical salinity, and sigma-4) in the S. Ocean and N. Atlantic. Two 1x3 figures of reference, mean differences, and standard deviations of AABW thickness and NADW thickness. This change would mean eight postage stamp “difference” figures in the appendix (NADW thickness, AABW thickness, and temper, salinity, and sigma-4 for both the Southern Ocean and North Atlantic. This suggested change would also require some additional text to describe the means and standard deviations of the differences of the models from observations, but it might be worth it. The statistical figures would probably be much more widely used than the postage stamp figures. They would be great in a general presentation on climate model evaluation.

This comment from the reviewer echoes the first comment made by reviewer 2, that the target or even the aim of this paper was somewhat unclear. This paper was written with model users in mind, with the aim to be the go-to reference when they need to justify their choice of models for their study. As I had to do at that time for another study with the CMIP6 models. Consequently, I am reluctant to send the postage stamp figures to the appendix, as at least to me they are the most useful. Nevertheless, I also really liked the reviewer’s suggestion of what could be called “summary figures”. So I created them, and in fact expanded on the reviewer’s idea to make it two 4 x 4 figures with reference, multi model mean, mean difference in property from reference, and standard deviation, for density, temperature, salinity and mixed layer depth, in the Southern Ocean and North Atlantic, complete with the median value quoted on each panel. As the aim of this change is to make the paper useful to as wide a range of readers as possible, I decided to include both the multi model mean and the mean difference in properties, even though they show the same thing. These two figures now are in the text as (new) Figs. 2 and 4, and their description has been added in

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the text where relevant. I chose to not add such figures for the AABW and NADW thickness, as the results of these postage stamps figures are already summarised in Tables B1 and B2.

Major comments:

2. L1. The first sentence is arguably inaccurate, as the global ocean circulation is mostly wind driven. Maybe “Deep and bottom water formation are an important part of the global ocean circulation” would be better.

Sentence changed to: “Deep and bottom water formation are crucial components of the global ocean circulation”

3. Throughout. Please use the commonly accepted terminology “bottom water” to distinguish Antarctic Bottom Water from “deep water” (North Atlantic Deep Water). The manuscript may be slightly longer as a result (as sometimes the use of “deep and bottom water” will be required), but will be more in line with the field, and easier to read.

Terminology changed throughout the manuscript to: “deep and bottom water” when referring to both AABW and NADW in the same sentence; “bottom water formation” when referring to AABW only.

4. L19. The opening sentence of the introduction doesn’t seem accurate, and it is difficult to parse the meaning. How about “Bottom water formation around Antarctica and deep water formation in the North Atlantic ventilate the global abyssal and deep ocean.”?

Sentence modified as suggested.

5. L23. This sentence does not seem quite right, as AABW influence spreads quite far into the N. Atlantic, albeit in a form highly diluted by mixing with NADW above. How about “In a substantial portion of the Atlantic, Antarctic Bottom Water spreading north is overlain by North Atlantic Deep Water spreading south.”

Sentence modified as suggested.

6. L63-65. This sentence conflates two different issues, and perhaps should be broken in two at the “and”.

Sentence modified to clarify how the two issues are related: “Furthermore, as some models are not fully independent as they share similar codes (Table 1), using different ensemble sizes would have accentuated the bias towards one model family”

7. L140-142. This portion is overly concise. How about something along the lines of: “Presently, Antarctic Bottom water is primarily formed in several locations (including the Weddell Sea, the Ross Sea, and the Adelie Lands) as water is cooled, made saltier, and denser on the continental shelves, then cascades down the continental slopes, entraining deep waters on its way to the sea floor.”

The sentence suggested by the reviewer has been added.

8. L160-161. The recent Polynya in the Weddell Sea that is mentioned later in the paper should also be mentioned here.

Sadly, the recent Maud Rise polynya was not associated with any deep convection (e.g. Campbell et al., 2019), so it cannot be mentioned here.

9. Tables 2 and 3. Consider that instead of years out of 30, a percentage would be more quickly and easily interpreted by most readers.

I agree with the reviewer that it would be quicker and easier, but it would also be misleading. The CMIP6 runs contain more than 100 years; presenting these values as a percentage would imply for many readers that I worked with 100 years. Hence I prefer keeping the values in the table as “years out of the 30 studied”.

10. L205. How is it possible that “No model has regional biases”? Perhaps just delete the part of this sentence on L206, and start the sentence with “CMIP6 models tend to be either biased light or biased dense”.

Here I tried to mean that unlike some models in CMIP5, there is no difference in the sign of the bias between e.g. the Weddell and Ross seas. I cannot find a better reformulation than what the reviewer suggests, so the sentence was modified as suggested.

11. L265. Consider changing “The picture is less grim regarding bottom property biases” to “CMIP6 water property biases at the bottom of the North Atlantic are smaller than those at the bottom of the Southern Ocean”.

Sentence modified as suggested.

12. L298. Here “convenient” seems like the wrong word. This reviewer can’t guess at what to suggest for a replacement.

The word has been removed: “a strong interhemispheric correlation”

13. L329-330. Consider changing “are rather accurately represented” to “often agree within observational uncertainties”.

The agreement with observational uncertainties is mentioned several times in the previous sentences. The last sentence “in summary, [they] are rather accurately represented” stays.

14. L469-470. This is a problematic sentence, because NADW does not occupy the global ocean, and in the real world the signatures of upper (subpolar gyre) and lower (GIN sea overflow) NADW are both traceable for substantial distances from their formation regions. How about “NADW formed in the subpolar gyre of the models clearly spreads southward, but the signature of the portions formed in the Nordic seas is less evident.”?

Sentence modified as suggested

Minor comments (typos, debatable word choices, and grammatical errors): All addressed

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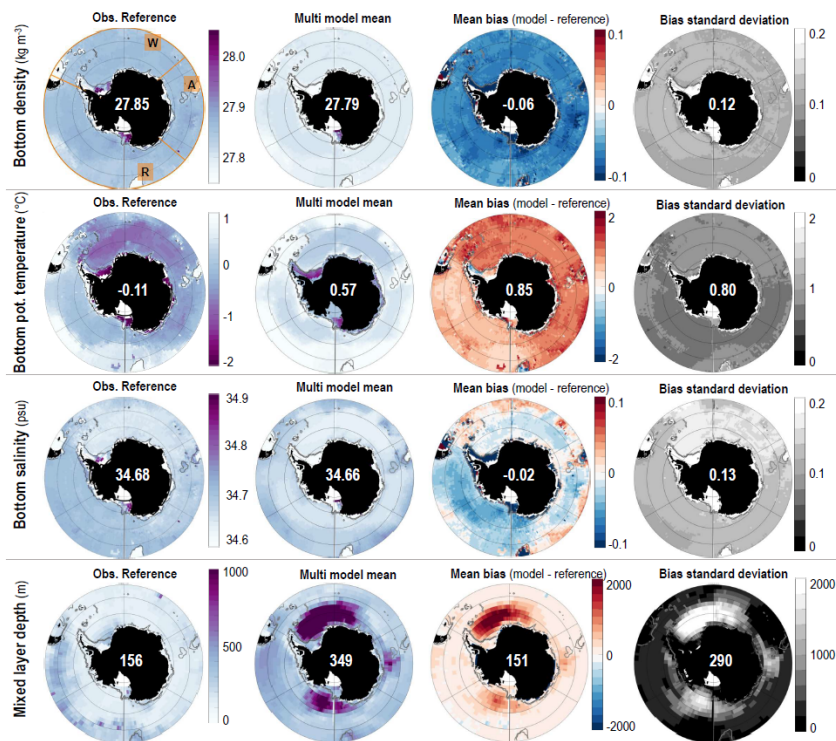


Figure 2. Multi model summary of the biases for the Southern Ocean. Columns: observational reference and multi model mean property (same colorbar for both), mean bias (model minus reference) and standard deviation of the difference; rows: bottom density, bottom potential temperature, bottom salinity and mixed layer depth. White numbers are the median value over the deep Southern Ocean, defined as per Fig. 1. Grey lines indicate the 1000 m and 2000 m isobaths.

Fig. 1. New figure suggested by the reviewer: Southern Ocean

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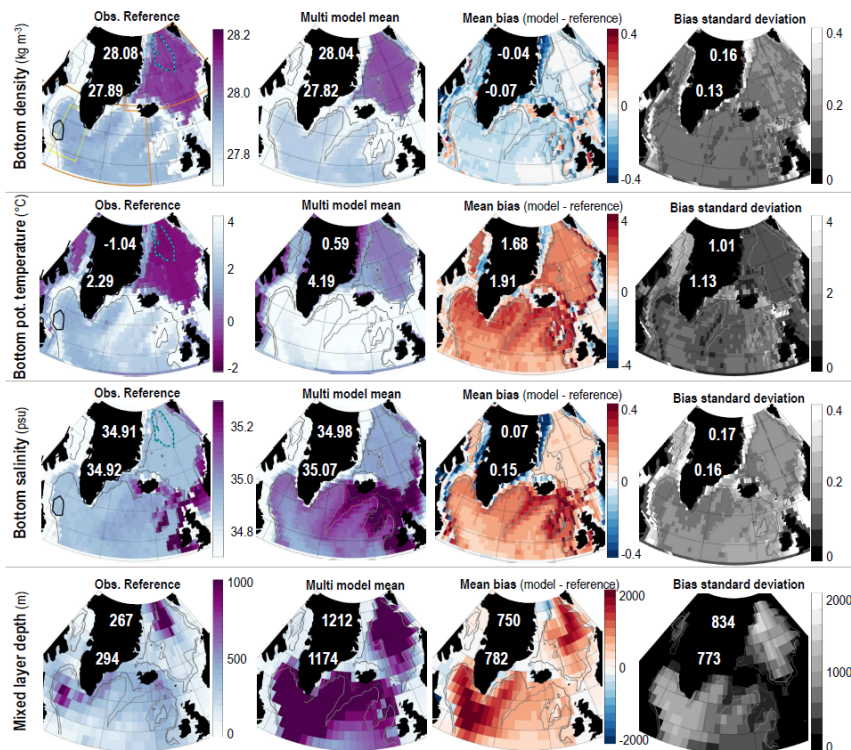


Figure 4. Multi model summary of the biases for the North Atlantic. Columns: observational reference and multi model mean property (same colorbar for both), mean bias (model minus reference) and standard deviation of the difference; rows: bottom density, bottom potential temperature, bottom salinity and mixed layer depth. White numbers are the median value over the deep GIN (top) and SPG (bottom), defined as per Fig. 3. Grey lines indicate the 1000 m and 2000 m isobaths.

Fig. 2. New figure suggested by the reviewer: North Atlantic

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