

Ocean Sci. Discuss., referee comment RC2
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Comment on os-2022-10

Anonymous Referee #2

Referee comment on "Causes of the 2015 North Atlantic cold anomaly in a global state estimate" by Rachael N. C. Sanders et al., Ocean Sci. Discuss.,
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The manuscript presents an in-depth analysis of the onset and evolution of the cold anomaly in the North Atlantic over the 2013-2017 period. Two versions of the ECCOV4 model were used to analyse in detail the different terms of the mixed-layer temperature budget. The new result from this study is the importance of vertical diffusion term in the re-emergence of the SST anomaly in summer, while the advection term is one order of magnitude smaller. This is explained by the strong temperature gradient at the base of the mixed layer, induced by anomalously high surface heat fluxes and subsequent cooling during the previous winters.

The manuscript is very well written, and figures are particularly nice and clear. This is a careful and very interesting study that deserves publication. Considering the temperature temporal variation instead of the usual heat budget is sometimes tricky to understand, but the authors are very careful to accompany the reader through the subtleties of the interpretation. Overall, I have one major remark that needs consideration, and then minor revision comments.

My general remark on the method is that the main result bears on the importance of vertical diffusion. However, this is precisely the term parameterized to close the budget, so to my point of view, it needs more than the figure in the appendix to justify this chosen parametrisation. To my knowledge, $K_v \sim 2 \text{ cm}^2/\text{s}$ is in the "high range" of values usually used in OGCMs. Could you comment more on this? I explain: imagine that the winter heat fluxes are underestimated in the model. Then the data assimilation will "correct" the insufficient cooling of the mixed layer, and this artefact will necessarily appear in the

parameterized term, and I don't understand why the closed mixed layer budgets gives an answer to this problem lines 370-375). I suppose that you have access to the diagnosed K_d in the model: could you make a comparison?

In the article, the role of horizontal advection is minimized, although it clearly plays two roles in the 2015 cold anomaly origin: onset of the cold anomaly in winter 2013-2014 (25%, line 222) and advection of cold water below the mixed layer during the following summer/autumn (lines 384-386). Although this does not concern directly the processes responsible for the 2015 anomaly, I think it should be more emphasized (in the abstract and conclusion) to contrast with what happened in 2015.

Minor revision:

- I think you should merge Fig. 1 and Fig2

- Fig. 5 and section 3.3: I would put the sum of terms in solid line (as the contributing terms) et and model tendency in dashed line (this is more intuitive). Could you add this figure 5 but in the northern and southern box in the appendix (to emphasize the difference in the entrainment term)?

lines 189-190: How do you explain that the difference between your budget and the model between May and June? Which assumption is the most problematic to your point of view? Is the possible warming just below the calculated MLD responsible for it?

- Section 3.4: you write that horizontal advection is responsible for about 25% of the cooling in December 2013. However, you disregard this result later on. The advection is more important in the southern box in your analysis (your Fig. 9), so it could confirm the schematics of Holliday et al. (2020), their figure 10. In conclusion, I disagree with the statement lines 383-385: "advection still played only a small role in the initial cooling in comparison to surface forcing". 25-30% is not small.

Figure 8: very nice: it concerns mainly 2014, doesn't it? To better understand, please add a figure in the appendix with the absolute values of Fig. 6b so that there is no confusion on the actual sign of each term. Consider adding a small arrow for advection in the first box, and also below the mixed layer in spring and summer to explain why the temperature keeps decreasing (although this is not proven in this ms).

Discussion: Some points are difficult to follow because most figures are anomalies (except diffusion term fig.7c), so we don't know the actual sign of each term. Otherwise, see my main comments above.