Ocean Science Discussions

Ocean Sci. Discuss., referee comment RC2
https://doi.org/10.5194/os-2022-18-RC2, 2022

Comment on os-2022-18 - Reviewer 2

Anonymous Referee #2

Referee comment on "Exceptional freshening and cooling in the eastern subpolar North Atlantic caused by reduced Labrador Sea surface heat loss" by Alan D. Fox et al., Ocean Sci. Discuss., https://doi.org/10.5194/os-2022-18-RC2, 2022

This article sheds new light on the main drivers behind the cooling and freshening recently experienced in the upper eastern subpolar North Atlantic. To this end, the authors analyze the outputs of a historical hindcast (years 1980 to 2019) performed with the eddy-rich ocean–sea-ice model VIKING20X, using a variety of techniques and diagnostics, from lagrangian particle tracking, to water mass transformation analyses.

The article is well-timed and well written, the methodology applied is sound, figures are clear, and many of the results will be of high interest to the climate community at large, and to anyone with specific interests in the recent changes experienced in the North Atlantic and its surroundings.

I recommend a minor revision of the manuscript and enclose a list of comments that the authors would need to address to render the article suitable for publication in *Ocean Science*.

General Comments:

- Agreement of the VIKING20X-JRA hincast with observations is mentioned several times throughout the text, but it is mostly derived from visual comparisons, which can be misleading. In some cases the agreement is clear, but in other cases is much less evident (see comments #4, #16 and #18 further down). Supporting these statements with some specific metrics, like linear correlations between the hincast and the observations, will help to determine more precisely to what extent they agree with each other.
- Given the comprehensive list of processes and mechanisms that are analyzed in the paper, which in many cases are interconnected, it would be very useful to include at

the end of the article a schematic figure summarizing the chain of events that give rise to the freshening and cooling of the eastern subpolar North Atlantic, as supported by the model analysis.

- Several figures from other articles are cited throughout the text, urging the readers to keep jumping from one article to another, and thus hindering the overall readability of the article. Some of those figures include indices that could be easily incorporated in others figures of this manuscript (see comments #6, #10 and #11), making intercomparison between those and the VIKING20X indices much more straightforward. I strongly recommend the authors to include them.

Specific Comments:

- [Lines 18-19] This sentence seems incomplete and inaccurate. It should (1) mention that there is a cooling on the eastern subpolar North Atlantic, not a surface warming anomaly, and (2) it should also specify that this is simulated in response to a "weakening" of the ocean circulation. Also, I recommend the authors to avoid the use of the term "predict" in the sentence, as "predictions" generally refer to historical simulations initialized from observations to phase the model with the observed internal variability. However, the warming hole is a feature that consistently appears in uninitialized historical simulations, and is therefore deemed to be mostly externally forced.
- [Line 108] It is unclear which "common technique" it refers to.
- [Figure 4b, caption] Is it "number of days" or "number of years"?
- [Lines 177-181, Figure 2] While the simulated upper temperature variability in the hindcast shows a good agreement with the observed timeseries from both OSNAP and EN4 products, this is not the case for the simulated salinity. This is particularly clear for EN4, which can be compared for a substantially longer period, showing large discrepancies in terms of both the high and the low-frequency variability. Indeed, a close inspection to Figure 2 reveals that the differences between EN4 and VIKING20X-JRA are not stationary in time, and reflect more than the systematic mean state bias stated in the text. It is true that salinity observations are quite scarce and therefore objective analyses like EN4 are subject to large uncertainties, but it remains to be checked whether the simulated variability is within the range of the observed uncertainty.
- [Lines 311-313] What do you mean by "contrasting evolution of transit times"? Are their associated histograms (like in Figure 4) substantially different? And in which way?
- [Lines 334-340] Instead of referring the reader to Figure 10 in Biastoch et al 2021, it would be preferable if the authors included the SPG index in a subpanel of Figure 9, where it can be directly compared with the AMOC indices.
- [Lines 339-340] The two parentheses referring to Figures 5 and 7 need to be closed.
- [Lines 363-364, Figure 9] Why did you choose to plot the AMOC at 29°N and not at the same latitude of the RAPID array (i.e. 26°N)? It would be indeed very interesting to include a direct comparison of the hindcast with the RAPID data, to learn more about the model realism in representing dynamical aspects, like the North Atlantic ocean circulation.
- [Lines 366-368] I would not say that the AMOC is responsible for a reduction in Gulfstream transport. The Gulfstream does not respond to the AMOC, it is a component of the AMOC and as such contributes to its variability, not the other way around.
- [Lines 371-372] This can be directly shown to the reader if, as suggested in Comment #6, the SPG index is included in Figure 9.
- [Lines 378-380] Here you compare again with an observed index from another article

that could be easily included in this one (in Figure 9).

- [Line 386] I do not find this summary statement fully justified. There has been no specific analysis in section 5.2 to rule out the AMOC weakening as a main contributor to the freshening of the eastern subpolar North Atlantic.
- [Line 394] The parenthesis needs to be closed.
- [Lines 520-521] It is important to specify that the doubling of the annual mean depth of those isopycnals only occurs in VIKING20X-JRA. In EN4, the increase in the depth of the isopycnals is very subtle and only discernible for σo > 27.65 kg/m3.
- [Lines 526-528] Figure 14 a-c □ Figure 14c (as this is the only panel showing the isopycnals)
- [Lines 537-539] From Figure 14 it is not possible to say if the model realistically represents the variability in salinity and density. Indeed, as mentioned in Comment #14, the strong deepening of the isopycnals in VIKING20X-JRA (one of the major reasons behind the freshening in the eastern subpolar North Atlantic identified in the paper) is not seen in EN4, and in particular in the upper layers.
- [Lines 544-545] Can you explain why it would be counter-intuitive?
- [Lines 589-593] Not all the model results are fully supported by observational data, in particular the deepening of the isopycnals in the Labrador Sea. Furthermore, the evolution of the Labrador Sea vertical structure only compares well with the EN4 data (Figure 14) for temperature. The agreement with the observed salinity and density is much more limited. It would be worth discussing whether, and if yes, in which sense, this poor agreement affects the main findings derived from the VIKING20X-JRA analysis.