

Interactive comment on “The GEOVIDE cruise in May–June 2014 reveals an intense Meridional Overturning Circulation over a cold and fresh subpolar North Atlantic” by Patricia Zunino et al.

Anonymous Referee #3

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In this manuscript the authors present the results from analysis of a 2014 CTD section taken along the OVIDE section. The cruise was a contribution to the GEOTRACES program and so the results of this hydrographic analysis will allow analysis of the extensive chemistry data also collected on the cruise. The authors describe the OVIDE section from the cruise data, place it in context of data along the OVIDE section from 2002 to 2012, and attempt to explain some of the differences.

The paper is a good, straightforward description of a cruise data set, and gives a highly valuable look at the MOC and gyre circulation of the eastern subpolar North Atlantic in summer 2014. The text is well written and the figures are relevant and mainly well

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presented.

The weakness of the paper lies in the authors attempt to understand the reasons for the cooling and freshening they observe in the 2014 section eastern basins compared to the earlier data. The introduction is a little muddled on this topic, and the conclusions that they draw from their analysis are not as robust as they could be. Below are some comments that I hope the authors can use to improve that aspect of the paper, as well as some minor edits.

1. Timescales of change. The authors have missed a key aspect of the literature on changes in the subpolar North Atlantic, and that is about timescales. If you could re-write the introduction considering the timescales of each of the papers that you cite it would help you focus your own analysis. In short, the arguments for ocean heat transport convergence being the primary control are all on long timescales - multiyear at least, certainly decadal. The "cold blob" analyses and the evidence for air-sea fluxes are all about short timescales - seasonal to a year or two. You should also consider the possibility that temperature anomalies and salinity anomalies may have some different forcing mechanisms on different timescales. You may not have enough data to look at long-term changes, and a focus on the short term may be more appropriate with the analysis that you have done already.

2. Methods. I realize that the authors are using well-developed methods described in earlier papers from the group, but a little bit more information would help the reader understand their method. In particular I was not sure whether the SADC data are used in the inversion. I had thought they were, so it is surely not a surprise that the main features in the SADC data are also seen in the solution?

I felt there should be more information about the reduced resolution of the CTD spacing in 2014. You say in lines 123-124 that you will later show that the features were "correctly sampled", but your evidence for this in lines 386-387 seems to be just that all the circulation features are identified (Table 1). I would like to see this explored more - is

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the higher uncertainty in Table 1 because of the resolution? If you subsample an earlier cruise at the 2014 resolution do you get the same results as the original resolution?

It would be useful to have more explanation about how you computed the gyre and overturning heat transport (lines 267-270)

3. I struggled to see the importance or relevance of section 3.2 (fronts and eddies). This looks like a description that will be useful for colleagues who are writing papers on the GEOTRACES data, but it seems to sit a little uneasily in the context of the rest of the paper. The same can be said for section 3.4. I can imagine that these lines of text could be usefully transferred into a companion paper.

4. Thermohaline anomalies. You need to state how you computed the anomalies - presumably on pressure surfaces. Your description would be more easily followed if you related the anomaly patches to the circulation features that you have already described. For example, is the first anomaly (lines 333-334) in the Irminger Current? If the anomalies are focussed in the main currents (IC, NAC) could that be evidence for ocean transport as a source of the anomalies?

An important point: I do not agree that the bottom of the anomalies is at the depth of the winter mixed layer - in most cases they extend deeper than the WMLD, which is surely significant and counter evidence for your hypothesis of air-sea fluxes being the key driver.

line 360 and elsewhere - it is best to avoid subjective words like "remarkably" especially when you do not explain what is remarkable about that observation.

5. Discussion. This section needs some improvements because the writing becomes less clear and sometimes less focussed.

Paragraph 2 (lines 392 onwards) is very unclear. I'm not always sure which data set or feature you are referring to when you quantify the transport, and how that relates to Table 1. You conclude that the Irminger Current is significantly strengthened in 2014,

C3

but from the numbers in Table 1 it looks as they are not significantly different within the error bars (the uncertainty on the 2014 estimates are large).

para 4 (line 413 onwards). It is interesting to me that the SAF has shifted southeastward (by how much?). Does this actually imply that the Bersch mechanism for freshening of the eastern basin might be at work, even though you are arguing for this not being the source of the freshening? You need to explain why the Marsh and Grist papers are relevant to this work, since they refer to a different branch of the NAC that does not come here - what is the connection?

Finally, I come back to my point about timescales of forcing. I think your result that the heat transport is high even though the upper ocean is cooler is interesting, but I don't agree that it is necessarily contrasting with the results of Desbruyeres et al. The air-sea fluxes that you present are a great result - but they are only for 1 year, and many of the papers that you refer to are talking about ocean transport convergence as the primary factor over longer timescales. It is not correct to say that the 2014 anomaly comes after 18 years of warming and salinification - papers by Robson, Holliday, and the ICES Report on Ocean Climate show observed declining temperatures and salinity in these eastern basins since the late 2000s, part of multi-year variability. That said, the obs also show a sharp drop in salinity and temperature in recent years, so it seems likely that the longer term changes in circulation are being reinforced by enhance air-sea fluxes. It might help if you focused the discussion on a short term atmospheric influence, superimposed on a longer term trend.

Minor edits

- Lines 88-89, Holliday et al does not look at the Irminger Sea. Their hypothesis was about a shift of the subpolar front (the Bersch mechanism) not advection.

- line 144 (and elsewhere) "hydrological" should be replaced with "hydrographic"

- line 219 use "Fig. 3b" rather than "Fig. 3, lower panel"

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- line 239 what do you mean by barotropic streamfunction here? You are referring I think to the plot of accumulated transport - is that the same thing?

- line 246 and Fig. 5, I find the green dots hard to see - can you use a color that stands out more clearly?

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