Review of "The evolution of anthropogenic carbon accumulation in the North Atlantic Ocean: the influence of physical and chemical drivers over the last three decades" by Wimart-Rousseau et al. for Biogeosciences

Paper synopsis

This paper is based on a 30 years dataset and aims to quantify the variability of anthropogenic carbon (Canth) on a spatio-temporal scale over the whole North Atlantic. In addition, the paper aims to identify the drivers of Canth variability. The drivers are the North Atlantic Oscillation (NAO), the Atlantic Meridional Overturning Circulation (AMOC), water mass volume changes and Canth concentration. All these drivers act on Canth variability but at different temporal and spatial scales.
The paper is well written, figures are clear and the main text is comprehensive. I particularly appreciate the comparison between NAO-influence and AMOC influence on Canth variability. However I have two concerns:

(1) The manuscript is long and there are a lot of analyses. Without changing the subregional division and the density layers division, I think the authors should summarize some of their findings. It would help the reader to follow the manuscript. Sometimes I felt a bit loss and had to go back several pages to check the figure or read the main text again.

(2) In my opinion, the "Methods" section can be improved. For instance, the authors could detail how they computed the Canth inventories and the area-normalized Canth inventories. How is the surface of each subregion computed? Canth saturation is only introduce at the end of the manuscript. How was is computed? This explanation should be added in the "Methods" section. In the main text, the authors describe how accumulated AMOC anomalies are computed and they justify their choice. However, it comes within the "Results" section, and this should be moved to the "Methods" section.

The rest of my comments are listed below.

Major comments

Abstract

In the abstract, I would add one sentence to detail how you compute Canth. Say that you use the ϕC^0_T back-calculation method.

Carbon data

If I understand correctly, to obtain your Canth data, you use the GLODAPv2.2023 variables (DIC, TA, O2…) as inputs for the ϕC^0_T back-calculation method. Did you compare your results with the GLODAPv2 Canth database (Lauvset et al., 2016)? This database uses the TTD method to compute Canth and I would be curious to see if there are differences between your estimates and Lauvset et al. (2016) estimates.

Concerning the uncertainty, it is true that the original uncertainty for the ϕC^0_T back-calculation method is ±5.2 µmol kg^{-1}. However, concerning the ±5.9 µmol kg^{-1} and ±3.9 µmol kg^{-1} values that we found with Monte Carlo simulations, they represent the uncertainty of our whole methodology chain (Argo T/S/O2 data + Neural netwoks nutrients and TA/DIC + ϕC^0_T back-calculation method). So, these values are not uncertainties for the ϕC^0_T back-calculation method but uncertainties resulting from our whole methodology.

Water mass volumes and mixed layer depth

I agree with the authors that the density threshold approach to compute MLD is better than the temperature-based criterion. However, I would like to point out that the threshold of 0.03 kg m^{-3} overestimates MLD values in the Irminger and Labrador by up to several hundred meters (Piron et al., 2016 ; http://dx.doi.org/10.1016/j.dsr.2015.12.012). For these basins, the recommended threshold value is 0.01 kg m^{-3}. On Figure 10 you show the MLD for the Irminger and Labrador basin so it would be more appropriate to use the 0.01 kg m^{-3} value.

Biogeochemical provinces and density layers

The authors evaluate the Canth concentration, inventories, etc. along seven neutral densities. In my opinion, they should introduce here which water masses these neutral densities represent. Especially because it is introduced in the results section while, in my opinion, it should be introduced in the methods section. For instance, line 226 the North Atlantic Deep Water is defined (γ_n>28.16 kg m^{-3}) while it should be done before. The reader could then directly understand why the authors selected these seven neutral densities.

Regional distribution and average states of Canth in the North Atlantic Ocean

I like Figure 2 because it clearly shows that warm waters contain high Canth concentrations. However, to help the reader, I would add a linear regression fit on each panel and maybe its R^2 value to illustrate this result. Adding the R2 value could, for instance, show the noisier relationship in the subpolar regions compared to the

subtropical/tropical regions. It is just a suggestion and, doing so, could overload the Figure.

Line 212-215: I agree that Canth concentration is higher in the Irminger and Iceland basins compared to the Labrador basin within the density range 27.25-27.8 kg m^{-3} whereas the opposite pattern is observed for the density range 27.8-28 kg m^{-3}. However, the evidence for an east-west enrichment within the 27.8-28 kg m^{-3} layer is less convincing because it falls within the uncertainty of the method. Using the values the authors give in the main text, Canth concentration increases from 31±5.2 µmol kg^{-1} in Iceland basin to 36±5.2 µmol kg^{-1} in Labrador basin, a difference that is not statistically significant.

Interannual variability in the Canth storage

Line 423: I do not agree with "basin-wide inventory increases steadily". Figure 4 and several papers (Gruber etla., 2019; Müller et al., 2023; Steinfeld et al., 2024) show that this increase is not steady over time. I think, what really bothers me is the word "steadly".

Interaction between the NAO and the Canth evolution

I would be careful with Figure 7 and its analysis. If I understand correctly, the numbers over the while labels are the coefficient of determination (R^2). For the Nordic NA provinces, the maximum R^2 value is 0.4, which is reported in the main text. However, most of the R^2 values range from 0.0 to 0.1 for these regions. This result indicate that NAO variability is poorly correlated with Canth concentration residuals, Canth inventory residuals and water mass volume anomalies. By consequence, NAO variability explains only a small part (~10%) of the interannual variance of Canth concentration/inventory residuals and water mass volume anomalies in most of the Nordis NA provinces and over most of the density layers. I think it should be mentioned somewhere.

Same applies to Figure 8 where most of the R^2 values range from 0.0 to 0.1.

NAO and AMOC: relationships and controls on the Canth content

Line 619-623: Here the authors justify the choice of accumulated AMOC anomalies and how it is computed. I think this justification much come before, when the accumulated AMOC is first introduced or even in the "Methods" section.

Local processes and events: the peculiar subpolar regions

I wonder why the authors chose to show only the density layers 27.25-27.8 and 27.8-28 kg m^{-3}.

Looking at Figure 10, I wonder what happened in the Labrador Sea, for Canth saturation between 1998 and 2001. That's the only moment where the yellow line passes below the purple one. It indicates a higher saturation for the denser layer comparable to the lighter layer, right? Do the authors have an hypothesis for this particular period?

Minor comments

Line 60: remove parenthesis around Canth.
Line 72-73: "The key behaviour… processes" please rephrase, I feel there is a verb missing.
Line 84: replace "anthropogenic CO2" by "Canth".
Line 88: replace "anthropogenic carbon" by "Canth".
Line 127: you excluded 37 Canth data points but which percentage of your database does it represent? I guess a tiny fraction, looking at Figure 1.
Line 146: "spanning Labrador Sea"?
Line 162-165: "In this study… area (Fig.1)" this sentence is quite long and difficult to follow. Please separate it in two sentences.
Line 169: remove the parenthesis at the end of the line.
Line 175: there is a parenthesis and a comma directly after. And then there is no closing parenthesis.
Line 210: "Notably… buffering capacity" I guess this sentence refers to the density layer <26.7 kg m^{-3}? Please add this information.
Line 213: "27.26-27.8" units are missing.
Line 273: "panel b" of Figure 5, right?
Line 290-292: Please rephrase, I don't understand this sentence
Line 299: "Over the considered time period", please indicate specifically which time period (1993-2021, right)?
Line 426: I don't get the "and deviations from linear trends" at the end of the sentence.
Line 439: What are the "intermediate density layers"?
Line 442: The reference should not be between parentheses. In addition, Raimondi et al. (2021) only focuses on the Labrador Sea. I would suggest finding a reference for the Irminger Sea as well.
Line 465: Replace "upt" by "up".
Figure 7: For the colorbar label, wouldn't it be "Regression slope" rather than "Regression coefficient"?
Line 523: I think the authors should add a reference to Fig. A1 so the reader could see where OSNAP and RAPID lines are located.
Figure 8: Panels (d), (e) and (f) are missing.

Figure 9: Colorbars on the upper panels cannot be read. Please change “four panels” to “six panels”. The figure caption says that there are “four main regions” but I think there are more regions displayed.
Line 649: There is an issue with the parentheses between the references and the figure reference.

I wish you all the best for the resubmission,
Rémy Asselot