Review on 'The evolution of anthropogenic carbon accumulation in the North Atlantic Ocean: the influence of physical and chemical drivers over the last three decades‘ by Cathy Wimart-Rousseau

This paper describes the temporal increase of anthropogenic carbon (Canth) in the northern part of the Atlantic from 1993 to 2021. Therefore, the North Atlantic is divided into 13 biogeochemical provinces and 7 isopycnal layers. The Canth increase in each of these regions and layers is divided into the contribution from volume change of the layers and Canth concentration increase. The results are then correlated with NAO (North Atlantic Oscillation) and the AMOC at RAPID and OSNAP to identify the physical drivers of the Canth change. I find the topic of the manuscript is of high interest and merits publication in BG after major revisions.

General comments

Such a detailed analyses of Canth changes and its causes is an ambitious task, maybe at some points too ambitious. This refers to the availability of Canth data as well as to the conclusions drawn in the text. These often sound reasonable, but sometimes they are not supported by the presented data/results, sometimes they even contradict the results from the data analyses. Also the direct results presented in the figures are sometimes questionable.

Specific comments

Section 2, Data and methods
This section does not adequately describe the methods used for the following analyses of Canth inventories.

Subsection 2.1, Carbon data
l. 114/115 ‚Canth values from GLODAP‘ and l.117/118, ‚Canth observations‘
The GLODAP data product does not contain Canth values, and there are also no (direct) observations of Canth. Canth is a (theoretical) quantity that might be inferred/calculated from measurements of other quantities. Please always differentiate properly between measured/observed and inferred/calculated values.

l.114-116
‚Canth values from GLODAP were annually averaged to reduce seasonal bias, and trends and standard deviations were then calculated per region, density interval and year‘:
I was really surprised when reading that, as the GLODAP data product does not contain enough carbon (and carbon related data) to do so. When reading further, it became clear mainly from the figures (Fig. 6 and A2), that Canth data are NOT available for every year/region/layer, but often they are (linearly) interpolated. This has to be clearly stated here in the method section and not be ‚hidden‘ in the legend of a figure.
Together with the temporal interpolation, another question arises: Which time series did you use for estimating the correlations and their significance? The time series based on the available Canth data, or the one with the linearly interpolated Canth quantities? Using the linear interpolation might alter the correlation and especially the significance, hence I would really recommend to only use the ‚real‘ Canth values here.
Another question is, how did you calculate the mean values for one year/region/layer? Did you take the mean of all Canth values within one region/layer? Or did you grid the Canth data to infer the regional mean? If you calculate the Canth inventory just from the total volume and the mean Canth value for every region/layer, you introduce an error as Canth and layer thickness might be correlated. You also introduce an error due to the sparse Canth data, which even within one region are not located at the same places from year to year (spatial bias).

I am not going to force you to use a specific method for calculating all the layer mean Canth concentrations and inventories, but you have to (i) clearly state WHAT you have done and (II) estimate the uncertainties arising from that procedure.

l.126/127
‚annually averaged Canth values deviating … from the regional-layer-mean pressure‘

A Canth value cannot deviate from a pressure value. You probably mean the location (in depth/pressure) of the Canth values.

Subsection 2.2, AMOC and NAO time series
Here you say, a 12-month running mean of AMOC strength was used. Later, you mention an ‚accumulated‘ AMOC according to Bryden et al. (2014). Which of the two have you really used? If you used the accumulated AMOC, you should show that time series, maybe in Fig. A1 together with the ‚real‘ AMOC.

Subsection 2.4, Biogeochemical provinces and density layers
I think the area of the ‚Caribbean‘ province should be revised. According to the map in Fig.1, this province contains a small area north and west of the Antilles Islands. There, the Deep Western Boundary Current (DWBC) is located. This means, for the Caribbean province you combine the old deep water from within the Caribbean (LSW only) with the young deep water from the DWBC, which for me does not make sense. The DWBC east of the Antilles should be accountd to the West Tropical Province. Note that inside the ‚proper‘ Caribbean (south and west of the Antilles), the maximum density is smaller than gamma_n=28. The ‚Caribbean‘ data for the denser layers originate completely from the DWBC outside the ‚real‘ Caribbean. This can also be seen from their Canth values, which are higher for the densest Caribbean layers than for the densest West tropical layers.

Density layers (l.169)
You note the density layers, but you do not give any information which water mass is in which density layer (e.g. 27.8-28: LSW, >28.16: AABW). Please do so.

l.250
‚increases this contribution to35%‘
I have no idea what ‚contribution‘ is meant here. Do you refer to the surface area, or to the surplus in efficiency?

l.256/257
‚In the Nordic provinces, … the densest layers contribute more substantially‘.
This is not surprising, as they have by far the largest volume (see Fig. 3b), please mention that here.

Fig.5 (l. 264) is mentioned before Fig.4 (l.268), exchange the numbering.

l.281 and l.283
In l. 281 you mention 3 decadal Canth inventories, which increase roughly by 10% per decade. How can you infer an annual increase rate of 1.72% from that? Or did you apply a linear fit (inventory versus time) in Fig. 4a? Please explain. If you apply a linear fit, include it in Fig. 4a. Later, in l. 285/286, you mention a linear fit. However, the increase rate of 0.39 PgC/yr does not equal 1.72%/a if the total inventory is about 35 PgC.

l.304/304

‚Nordic-W shows strong positive trends in multiple density classes (27.25-27.8), consistent with isopycnal deepening and enhanced deep water formation.
The positive trends are correct, but the deep water formed in the Nordic seas is denser than 28.0. Note that the volume of the lighter layers is very small, so trends here do not alter the Canth inventories significantly.

l.323-324
‚Conversely, the loss or redistribution of water mass with relatively low Canth content induces a positive contribution to the total inventory'.
First, in Fig 5 only the contribution of volume change to the layer-wise Canth inventory is shown, not to the total (top to bottom) inventory. Second, I think your statement is a misinterpretation. If the Canth inventory trend is negative (as it is for the upper Nordic-W layer), a volume reduction is accounted positive according to your algorithm (i.e. the contribution of the volume reduction strengthens the negative trend), whereas a volume increase opposites the trend and hence is counted negative. I would change that and show a negative volume trend always as a negative contribution to the Canth inventory trend and vice versa, independent from the sign of the Canth inventory trend. The same feature (negative volume trend, negative Canth inventory trend, positive contribution of volume to inventory trend) can be seen e.g. for the gamma_n=27.8-28.0 layer in the Caribbean.

l.348
Explain here in the main text, what volume anomalies and Canth concentration residuals are, and not in the legend to Fig. 6.

l.359-360
‚The Nordic W region exhibits large swings, broadly following NAO phases.'
This is wrong. Only the increase in the densest layer in 2014 is in line with the NAO. Before, the volume of the densest layer appears almost anticorrelated with the NAO.

l.361-362
‚In both provinces, Canth residuals oscillate around zero rather than showing steady accumulation.'
That is true, but it is merely a consequence of the definition of the Canth residuals. The linear trend has been subtracted from the residuals, so there CANNOT be a steady accumulation.

l.363
‚intermediate density classes (yellow and purple line)'
What do you mean with ‚intermediate? From your 7 density classes, these (3, yellow: subpolar Mode Water and 4, purple: Labrador SeaWater) are somehow in the middle. Regarding the water column, the SPMW is in the upper 1000m, LSW reaches from a few hundred down to ~2000 m. Regarding the classification, however, LSW for me is a deep water mass, as it is part of the lower AMOC limb and also called Upper North Atlantic Deep water (south of the Labrador Sea). I know that some people interpret LSW as a kind of mode water, but I think it has clearly be distinguished from the subpolar Mode water, which is mainly formed in the northeastern Atlantic. Please make clear what you mean.

l.368
‚… in close agreement with Canth concentrations ...'
I do not see a volume decline in the Labrador Sea of the LSW layer from 2000-2007. I only see a minimum in the Labrador Sea in 2006-2007.

l.369
‚… the densest layers show reduced ventilation ...consistent with the weaker Labrador Sea Water formation ...'

Which layers do you have in mind? The LSW layer is the gamma_n=27.8-28 layer, all deeper/denser layers are not (directly) influenced by convection in the Labrador Sea.

l.373
‚… and again from 2013-2017 … (Yashayaev and Loder, 2016)‘
How can a paper from 2016 say something about convection in 2017?!
In fact, the intense convection in the Labrador Sea continued until 2018, not only 2017 (see e.g. Yashayaev, 2024).

l.376-377
‚… positive residuals (e.g. early 1990s, 2013, 2017) alternating with negative phases (e.g. 2000, 2005-2008).‘ I do not see these features in Fig. 6, and also not in Fig. 10 (where they would be better visible due to the larger figure size).

l.378-380
‚In the Nordic West province, sharp Canth deep density layer (>28.16 kg/m³) shifts in 2015 and 2017 (Fig. Supp. A4) align with slightly earlier volume anomalies in the same density class, a pattern also evident in the late 1990s.‘
In the early 1990s, volume AND Canth anomalies are negative, in 2015 both anomalies have an opposite sign, hence it is not comparable.

l.398-399
‚In contrast, the Northeast region exhibits episodic positive deviations from the expected trend beginning in the late 2000s, including within the deepest density layers.‘
I am pretty sure that the high Canth concentration anomaly in 2009 in the 28.08-28.16 layer in the Northeast region is not real. The mean Canth concentration there is 9 µmol/kg (Fig.3), and the anomaly is at least as high, i.e. Canth would have doubled from one year to the other. This high value is probably either due to a regional bias of the single Canth points or it is due to a data quality issue.

l.424-426
‚While the basin-wide inventory increases steadily over the study period (0.39 ± 0.02 PgC/a), the magnitude and timing of this increase differs markedly between the five main regions.‘
that the magnitude of the Canth storage varies between the main regions is mainly a consequence of the different volumes of these regions.

l.443-445
‚In subtropical regions, inventory anomalies are particularly large (up to ±0.05 PgC/a in the West subtropical province)‘
That is correct, however, if I see it correctly, according to Supp. Fig. A5, these anomalies are not significant.

l.465
‚… explains up to 40%...‘
This is true, but only for one region/layer. In most cases, the R^2 value is between 0 and 0.2. Please make that clear.

l.477-478
‚In addition, the similarity in spatial patterns of inventory anomalies and water mass volume residuals in most subpolar regions (Fig. 7b & c) reflects the tight coupling between carbon concentration anomalies and water mass volumes.‘

Note, however, that all correlations between NAO and Canth inventory residual in the subpolar regions are not significant.

l.485-490
it could also be possible that the waters exported from the subpolar North Atlantic, which are high in Canth during high NAO phases, arrive in the tropics/subtropics several years later, and then they are out of phase with the NAO. At least, the gyre circulation (subtropical gyre?) should only have a small impact on the deep water layers, where the negative inventory-NAO correlations are highest.

l.503-505
‚These strong into-the-ocean fluxes imply that mode waters formed predominantly during positive NAO phases initially have low pCO2 values, introducing a negative relationship between local mode-water Canth content and the NAO.‘
I do agree that the newly formed mode waters are still undersaturated with respect to CO2. But do they really have lower Canth concentrations than the old mode waters which they replace? In addition, outcropping of mode waters would hardly reduces their Canth concentration.

l.510-511
‚… in newly formed, outcropping subtropical mode waters. However, it can be noted that subtropical and tropical regions tend to be more influenced by advection and air-seaCO2 exchanges than water volume variations.‘
This is true, but the reason for this is mainly the relatively small change in water mass volumes in the (sub-)tropics. Note that these regions have much larger volumes than the Nordic/Subpolar regions, but the volume anomalies are of the same size (2 * 10^14 m³ for the most variable layers).

l.519
‚accumulated AMOC‘
Please explain what is meant by this (see remark above). If I understand correctly, the AMOC anomalies are summed up over time. However, I doubt how reasonable this is. In Bryden et al. (2014) this was done for a few years after the AMOC decline at the RAPID array. But is it really reasonable for a 28 years period? There are a kind of ‚saturation‘ effects, e.g. the volume of LSW in the Labrador Sea cannot increase more and more despite of intense convection/formation abd high AMOC, because it already reaches close to the surface after a few years of intense convection. Also the Canth saturation does not steadily increase for a period of years with strong convection (see Fig. 10).

l.524
‚… mode-water formation in the subpolar gyre‘.
Do you mean Subpolar Mode Water (SPMW) or Labrador Sea Water (LSW) or both? Also note the ‚dipole‘ in the Labrador and Irminger Sea between the SPMW(27.25-27.8, negative correlation with OSNAP and partly with NAO) and LSW (27.8-28, positive correlation with OSNAP and NAO).

l.530-532
‚In several northern provinces, densest layers exhibit positive concentration anomalies but weak or negative inventory anomalies because enhanced overturning shoals or thins these density classes.‘
I do not see any negative correlation between the AMOC at OSNAP and the volume of dense northern layers, only the opposite (Fig. 8b).

l.537-539
‚This behaviour reflects classical density-layer heave (e.g. Eden and Willebrand, 2001), whereby accumulated AMOC-driven renewal ventilates intermediate waters but compresses deeper ones...‘
Again, I cannot find an example for that in Fig. 8b.

l.544-546
‚This reflects its downstream position within the overflow-fed circulation of the subpolar North Atlantic: during strong accumulated AMOC phases, the basin is flushed by recently ventilated overflow waters low in Canth. Thus, overturning enhances renewal and slightly expands volumes, but reduces local Canth concentrations and inventories.'
Why should recently ventilated overflow waters be low in Canth?! LSW is higher in Canth, indeed, but that belongs to another density layer. In addition, it is new to me that the Iceland basin is ‚flushed' by overflow waters during strong AMOC phases. So far as I know, the overflow transports are fairly constant in time. Please give a citation here that proves strong overflows in concert with strong AMOC at OSNAP or remove this statement.

l.550-554
Indeed, waters formed in the Nordic Seas and subpolar gyre experience short surface exposure times and thus do not fully equilibrate with rising atmospheric CO2 (Olsen et al., 2010). During strong accumulated AMOC phases, a greater fraction of these young and recently ventilated waters which can exhibit low apparent Canth concentrations (i.e., because they were not fully equilibrated with atmospheric CO2 when ventilated; Matsumoto and Gruber, 2005) is flushed downstream, reducing local concentrations even as ventilation increases.'
At least for LSW this is wrong, as the Canth concentration residuals of the LSW layer in the Labrador and Irminger Sea are positively correlated with the AMOC.

l.557-558
‚These correlations likely reflect changes in net meridional export associated with high-latitude overturning variability, rather than direct advective connectivity.'
Net meridional export provides an advective connectivity, I do not see the difference.

l.561-563
‚In contrast, tropical provinces show mostly positive correlations with OSNAP and RAPID, consistent with downstream dilution of signals through mixing and recirculation.'
If the signals are diluted, the correlation should decrease/vanish. In addition, the recirculation would disturb a clear temporal correlation between Canth and AMOC.

l.571-573
‚In the subpolar provinces, surface layers generally show positive slopes: when accumulated AMOC is stronger, enhanced overturning injects Canth -rich surface waters into the upper subpolar gyre, increasing carbon concentrations.'
I do not see a large difference between the Canth-AMOC correlation between RAPID and OSNAP for the upper subpolar layers. Only in the Labrador Sea, this correlation is positive for the upper layers, but for both AMOC estimates, at OSNAP and RAPID.

l.573-575
‚In contrast, intermediate and deep density layers exhibit negative slopes, as strong accumulated AMOC intensifies subpolar convection and exports recently ventilated, relatively low-Canth waters southward.'
The correlation between the AMOC at RAPID and Canth of the deep subpolar layers is indeed negative. However, for the ventilation variability in the subpolar North Atlantic, the NAO and the AMOC at OSNAP are better proxies than the AMOC at RAPID, and for them, the correlation is positive. I also do not understand why recently ventilated waters should be low in Canth. The Canth residuals of the LSW and most other layers in the subpolar North Atlantic are positively correlated with NAO (Fig. 7a), which influences/strengthens convection.

l.575
‚...Canth at RAPID...‘
What is this?! It sounds like the local Canth concentration at the location of the RAPID array, but this not shown at all.

l.578-579
‚Here, stronger accumulated AMOC enhances southward return flow and retention within recirculating pathways‘.
First, the AMOC is identical with the ‚southward return flow‘ (upper and lower limb of the AMOC have the same strength). Second, is the recirculation really increasing? A recirculation does not increase the net southward flow. And why should a recirculation increase Canth? Recirculation makes waters older, and older waters normally have lower Canth concentrations.

l.580-581
‚Upper subtropical layers may show weaker or mixed slopes due to competing influences of northward export and local recirculation.‘
Note that subtropical mode water is also exported southward (equatorward) in the tropical-subtropical cell.

l.582-584
‚Stronger accumulated AMOC here corresponds to greater accumulation of carbon-rich water along advective pathways, producing consistent positive anomalies.‘
I do not see why this effect should be most pronounced in the tropics.

l.584
‚heatmap‘
Please refer to figure number here.
‚blue-red pattern‘
Please rephrase (correlation-anti-correlation pattern), the color scale is arbitrary.

l.586
‚subpolar intermediate waters‘
Do you refer to LSW? That is a deep water mass (see remark above).
‚incoming northern-sourced waters ...‘
What do you mean with ‚northern‘? The Nordic Seas or the subpolar region?

l.590-593
‚This dual modulation of tracer content and layer geometry produces the strongest multi-decadal accumulated AMOC sensitivity in intermediate density classes, where both mechanisms act together. ‚
Again, LSW, where the signal is strongest, is a deep water mass.
‚It also clarifies why the intermediate density layer highlighted by Müller et al. (2023) exhibits a particularly pronounced accumulated AMOC imprint: it lies at the transition between subpolar ventilation and subtropical redistribution.‘
I cannot see this ‚particularly pronounced accumulated AMOC imprint‘. Please refer to a figure.

l.597
‚… enhanced subpolar storage of anthropogenic carbon and volume increases in intermediate layers‘
Again, note the SPMW/LSW dipole in the Labrador and Irminger Sea

l.597-598

‚compensated by negative Canth concentrations residuals in subtropical reservoirs‘
Which layers do you have in mind? I still do not see a physical mechanism for this anticorrelation, which is also restricted to a few layers.

l.601-602
‚by the time waters reach 26°N, the imprint of northern uptake has been redistributed and partly compensated across basins, so that local Canth anomalies are weaker or even reversed.‘
I do not see a reversal of the Canth anomalies. On the contrary, in the regions close to the RAPID array (subtropics & tropics), the correlation of the Canth residuals is mainly positive.

l.610-611
‚OSNAP, located in the region of deep-water formation, therefore shows opposite signs for NAO- and accumulated AMOC-driven anomalies‘
This sounds as if the anomalies were located at the OSNAP array. The OSNAP transport might ‘show a sign for NAO driven anomalies’, but that is not investigated here. Make clear what you mean. The largest difference between the NAO and OSNAP correlations are in the tropical provinces, which are not directly effected by NAO.

l.615
…denser, lagged accumulated AMOC response’
What is a denser AMOC response?

l.616
‚… which smear out the immediate NAO signal‘
I do not see why deep waters in the (sub-)tropical region should be immediately impacted by the NAO. The fact that the Canth residuals there are mainly negatively correlated with NAO might indicate a delayed response, which is out of phase with the NAO.

l.619
‚… use of accumulated AMOC anomalies‘
See remark to l.519.

l.640
‚In the late 1990s and mid-2010s, periods of persistent positive NAO ...‘
The mentioned time frame for the positive NAO is wrong. The NAO was positive in the early/mid 1990s and the mid/late 2010s.

l.640-641
‚… water mass volumes in the densest layers (γn = 27.8-28 kg/m^3)‘
This is only one layer and not the densest one! (it is the densest layer that is influenced by deep convection in the subpolar North Atlantic)

l.646
‚… in both basins, saturation decreases during periods of sustained positive NAO‘
I do not see that from Fig. 10. On the contrary, during the long positive NAO period in the 2010s, Canth saturation is relatively high in the Labrador Sea (Fig. 10b) and increasing in the Irminger Sea (Fig. 10e),

l.649
‚… and deeper, less frequent convection compared to the Labrador Sea‘
The convection in the Irminger Sea is not ‚deeper‘ than in the Labrador Sea. You probably mean ‚less frequent deep convection.

l.666
‚...particularly in the densest layers‘
Again, you probably mean the LSW layer, which is not the densest one.

l.682-683
‚The mirror-image patterns between NAO at accumulated AMOC heatmaps OSNAP...‘
This sentence does not make any sense. I would also not use the word ‚heatmaps‘ here, but correlation (maps) or something similar, which is more meaningful.

Figures

In all figures the font size of the axis‘ labels needs to be larger (except Fig. A3).

Fig. 4: The left y-axis in Fig. 4b shows wrong numbers. The Canth column inventory in the Atlantic does not exceed 200 moles/m², some of the values in Fig. 4b are twice as high.

Fig. 6, A2 and A4: Please increase the height of the subfigures, there is some space left on the pages.

Fig. 6, 7, 8 and 9: The regression coefficients should have units.

Fig. 7 and 8, legend: Why do you use a p-value of 0.5 here?

Fig. 8: Panels d-f are erroneously labeled a-c. As panels d-f are on a new page, I would suggest to give them a new figure number (9).

Fig.9: The colorbar inside the panels is not readable at all (far too small).
Legend:
You say that the correlation for the four main regions is shown. In fact, you show the correlation for every single province.
‚Dashed-dotted light-pink solid arrows represent the upper AMOC limb (NAC).‘
I do not see them. Instead, I see grey dotted lines/arrows, probably meant to represent the upper circulation including the subtropical gyre. There is also a light pink large arrow in the upper panels, which I cannot assign to anything.
‚...the apparent negative Canth correlation in subpolar regions under stronger accumulated AMOC (top-middle) reflects the downstream RAPID signature of enhanced export of recently ventilated, relatively low-C Anth deep waters via the DWBC.‘
The correlation with the RAPID array is shown in the top right, not middle.
Again, I do not see why the exported recently ventilated deep water should be low in Canth. If that would be true, the correlation of the Canth residuals should be negative along the export pathways, which they are not, they are positive there. The (small) negative correlation is probably caused by the time delay between Canth anomalies in the subpolar region and the AMOC at RAPID.
‚not a true reduction (which would be positive as seen at OSNAP, top-right)‘
OSNAP is shown in the middle.
I do not understand how a ‚true reduction‘ can be ‚positive‘

Fig.10
The x-labels in panels (c) and (f) differ from the other panels. Please unify.
Panels (a) and (d) do not show exactly the same time period as the other ones. Please unify.
Legend:
‚… the maximum (purple) and average (pink) mixed layer depth‘
Please add that the pink line is dotted.

Minor comments
You often quote density values without ‚gamma_n =‘ in front. Please add.

Examples for questionable/wrong results:
Fig. 6b and Fig A2
Both figures show Canth values. In 6b, I assume, only the years with Canth data are shown. In Fig. A2 these are marked with circle dots according to the text in the legend. However, the data based Canth points in both figures do not coincide in time. How can that be?!
In Fig. 6b, the deeper layers for the W. Subtropical region are missing completely.
Fig. A2
The years with with Canth data sometimes stick out, especially for the LSW layer in the Caribbean. This might be due to spatial aliasing (data from inside the ‚real‘ Caribbean and from the DWBC are mixed). This can probable be reduced by taking the DWBC east and north of the Caribbean region to the W tropical region.
In general, the deviations of the years with Canth data from the longterm trend show the uncertainty and should be discussed.

Fig.9
I am concerned about the spatial pattern of the regression coefficients. The NAO has its largest impact on Canth in the subtropical and tropical regions, although one would expect the largest impact in the subpolar regions. The AMOC has its largest impact on Canth in the eastern tropical Atlantic, a region which is not in the main AMOC pathway and hence should be effected less. In the light of this, how reliable are your findings? At least you need to discuss the unexpected pattern of Fig.9.

Fig. 10
Canth
The low values for the Labrador Sea in 1999, 2006 and 2007 might be artefacts (spatially biased or data quality issues). Especially the low upper layer values in 1999 are not realistic. Such drastic changes are also not present in the time series of oxygen and Canth for the central Labrador Sea in Rhein et al.(2017). Also the high lower layer values in the Irminger Sea in 2017 appear too high (although I would expect a maximum).
MLD
The maximum mixed layer depths are too high for my knowledge. I do not belive the values close to 3000 m in some years. In most of the years, the maximum MLD is close to 2000 m both in the Irminger and Labrador Sea. This would indicate very deep reaching convection every year. In addition, the values for the Irminger and Labrador Sea are comparable. In the text you have written that convection in the Irminger Sea would be less frequent, which is a contradiction to Fig. 10. I also wonder how the average MLD can be larger than the maximum MLD, which is the case for the first year in the Irminger Sea.

Literature:
Rhein, M., Steinfeldt, R, Kieke, D. Stendardo, I. & Yashayaev, I. Ventilation variability of Labrador Sea Water and its impact on oxygen and anthropogenic carbon, *Phil. Trans. R. Soc. A*, 375(2102) (2017), doi:10.1098/rsta.2016.0321

Yashayaev, I. Intensification and shutdown of deep convection in the Labrador Sea were caused by changes in atmospheric and freshwater dynamics. *Commun Earth Environ* **5**, 156 (2024). https://doi.org/10.1038/s43247-024-01296-9