

Response to reviewer #2 and Editor for manuscript “Long-term eddy modulation affected the meridional asymmetry of halocline in the Beaufort Gyre” by Lu et al.

October 2023

Responses, point-to-point, are given below in [blue](#).

Anonymous reviewer #2:

The manuscript text has clearly improved from the last iteration, and I appreciate the efforts the authors have put in to address my previous concerns. In particular, I am pleased that the authors took on board my comments about the spatial extent of the gyre and provided more evidence to support their claims. I still have some further comments, however, which I have outlined below.

Note that while the authors have demonstrated that there is more eddy activity in the region, I still do not feel that the gyre positioning has been emphasised enough as an additional potential contributor to the halocline changes described. While in essence this is just a case of wording, I feel it is necessary to state these potential caveats at the relevant points in the text. I think the main issue I have is that the title directly attributes the changes to eddies, which does not leave room for any other factors.

[Thank you very much for taking the time to review our manuscript again. These suggestions were adopted in our revised paper where we believe they were useful to impress our thoughts. We have carefully considered your further comments and made corresponding modifications. While in this paper only eddy modulation is analysed, eddy is not the only factor in the halocline variability. Especially, we modified the title as “Long-term eddy modulation affected the meridional asymmetry of halocline in the Beaufort Gyre”.](#)

Abstract

Line 16, “reduced in the final” – the end of this sentence is missing.

[Thanks for pointing it out. The wording was corrected.](#)

Lines 18-19: “halocline structures on either side of the central gyre reached a nearly identical and stable regime” – how far either side is being considered? It has already been acknowledged in the first period the gyre was closer to the continental slope and so was affected by that. What distance is considered “close” when considering asymmetry?

[Thanks for your recommendation. The distance from the central gyre was considered. Considering in different periods the position of central gyre moved, here we just took the position in the middle of either edge and central gyre as “either side” that is at least 120 km from gyre center.](#)

Introduction

I feel like the structure of the introduction is still a little odd. From lines 48 onwards, we are first told about previous studies about eddies without knowing why it is relevant. We are then told the focus of the paper. We are then told about importance of eddies, before reading a paragraph that mixed the three topics. I found the logical progression and the role of each paragraph a bit unclear.

Thanks for this suggestion. We modified the structure of the introduction to be clearer. The importance of eddies and its impacts on the halocline are introduced first before listing previous studies about eddies. The sequence of some sentences is appropriately modified for a better flow.

Line 36: what happened to freshwater content after 2012?

“While in 2013 FWC decreased, it again increased from 2014.” was added here.

Lines 44-45: why are isopycnals steeper nearer the gyre edge due to topography? In the north this is not the case.

Because southern gyre edge was limited by topography, eddy diffusivity increases towards coastal gyre edge. Eddies can redistribute isopycnal layer thicknesses laterally and as a result affect the halocline depth (Manucharyan et al., 2016). In the north there is an abyssal plain.

Data and methods

Line 98: why do the reanalysis datasets “mainly” consist of the two listed? What else is there?

“mainly” was removed. There are no else reanalysis datasets.

Lines 106-108: If the shallowest moorings start from between 50 and 90 metres, how does this affect the computation of the top of the halocline/thickness in Figure 2a/b and Table 1? The diagnosed “top” is consistently between 50 and 90 metres, which would suggest that it is above the first available data points sometimes. How does this affect the results?

Thanks for pointing it out. Considering there was no available moored data above 50 m, we used CTD observations to diagnose the depth of halocline top and halocline thickness. However, there are only annual CTD surveys and not enough sample counts, so trends of halocline top and halocline thickness were not calculated by CTD. Figure 2 and Table 1 were modified accordingly.

Lines 124-126: You state that the dynamic topography dataset is available in ice-free regions. What do you do when there is ice? You may be comparing quite different domain sizes when computing the EKE – does that affect the interpretation of the results?

Considering surface eddy activity is strongest during ice-free seasons (e.g., Meneghello et al, 2021), we optimally interpolated long-term EKE daily time series from altimetry data to supplement the missing value in ice seasons. Based on interpolated data, we calculated annual mean values. When we compare EKE variability in different domains, the results are averaged in the area.

BG halocline variability

Lines 191-193: I don't think you can say the variations at both northern sites cover 3 periods. Mooring C is only available for the first period. So, it is only Mooring B that is relevant here. Results from CTD observations were supplemented to address the missing of mooring data. The related texts were modified accordingly.

Lines 216-219: I think you should state what Zhong et al (2019) find explicitly here. What rates did they find? I would suggest that if they also find more deepening in the northwestern basin, then your findings do not "deviate" from previous findings.

Thanks for this suggestion. We checked these sentences and made necessary modification.

Line 240: re-iterate that you are talking about the supplementary figure here. You also need to state explicitly why you have introduced a supplementary figure before you reference it (not just at the end of the paragraph) – just state that you are verifying that the behaviour north of the extent of the dataset is consistent.

Thanks for this suggestion. We added the statement here.

Lines 259-265: As in the abstract, be very clear about what you mean by "close to gyre center". How far away do you need to be to still be classed as close? It looks like Figure 4c shows a steeper north close to the gyre after 2014... (around 77N). In general, I still think it needs to be explicitly said that **a**) the fact that the gyre has moved northwards means its southern edge is not as affected by the topography (and resulting asymmetry), and **b**) the section is not always capturing the same portion of the gyre. I know the latter point was meant to be demonstrated by taking a section along 140W, but to me this demonstrates more the thickening than the asymmetry – it shows that there is variability based on what specific section you take at a given time, and that the gyre moves. Figure 3 shows the part of the gyre that is being captured – after 2014, it is more the centre than before.

Thanks for this suggestion. The inappropriate interpretation was modified. After 2014, there was steeper halocline on the northern side. This was added (Line 263). We emphasised the effect of gyre northward movement, which induced less affect by the southern slope (Line 262). I agree that the section is not always capturing the same portion of the gyre. The effect of the variability in the BG spatial movements on halocline via different sections and more areas of gyre center in the final period were added accordingly (Line 230).

Spatiotemporal variability in eddy activity

Line 363: How much is this affected by presumed less open water periods before 2003? Some points before 2003 are of a similar magnitude to points after 2003, is it ok to rule them out?

The inappropriate interpretation was modified. There was low APE within BG region initially during 2003-2005 and more missing velocity data before 2003. Because EKE is strongest in the AL region, some points before 2003 are of a similar magnitude to those after 2003. From the views of surface EKE patterns, EKE was relatively low in the first period. Therefore, we do not emphasize eddy variability during this period here.

Line 373: Can you provide a summary sentence about the main takeaway message from the

three datasets over time? There is a lot of detail here but hard to know what the overall conclusion is.

Thanks for your suggestion. The related texts were added.

Eddy modulation in the asymmetrical halocline

Lines 423-424: which EKE plot are we referring to here? A figure reference would be useful.

Thanks for pointing it out. It was added.

Line 429: Is it a problem that the error of 30-40 metres is of the same order of the deepening seen in the data?

The error of 30-40 m is existing along the whole transect and over three periods. Despite of an overestimate of halocline depth, the deformation of halocline structure is captured.

Line 493: You cannot use the word “credible” here.

It was removed.

Editor:

I have read the revised paper myself and agree with the reviewer that there are still some areas requiring clarification. The attached pdf has some highlights where wording needs to be rephrased or clarified. Perhaps most importantly, I did not find the paper clear about what was shown that was new. You have obviously done a great deal of analysis and work, and you present plenty of nice figures and numbers. In many places you set this in the context of the literature. That's all good. But the summary and discussion section states again the things you have done and the results found. It would help if you could specifically and briefly identify what was new about the findings (i.e. had not been stated in the literature previously) and why this matters? e.g. This disagrees with..... or This extends the analysis ofinto a different region/time? You state in the Conclusions "This paper provides a possible perspective..." - can you state what that perspective is exactly? I was not sure what you meant here.

Please revise the paper taking into account the concerns of the reviewer and my suggestions above. If I consider that you have suitably addressed the reviewer's concerns, it should not be necessary to undergo further external review.

Thank you for your prompt and constructive comments on my manuscript. I have carefully reviewed the attached PDF to improve the manuscript further. I acknowledge the comments regarding the need for more clarification in certain areas of the paper. The wording was rephrased and clarified where necessary, particularly in the summary and discussion section. Regarding the suggestion of identifying what was new about the findings and why it matters, I rephrased the key contributions of the paper in section 6. I revised the statement in the conclusion, in a briefer manner, to more precisely identify the perspective offered by the paper.