Response to Reviewer's comments (R2) on

The impact of atmospheric and oceanic circulations on the Greenland Sea ice concentration
by Sourav Chatterjee, Roshin P. Raj, Laurent Bertino, Sebastian H. Mernild, Nuncio Murukesh, and Muthalagu Ravichandran

Reviewer's Comments:

Review of the manuscript The impact of atmospheric and oceanic circulations on the Greenland Sea ice concentration, submitted to The Cryosphere General comments This is a novel study that focuses on the dual influence and control that oceanic and atmospheric circulation have on several key parameters in the Greenland Sea. It aims to show how the complete system works together to shape the sea ice conditions, ocean stratification and upper ocean heat content, also aiming to explain why the characteristic sea ice shape 'Odden' tend to occur in some winters and not others. The latter through influence of Atlantic Water higher up in the water column and increased inflow of Atlantic Water during periods with an anomalous strong gyre. The paper largely succeeds in showing this interplay. The authors also show how their results fit into a bigger picture of processes through framing it well into published literature.

One of the strengths of the paper is the focus on both vertical and horizontal processes, both from the atmosphere to the ocean and sea ice, and from the ocean to the sea ice (the impact further from the ocean/sea ice on the atmosphere is less mentioned). The paper has a high and complex aim, trying to reveal a complex interplay, and it therefore needs to be very well written and have a tidy structure in order to give a clear presentation of the results. Unfortunately, this is not good enough in the current version. Sentences are mostly well written, but the organization of the paper needs improvement, and some parts are weak or even lacking, e.g. Ch. 1 lacks a clearly stated objective and Ch. 2 lacks a thorough description of the methods. Ch. 3 Results and Discussions appear messy since sentences that belong to the introduction and methods are blended in, and there are some repetitions in this chapter. This tends to preclude the key results and make it harder to follow the discussion. However, with a largely improved presentation of the findings, including a clearer focus on the objective, an addition of a thorough description of the methods and a model evaluation, the paper will be worthy of publication. Note that even if the numerical model has been evaluated previously, this is not equivalent to it being adequate for investigating the processes which are analysed here. A model evaluation is therefore needed in this paper, see comment below. It is also important to treat uncertainties better in the paper, to show that the results are significant.

My conclusion is that an improved version of the manuscript will be well-worthy of publication and deepen the insight on how the atmosphere and ocean act in tandem in the Greenland Sea. The paper gives rise to an improved understanding of the complex and important interplay that takes place between the ocean, sea ice and atmosphere, and the results can have value for understanding regions outside the Greenland Sea as well. I encourage the authors to add a discussion on how the complete set of results can be viewed schematically. My suggestion is a divergence/convergence situation or strong divergence (pos. GI periods) versus weak divergence (neg. GI periods) situation, see major point below.

Authors' reply:

The authors thank the reviewer and highly acknowledge the effort for such in detail evaluation and valuable suggestions which will strengthen the study. We will work on the presentation of the results and make it more clear to follow.

Specific comments

It would improve the paper to include a discussion on the overall picture of processes towards the end (discussion), accompanied by a schematic illustration of the process described. What may be the overall picture of processes here? Is it strong divergence versus weak divergence with the associated Ekman transport and pumping? The analysis compares periods with a strong and weak gyre circulation and show that it corresponds to periods with sea ice transport towards the Greenland coast versus periods with sea ice transport towards the gyre and shaping of the characteristic Odden sea ice shape. Is this also valid for a larger domain encompassing the study area? I.E., is this comparable to a large divergence situation where low sea level pressure induces stronger cyclonic motion in the gyre, which in turn is associated with stronger Ekman drift of sea ice and surface water away from the gyre, inducing a lift of the interface between the fresher waters in the upper ocean and Atlantic Water below? And that this also involves Ekman pumping in the centre of the gyre, lifting the interface and inducing stronger inflow of Atlantic Water towards the gyre? When the gyre is more relaxed, there is less divergence and the sea ice can drift also towards the gyre region, particularly with the Jan Mayen Current and shape the characteristic 'Odden' tongue of sea ice. There is a need to summarize this at the end of Ch. 3 and to add schematics of the horizontal and vertical conceptual framework that the authors mention several times in the manuscript.

Thank you for suggesting these important points. As suggested a schematic picture detailing the overall process will be added.

The divergence related with gyre circulation can also be important along with the wind driven Ekman transport. Thank you for the useful suggestion.

Also please note that, our main objective is to find the process(es)/mechanisms through which Greenland Sea gyre (GSG) affects the sea ice concentration of the region. In the revised version we have shifted the focus to the western Greenland Sea, where the interanual variation and the effect of GSG is most prominent (Figure 2 and 3) instead of the 'Odden' region (and/or centre of the gyre).

Why use the smaller region to the west (72-75N, 18-10W) when investigating the covariability between stratification strength and gyre strength in Fig. 7? These two study regions are not similar. Why not use the same region as for the Gyre Index? It is logical to use the 72-75N, 18-10W for showing flow of AW upstream of the gyre, but for the stratification comparison I assume it is better to look at the actual response of the gyre. From reading the manuscript one gets the impression that the figure intends to show the change in stratification in the gyre itself, not upstream.

The influence of gyre on sea ice is shown Fig 3. Note that the marked region is where (1) the influence of gyre index on sea ice is maximum and also the same region has (2) the strongest interannual variability (Fig 2). Also in the core of the gyre and/or in the Odden region sea ice is ocassionaly formed, making it tricky to meet our objective i.e role of atmosphere ocean dynamics on interannual variability of sea ice. So for the strength of gyre circulation, the core of the gyre is chosen, but for its impact on sea ice, the western Greenland Sea region with the two features above are chosen. We will clearly mention these points in the revised manuscript to improve the readability.

Present the Gyre Index thoroughly early on, as it is a key part of the analysis. This can be done by adding a time series of it in Fig. 1b and highlight the positive and negative time periods that are used for the analysis. A rationale for using the chosen threshold values 0.75 and −0.75 is needed (in

the methods). The paper needs to show which time periods are used in the analysis, as the negative and positive periods are compared. Explain in the methods carefully how you have estimated the "composite differences". This explanation can refer to Fig. 1b, the time series of the Gyre Index. It can also be of good value to present maps showing the mean wind fields for the positive and negative periods as Fig 1c and d or add such maps to Fig. 4.

We will incorporate the suggestions and/or use improved analysis to bring out the findings more clearly.

The last paragraph of Ch. 1 needs a strong rewrite. Clearly state the objective of the paper and mention briefly in one or two sentences how the study is performed, which data have been used and how the rest of the paper is structured/organized. In the current version, the objective and hypothesis are mentioned indirectly in Ch. 3.

As suggested by the reviewer, the final paragraph of the revised manuscript will be rewritten considering all suggestions.

The Method section is poor. Ch. 2 Data and methods presents the data shortly but lacks a thorough description of the methods. Reorganize it to e.g. 2.1 Data, with three paragraphs on atmospheric, oceanic and sea ice data, and 2.2 Methods, with a careful explanation of what the authors did in this paper. An evaluation of the TOPAZ4 results are needed to show that the model results are appropriate for investigating the objective of the paper. Mention which oceanographic data are used for the data assimilation (how many, from which data sets and the distribution seasonally and through the time period). What are the typical discrepancies between the TOPAZ4 before and after the data assimilation? What are the parts of the ocean-sea ice system that the model performs well on and which is it not simulating well?

Thank you for pointing this out. We will rewrite the section with the suggestions provide. We will also discuss about the TOPAZ4 in more detail. Note that the detailed setup and performance of the TOPAZ4 reanalysis is exposed in Xie et al. 2017, including the counts of observations and the temporal variations of the data counts. Of particular relevance for the Greenland Sea are the assimilation of Argo profiles, research cruises CTDs from IOPAS and AWI (Sakov et al. 2012), satellite sea ice concentration, sea surface temperatures and sea level anomalies. We will rewrite the section with the suggestions provide. We will also discuss about the TOPAZ4 in more detail.

The evaluation needs to show that the TOPAZ4 results simulate reasonably well the key variables investigated in this study, which include the ocean stratification, sea ice concentration and ocean circulation in the upper 500 m., in terms of the spatial pattern of the mean fields and their temporal variability. It is also important to show the vertical structure of the ocean in temperature and salinity to check that TOPAZ4 reproduces the change in these variables between positive and negative Gyre Index periods. Add a brief discussion on TOPAZ4's applicability, strengths and weaknesses that shows why the model is suitability for the purpose here. Even if there are discrepancies from reality in the model results, they can still be useful for the purpose here. However, the discrepancies need to be shown and mentioned explicitly and it is necessary to discuss the findings in consideration of these discrepancies at the end of the paper. E.G., from Fig. 2 is clear that TOPAZ4 has a higher sea ice concentration variability than the observations. Does this imply that it exaggerates the variability, which in the time series analysis could result in a higher significance than in reality?

We will add analysis for validation of TOPAZ4 using EN4 gridded data. As suggested by the reviewer will in detail present the strength and weakness of TOPAZ4 in comparison to observations.

Results and Discussion is messy and needs a strong tidying job. Having the results and discussion in parallel may work, but that demands a very well written, tidy and organized results and discussion chapter. As it is reads now, Ch. 3 is a mixture of results and discussion blended with introduction and methods sentences. Stick to a structure of starting each paragraph with briefly stating a result and referring to the companying figure. Then discuss briefly what the finding means and how it is interpreted by the authors and where applicable shortly if that is in line or not with published literature. The paper needs a broader, separate discussion of the findings before the conclusions are drawn. This can be a last paragraph of Ch. 3 that presents the flowchart in Fig. 8 and a new schematic in Fig. 8b that shows the process in the horizontal and vertical.

We thank the reviewer for the detailed constructive comment. We will to our best follow as suggested here and rewrite the Results and Discussions sections.

Conceptual presentation: For this type of paper, that encompasses a complex and overarching picture of processes it is important to present the conceptual framework explicitly. Fig. 8 needs to be strengthened with a schematic of how the concept it is viewed from above, showing the case with the strong gyre/positive GI periods, with arrows showing the divergence of sea ice (and surface water) and stronger inflow of Atlantic Water, and a vertical sketch showing the lifted/raised pycnocline, with AW higher up in the water column. Then explain that during neg. Gyre Index periods, the gyre is more relaxed, there is less divergence/less Ekman transport and sea ice tends to be drifting more towards the gyre and the 'Odden' tongue of sea ice can be formed (helped by the JMC). In this way, the author's interpretation of the whole set of processes can be summarized and made easily accessible for readers and increase the impact of the paper.

We agree with the suggestion! A schematic of the processes may be useful. However note that, we are intended to focus on the watern Greenland Sea (will be made clear in the revised version of the manuscript) where the sea ice impact of the gyre is more, and not inside the gyre or Odden region, where we dont get clear evidence of the same.

Seasonal aspects: The paper does the analyses for winter (Dec-Jan-Feb), presumably because winter has strong wind forcing, thus likely a stronger signal-to-noise ratio which increases the chances of tracing the signals under investigation, with significant correlation coefficients. This is a reasonable choice, but the authors need to provide a rationale for it and discuss if the investigated processes are in effect and significant in other seasons. It is necessary that the model simulations are good in winter. I assume there is less observational CTD data to assimilate the model with in winter. It is therefore necessary to show the seasonal distribution of the observational data and that the model performs well enough in winter (particularly, the change between winters with different forcing is essential here).

We agree that the point raised by the reviewer is not clearly presented in the manuscript. Our rationale is the fact that the sea ice in the region are mostly present during winter only. Thus all though the processes may still be active during other seasons, but to show their impact on sea ice we need to choose winter months only. This will be made clear in the revised manuscript. In addition, we will add the analaysis for evaluating performance of TOPAZ4.

It has not been shown that AW reaches the surface in response to the anomalously strong gyre circulation. In the analysis, this is checked for the upper 400 m and even if the mean temperature and salinity increases in the upper 400 m, this is not equivalent to showing that AW reaches the surface. Either modify the wording to e.g. “implying a lift of the AW” or “raising the AW” or similar or strengthen the analysis to show that it does occur. It will strengthen the paper if the analysis is made for more specific parts of the water column, e.g. for 0-100 m and 100-400 m separately, or other depth spans that the authors find more appropriate for investigating how AW is lifted in the water column in response to the strengthened gyre. Fig. 7 is informative in this manner, and should be expanded to include Hovmöller diagrams of temperature and salinity in the same way as panels b and c.

We agree and will incorporate these suggestions and add the suggested figures.

There is a poor level of treatment of uncertainties in the manuscript. There are only a few years that goes into the statistical analysis (i.e. those with Gyre Index >0.75 or <−0.75) and it is important to show that the results are significant. Estimate the uncertainty and show it, in time series as e.g shading around each variable and in maps as shading or hatching over the significant areas. Write the p-value after each correlation coefficient. Why use the 95 % confidence level? Are the results valid on the 99 % confidence level?

We will use different analysis techniques (e.g regression analysis) to have more confidence on the results with increased number of samples than in composite analysis. We will check the results at 99% as well.

Technical corrections

TITLE -Remove the period at the end. -Consider a rewrite to highlight the finding, i.e. that there is a combined impact by the atmosphere and ocean. And since the ocean is the main focus here, consider mentioning it first, thus changing to “Combined impact of oceanic and atmospheric circulations on Greenland Sea ice conditions”. -Since the authors investigate the effect not only on sea ice concentration but also on ocean stratification and AW inflow, the title could end with “. . .Greenland Sea conditions”.

Thank you for this important suggestion. We will change it accordingly.

ABSTRACT -Regards the sentence “This in turn decreases the freshwater content and weakens the ocean stratification in the central GS”. This may very well be true, but it has not been properly shown that the freshwater content declined in response to a stronger Gyre Index and the associated Ekman transport of sea ice and freshwater away from the gyre. Can you add figures to show this? Is the freshwater input reduced in response to less sea ice transported into the GS? But the effect of that would be seen after the following summer? Second last sentence: It has not been shown that AW is reaching the surface. It has been shown that there are warmer waters in the upper 400m when the gyre is strong (GI>0.75). And how high up does the authors mean when they use the phrase “surface”? Upper 400 m is very large span and increased heat content in the upper 400 m probably reflect that the Atlantic Water is occupying more of the water column when the pycnocline is raised more (during periods with stronger divergence and increased Ekman transport of surface waters and sea ice away from the gyre).

We will try to add freshwater content analysis. As suggested earlier, we will also add further analysis to show surfacing up of Atlantic water.

CH. 1 INTRODUCTION

Paragraph 40-45: -Last sentence: ‘can also be important in terms of interactions’ is unclear. Rephrase. Paragraph 50-55: -Second sentence: rephrase ‘or the old sea ice’ to ‘or older sea ice’. The sentence reads as though there is either young or old ice. Can younger and older sea ice occur in the Odden region at the same time?

We will rephrase the sentence inorder to avoid the confusion.
Since we don’t have enough signal of GSG’s impact on Odden sea ice, we will reduce the discussion of Odden and stick to the region affected by the GSG.

Paragraph 60-65: -First sentence: change to ‘large-scale’. -Third sentence. Rewrite and add a hyphen between ‘NAO’ and ‘like’. Suggesting a rewrite to ‘The large-scale atmospheric circulation resembles the pattern of the North Atlantic Cir- culation (NAO), but the NAO-like pattern is not covarying significantly with the Odden ice extent (Comiso et al. 2001).’ Paragraph 70-75: -First sentence: Remove comma after parenthesis with references and add ‘and’. -Sentence starting with ‘Further, . . .‘Add em-dash around the embedded clause: ‘Further, the eastward flowing JMCâĂŤoriginated from the EGCâĂŤconstitutes the . . .’ -Second last sentence: Change ‘this’ to ‘the’ in ‘this cold and fresh JMC’. -Last sentence: Remove ‘current’ in ‘JMC current’. Also, note that this sentence mentions indirectly the hypothesis of the paper. Rather write it explicitly (e.g. starting with ‘Our hypothesis is. . .’) or rewrite the sentence to e.g. ‘This implies that the GSG circulation . . .’ and add a sentence stating the hypothesis explicitly in the following paragraph, where also the objective needs to be clearly formulated. Paragraph 80-85 – last paragraph of the introduction: A clear ending of the introduction is needed. This is an important paragraph of the paper and needs to state explicitly the objective of the paper, the hypothesis, which now is mentioned indirectly in the paragraph above and in sentences in Ch. 3. Also mention briefly how aim is investigated and how the paper is structured. -First sentence: Be specific and explicit. Add what is investigated before stating the aim, e.g. ‘In this study, we investigate . . . with the aim to . . .’ -Add a sentence between the current first and second sentences stating the hypothesis: ‘Our hypothesis is that . . .’. -Second sentence: Add briefly the approach of comparing time periods with weak and strong forcing, e.g. ‘Using a combination of . . ., we compare time periods with strong and weak gyre circulation and show that . . .’ -Last sentence: ‘Further, it is shown that . . .’ is a rather vague and passive start of the sentence. Rewrite to e.g. ‘We also show that . . .’. Consider to rewrite ‘. . . helps setting up . . .’ to something more clear.

We thank the reviewer for more specific suggestions which we believe will improve the readability of the manuscript. These will be incorporated in the revised manuscript.

CH. 2 DATA AND METHODS

Paragraph 100: -This is a too short introduction to the atmospheric data. There is information missing. State all the atmospheric variables that were used in the study. Were they monthly means? What more did you do with the atmospheric data? What were they used for? This is completely missing from Ch. 2.

We used monthly anomaly derived from the monthly climatology for the period 1991-2017. We will detail them as asked in the revised manuscript.

-Use en-dash, not hyphen when stating the time period, i.e., ‘1991–2017’. -add a ‘the’ in front of ‘ERA’. -Use past tense in the data and methods chapter, consistently. Paragraph 105-110: -Add which vertical resolution there is in the model simulation. This is important in order for it to be useful for studying the change in vertical structure of the water column and the changes in stratification between positive and negative Gyre Index periods. -Last sentence: add a comma after ‘observations’. Remove ‘s’ in ‘temperatures’ and ‘sea ice concentrations’. -From where were the observations collected? Which data set? How many profiles, and from which years, seasons, etc. -Add an evaluation of the TOPAZ4. Is the model simulation suitable for the purpose here? This needs to be shown.

All corrections suggested by the reviewer will be incorporated into the manuscript. We will add a details of TOPAZ4 dataset and also evaluation of TOPAZ4.

Paragraph 115-120: -Rewrite to ‘Following Chatterjee et al. (2018), we estimated the strength of the GSG circulation by area-averaging the winter-mean December-January-February (DJF) barotropic stream function within the 3000m isobath in the region 73–78 ◦ N, 12 ◦ W–9 ◦ E (Fig. 1).’ Which depth span was used in the water column for this estimation? Add the 3000 m isobath as a thicker contour in Fig. 1 so that it is easily seen which contour this is referring to. -Second sentence: Rewrite to ‘The area-averaged value was standardized over the complete time period 1991–2017 to . . .’. The phrase ‘to get the’ is a bit awkward. Consider refining it. Also, it would fit well to refer to a Fig. 1b with the time series of the Gyre Index here, as mentioned above. -Third sentence: A rationale is needed for choosing the thresholds 0.75 and −0.75. -Last sentence: Is this only for the oceanic data? This shows that it is tidier to have methods as a separate subchapter, not mention methods within the 2.2. Oceanic data. Paragraph in Ch. 2.3: Again, this is too brief. Add how the data was used in the analysis. -First sentence: Rewrite to ‘Monthly mean sea ice concentration data . . . were obtained from . . .’. At which grid size? -Second sentence: Rewrite to ‘Sea ice velocity data were obtained from . . .’ *METHODS section is missing. What did you do here? Add a proper evaluation of TOPAZ4. Explain the methods, mentioning the time periods, study area, that you used winter-mean values (and why), that you used anomalies, etc. How many years actually went into the analysis. Highlight in bands with shading in new Fig. 1b so that it can be seen how many winters (DJF) had a positive Gyre Index > 0.75, and how many was <−0.75. This will allow for a higher transparency and clarity through the paper.

The whole depth was used to estimate the stream function. We will mention the data resolutions clearly in the data and method section. All other corrections suggested by the reviewer will be incorporated into the manuscript. As asked we will add a detailed ‘Data’ and a seperate ‘Methods’ section describing all the methods applied.

CH. 3 RESULTS AND DISCUSSION Use past tense when presenting the results. Use present tense when discussing them. Start each paragraph with presenting a result and refer to the appropriate figure. Then discuss what the results can imply towards the end of the paragraph. End Ch. 3 with a separate paragraph with a broader discussion of the results and the authors interpretation of them. Start this paragraph with presenting Fig. 8 (and add a conceptual sketch to it). Paragraph 125-130: -The first three sentences belong to Ch. 1. The rest of the paragraph belongs to the evaluation. I suggest moving them to Ch. 2. -Forth sentence: Move to evaluation part in Ch. 2. Refine to “The standard deviation of winter-mean DJF SIC shows high variability along the MIZ and the Odden region, in the observational and reanalysis data (Fig. 2).” -Last sentence: Move sentence to evaluation part in Ch. 2. Also, add that the figure shows that TOPAZ4 has a higher interannual variability in the winter-mean DJF sea ice concentration compared with the observations. Add how this discrepancy can or will influence the results and conclusions of this study. Is it exaggerating the

interannual variability, thus giving a higher signal to noise-ratio, or is the additional variability not in phase with the observed variability? Please add a time series of the corresponding SIC variability of the observational and reanalysis SIC in the study area as a Fig. 2c. The model was assimilated with SIC data. Mention why it still has discrepancies from the observed SIC data. How often is the model assimilated (daily, monthly?).

TOPAZ4 assimilates data every week. Data assimilation returns an optimal middle solution between the model and the observations, according to their respective uncertainties, but it should not match exactly the observations. In the assimilation of sea ice concentrations, the sea ice model has a "tighter Marginal Ice Zone (MIZ) than observations" (as stated in the text): a sharper transition zone between the pack ice and the open ocean. After data assimilation, the location of the ice edge is moved closer to observations but the MIZ remains sharper than in observations. Therefore, the sea ice variability in TOPAZ4 is confined to a smaller area than in observations, thus reaching higher percentages in a narrower band. All in all, the TOPAZ4 reanalysis has filtered the observations, in the sense of the Kalman Filter, and gives a higher signal-to-noise ratio than observations, visible with stronger regression values in Figure 3b. The figure will be updated with a colour scale that does not make the variability of TOPAZ4 seem alarmingly high .

Paragraph 140-145: This paragraph is messy, it contains parts of the objective, results, methods and discussion, and it suffers from some poor, vague writing. It needs a strong rewrite, and the sentences that remain in this paragraph needs to be sharp "to the point". -First sentence is about the objective of the paper. Move it to the last paragraph of Ch. 1 and rewrite to a clear sentence. -Sentences 2-4 belong to this paragraph as they present the result and the accompanying brief discussion of the implication of the result, which is appropriate for the chapter. -Fifth and sixth sentences belongs to Ch. 1. I understand that the authors have a need to explain why they move on to investigating the atmospheric fields, but there is too much introductory text here, 'with full sentences simply stating the results of other references. Rather simply add a '. . ., in line with *REFS*' after the fourth sentence. -The last two sentences are a mixture of methods and discussion. I suggest taking them out and, if necessary, starting the following paragraph with a brief mentioning of why the atmospheric influence was investigated. Paragraph 155-175: Very long paragraph, which presents two different figures. Split into two paragraphs where Fig. 5 is presented for the first time. -The first sentence is unnecessary long and difficult to read. Rephrase it. The part "suggests that the large-scale circulation associated with the GSG circulation features a NAO-like meridional pattern although the SLP. . ." could be written as "shows a NAO-like atmospheric pattern associated with the GSG ocean circulation, but with centres of action north of their usual locations (Fig. 4a). "Further, it is not self-explanatory what is meant with the phrase "composite differences of anomalies of ". I understand from reading the paper that you have estimated the difference in winter SLP between the positive and negative Gyre Index periods, using anomalies from the long-term mean, but this should be explicitly written in the methods chapter and also understandable just from reading the figure caption and introduction of the figure in the Ch. 3. If you want to keep the phrase "composite differences of SLP anomalies" then explain its meaning explicitly in the methods. Write which time-period the anomalies are estimated based on, in the text and in the caption. -Sentence starting with "The GSG circulation responds to. . .": I suggest bringing it further up front in the paragraph, as the second sentence. Then say that the correlation coefficient with the static, traditional NAO-pattern is insignificant, showing the importance of taking spatial variability of NAO's centres of action into account. -The two sentences starting with "However, at the same time. . .": It is awkward and needs a rewrite, to e.g. "The associated wind stress can influence sea ice transport through Ekman transport, to- wards the central GS and Greenlands west-coast due Ekman transport" and "We find anomalous northerly wind stress in the central GS during the positive Gyre

Index periods, and vice versa for southerly wind stress." Comment: Is it a southerly wind stress or a weaker northly wind stress during negative Gyre Index periods?

Yes, weakened northly wind stress. All Above suggestions will be incorporated in the revised manuscript.

It would be clarifying to show the maps with the mean wind fields for the two different cases, strong and weak gyre. -Panels are introduced in the opposite sequence. Introduce Fig. 5a first, then 5b. -This last part around lines 170-175 contains key discussion that is important and may fit better in a separate paragraph for the broader discussion at the end of Ch. 3. Paragraph 185-190: -The entire paragraph is introductory text and includes what the paper investigates in the third sentence. Move this information to Ch. 1. Paragraph 195-200: -First and second sentences: Rewrite to state the result explicitly, then end with '(Fig. 6a)'. The term 'composite differences' is not very intuitive. Could this be rephrased to something more easily understood? The point is that the figure shows that the ocean temperature in the upper 400 m is higher during the positive Gyre Index periods, right? Please write this simply and explicitly and mention how much higher the temperature is during these periods compared with the mean of the negative Gyre Index periods.

We will provide a quantification of the warming. As asked we will have a seperate Discussions section as well.

Third sentence: Remove. This is repetition and another mentioning of introductory text that does not belong to Ch. 3. -Fourth sentence: Rewrite to start with bluntly presenting the result coming from Fig. 6b, i.e. 'There is a significant positive correlation between the Gyre Index and ocean heat transport in the upper 400 m in the smaller study area west of the main study area (r=0.7)'. (The phrase will improve when the two study areas are named and introduced in the same panel in Fig. 1a.) It is cluttering the structure to start with how a previous finding is confirmed here. This is not a proper way to introduce Fig. 6b. Again, stick to the pattern of first presenting the result, and secondly discuss briefly its meaning, implication, mention how it confirms a previous finding or the like. -Last sentence: If this is also for the upper 400 m then it mixes the signatures of variability in the AW with the upper water masses. It would be more appropriate to check separately for different parts of the water column, e.g. 0-100 m and 100-400 m, separately, as AW is typically in the latter whereas the surface waters and polar/Arctic waters occupies the upper part. That would allow for seeing if the surface water decrease in salinity in periods with negative Gyre Index and more sea ice drift towards the gyre and would give a stronger result on whether AW is influencing higher up in the water column during positive Gyre Index periods. The term 'surfacing' is too strong given that it is likely rising but not necessarily reaching the surface. Be specific about which region this is estimated for.

We thank the reviewer for the above detail constructive suggestions. All suggestions will be incorporated in the revised manuscript.

Kindly note that, the salinity is not for the 400m but at the sea surface, the first depth level at the reanalysis data. So the signature of AW to the surface is there. We tried to show in Figure 6b, that with strong gyre there is increased temperature transport (within AW column~0-400m) in the region indicating warmer AW transport by GSG. The salinity was chosen at the surface level to show that this AW surfaces up in a weakly stratified condition and thus with a strong gyre we get higher salinity at the surface. We will clearly indicate these in the revised manuscript with added analysis to support our claim.

Paragraph 210-215: The paragraph is messy and needs to be tidied up. It starts with discussing figures 4 and 5. Rather start it with ‘The Gyre Index is covarying with the Brunt-Väisälä frequency (Fig.7).’ And add which depth span of the water column the stratification is estimated over. I suggest continuing with ‘Our comparison shows that a weakening of the stratification in the upper part of the water column coincides with a stronger GSG circulation and viceversa.’ -Sentence 4: Rewrite to ‘This supports that . . . by the GSG can rise under a . . ., hence potentially also the SIC.’ -Last sentence: Delete ‘further’ and ‘eastward flowing’. Change ‘EGC’ to ‘JMC’. Delete the clause starting with ‘, which constitutes’ because it is repetition. *A summarizing paragraph with a broader discussion is needed here. This should start with presenting Fig. 8 and write up the complete picture of processes and how the authors interpret their findings.

As suggested we will incorporate all changes and will have a separate discussion section in the updated manuscript.

CH. 4 CONCLUSIONS Please state if atmospheric or oceanic circulation when ‘circulation’ is mentioned in the conclusion, to avoid confusion. -First sentence: Unclear. Please rewrite. I suggest starting with e.g. ‘Here, we investigate . . . and show that . . .’. -Second sentence: add ‘the’ before ‘wind stress curl’. -Third sentence: Rewrite to be more specific, e.g. ‘The large-scale atmospheric circulation pattern that influences the GSG circulation resembles a NAO-like pattern with its northern centre of action situated northeast of the typical NAO pattern.’ -Fourth sentence: Add a ‘s’ in ‘sea ice conditions’. After ‘Odden region’, add ‘in the GS’. Modify end of sentence to ‘through Ekman drift of sea ice toward the Greenland coast during periods with northerly winds (Germe et al. 2011).’ -Fifth sentence: The sentence is a bit messy. Rewrite it to e.g. ‘During periods with anomalously low SLP and strong gyre circulation in the GS, northerly winds and associated Ekman drift causes sea ice drift towards the Greenland coast. This reduces the SIC in the central GS.’ -Sixth sentence: Consider a rewrite to ‘We show that this is associated with a weakening of the stratification in the upper water column.’ or similar, to be more direct and specific. -Seventh sentence: Add a comma after ‘into the central GS’. Modify the latter part of the sentence. It has not been shown that the AW reaches all the way to the surface, only that the upper 400 m become warmer and less saline. -Eight sentence: Presentation of Figure 8 is too short and should have been mentioned at the end of Ch. 3 and with a broader discussion of the conceptual view of the findings. -Last sentences after “. . .(Fig. 8)”: This part is taking up too much space in the conclusion and gives the impression of dampening the value of the findings of the paper and the closure of the paper becomes too vague. Rather mention this clearly in the methods, that the impact of other smaller scale processes would largely cancel out or act to reduce the correlation coefficients in the processes studied here. But despite these smaller scale processes the results are significant. However, if mentioned in the conclusion it could be rephrased to e.g. “Despite the presence of smaller scale processes, such as eddies and wave interactions, our results on the larger scale processes are significant with high correlation coefficients. This implies that smaller scale processes largely cancel out over time or are not strong enough to dampen the larger scale processes, at least not when comparing periods with weak and strong gyre circulation in winter when the wind forcing is strong”.

We take note of these important suggestions and they will be incorporated in the updated manuscript.

FIGURES
In general, figure captions are lacking information and are not complete, and there are incomplete sentences, e.g. when explaining place names in Fig 1. Make sure all the information is given for each figure. The introduction of study areas should be made up front in Figure 1. In the current

version of the manuscript the reader is asked to check for other figures to see which study region is meant. Rather include the two study regions and bathymetry in all the maps were those are needed in order to interpret the results from that figure. Be consistent. Consider to move the larger map from Fig. 4 to Fig. 1, as it fits with zooming in to the study area, and can be referred to in Ch. 1 Introduction. The term “composite differences” is used without further explanation, but is not self explanatory. Please be clear so the reader does not have to check the methods to understand what the figure shows. It can be written out full without too much space, e.g. ‘Difference in winter-mean SLP for DJF between time periods with strong and weak Gyre Index during 1991-2017’, or something similar.

We take note of this and will have legends with more self-explanatory details. Also a larger map in Figure 1 will be added.

Figure 1: -Consider moving the larger map in Fig. 4a to here to zoom in early on. -Add the other smaller study region as well and name the two. -It is a bit misleading to show the larger study area as a box when in reality is following a bathymetry contour. Rather show it with the 3000 m bathymetry contour. Consider showing it in all the figures that have a map. It should be possible without cluttering the figures. -Add a time series of the Gyre Index as Fig. 1b, and highlight the positive and negative time periods and threshold values 0.75 and −0.75 as e.g. shaded bands and dotted lines. -Highlight the 3000 m isobath contour as e.g. a thicker contour line than the others, to show theregion where the Gyre Index is estimated from.

We will modify the Figure 1 accordingly with clear representation of the regions of interest.

Figure 2: -This figure belongs to the Methods section, showing the variability of the sea ice concentration fields in winter and is used for evaluation of TOPAZ4. Rather refer to it in Ch. 2. Add label to the colorbar. -Rephrase ‘winter (DJF) mean’ to ‘winter-mean DJF’. -Add more panels to evaluate the model thoroughly. It is important to show that it simulated the ocean stratification and temperature and salinity well.

We will rearrange and add new the figures to incorporate the suggestions.

Figure 3: -Caption: Explanation of the red square is missing. -This can also be part of the evaluation and mentioned for the first time in Ch. 2. Why is the co-variability between SIC and the Gyre Index stronger in TOPAZ4 compared with the observations? How can this influence the results and the interpretation of them? This should be discussed in the methods section. -Fig. 3b: Panel is denoted as (a). -Interpretation of Fig.3: The authors conclude on causality when the figure only shows inverse co-variability. It could be that SIC and the Gyre Index are both affected by the atmospheric wind forcing? Sentence in paragraph 140-145 could be rephrased to e.g.: “This indicate that the GS SIC variability is covarying with the GSG circulation.” -Correct the first sentence of the caption to ’. . . (a) satellite observations and (b) the TOPAZ4 reanalysis. . .’.

The stronger regression has been explained above: the data assimilation analysis is a Kalman Filter and has less noise compared to observations.

Figure 4: -Show also the mean wind fields of positive and negative Gyre Index periods, not only the anomalies to show the differences between the positive and negative periods. Is the mean of the negative periods a weaker northerly wind field compared to the mean of the positive periods, or is it a southerly wind field, with wind from the south? I assume it is not a mean southerly wind field in

the negative periods, but a weaker northerly wind field, and that the anomalies show southerly wind because they are less northerly compared with the temporal mean for the whole study period. But this needs to made clear for the reader. Showing the mean fields would make the interpretations more intuitive and the paper easier to follow. -In the caption, add which time period the anomalies are estimated from. Add which data set the SLP is from. -Consider to add similar maps as b and c for Ekman pumping to make a stronger argument for the “lift of AW” during positive Gyre Index periods. -This figure has different coastlines compared with the other maps. Please be consistent.

Yes, it is weakened northerly wind field. We will add more explanation on this.

Figure 5: -In caption, delete ‘vectors’. -Again, showing only the anomalies means it is not entirely clear if the positive Gyre Index periods are associated with weaker southward sea ice drift or if the mean sea ice drift is from the other direction, i.e., northward sea ice drift. It would be more intuitive and easier to follow the manuscript if the mean field is shown for sea ice drift in positive and negative Gyre Index periods.

Kindly note that, Figure 5a is the climatological ice vector fields, while %b is regression of ice vectors on Gyre index.

Figure 6: -Panel 6a: Add outlines for the study areas from which the variables in 6b are estimated from. -Panel 6b: Add line for y=0. Add bands of shading showing the positive and negative Gyre Index periods, from which the map in 6a is estimated from. Consider adding a similar map as that of panel 6a for the upper 100 m or even the upper 50 m. This could be very interesting and give information that helps make the interpretation of the complete picture of processes (i.e., regards Ekman transport of surface water). -First sentence in caption is unclear. Rephrase to ‘Difference in average potential temperature anomalies in the upper 400 m of the water column between positive and negative Gyre Index periods during 1991–2017.’ -The term ‘temperature advection’ is perhaps better phrased as ‘heat transport’. Explain in the methods how it was estimated. -Second sentence in caption is unclear. Rephrase to ‘Time series of the Gyre Index (blue curve) and standardized anomalies of the salinity and tempera- ture advection in the upper 400 m.’ Please do not use the term ‘surface salinity’ for the salinity in the upper 400 m, as ‘surface’ is typically associated with the upper 0-50 m or so.

We will add or modify the analysis, figures to clearly present as it is suggested. Kindly note that, In Figure 6b, we showed salinity at the surface level only not in upper 400m. We tried to show in Figure 6b, that with strong gyre there is increased temperature transport (within AW column~0-400m) in the region indicating warmer AW transport by GSG. The salinity was chosen at the surface level to show that this AW surfaces up in a weakly stratified condition and thus with a strong gyre we get higher salinity at the surface. We will clearly indicate these in the updated manuscript with added analysis to support our claim.

Figure 7: -Add similar panels for temperate and salinity in ocean and increase the depth span to show the lift of AW. This can help justify the conclusions regards thelifting of AW in periods with positive Gyre Index. -Why is the Brunt-Väisälä frequency not estimated for the same region as the Gyre Index? Using the other smaller region outside the gyre makes the interpretation harder. The main response regards the lifting of the interface between the upper polar water masses and AW is occurring most strongly in the centre of the gyre?

We will add the analysis with temperature and salinity. The main reason for selecting a different region is shown in Figure 2 and 3. While the gyre circulation changes in the central GS, the effect of it on sea ice is most realized in the MIZ, where the Brunt-Väisälä frequency is shown. We intend to focus the on gyre's impact on the SIC. In the centre of gyre we dont get any clear signal that says the gyre could affect the sea ice there. Also the region in MIZ shows maximum interannual variability in both observation and model. Note that, allthough they differ in magnitude but for understanding the processes the similar pattern of significant influence is compelling.

Figure 8: -Flip the diagram on the side, with the atmospheric pathway on top and the oceanic pathway below. -Add schematics of how the authors interpret the process in the horizontal (showing divergence of sea ice and freshwater due to Ekman transport in response to stronger wind forcing and related increased AW recirculation and inflow to the GS) and vertically (showing the Ekman pumping and lift of the AW in response).

We will incorporate the suggestions and add a separate schematic for the processes.

USAGE OF TERMS -use the term "winter-mean (DJF)" instead of "winter time (DJF)". Avoid abbreviations as much as possible for easy reading. -the term "northerly" is used for both wind direction and sea ice drift. To avoid confusion, consider using "northerly" and "southerly" only for wind, and "northward" for sea ice drift and oceanic currents. See e.g. second sentence at the beginning of page 8, where the usage of "northerly" for both wind and sea ice drift is confusing. It is not clear if the sea ice drift is from the north or from the south from this sentence. -use apostrophes only when introducing a new term, like 'the Gyre Index'. Then refer to it simply as the Gyre Index without apostrophes on later mentions. The same goes for the Odden region. -Present the two study regions in the methods section, new Ch. 2.2., in Fig. 1a and Fig. 1 captions. Name the two study regions and use these names consistently throughout the paper. Write in the methods what you have estimated for each study area. -Which depth range is the surface salinity anomaly estimated for? Write this in the methods. If this is the upper 400 m then "upper ocean salinity" is more appropriate. -The term 'validation' is used in section 2.2. 'Evaluation' is a better suited term because it reflects that all models have strengths and weaknesses, no models are perfect, and a key point is to make sure that the model results are useful for investigating the objective of the paper with the chosen approach.

We thank the reviewer for his in details evaluation of the manuscript. We strongly believe this suggestions will improve our manuscript's presentation and readbility to a great extent. We will incorporate the suggestions made and/or modify the figures, analysis, presentation style so that the points raised here are adequetly addressed.