

Response to Reviewer 1

General comments

This manuscript is overall of good quality. It aims at understanding the drivers of the interannual variability of salinity in the Barents Sea and its impacts on the dense water formation in that region. To do so, it relies on satellite, in-situ and reanalysis data.

This manuscript is interesting, of good scientific quality, well structured, and overall well-written making it easy to follow the stream of thoughts, and addresses successfully the scientific question.

We thank the reviewer for the positive and constructive comments. We sincerely appreciate the reviewer's effort in providing the detailed feedback. In the revised manuscript, we have included all suggestions and corrections pointed out by the reviewer. A point-to-point response to the reviewer comments are given below (in blue).

Specific comments

Introduction:

Line 29-31: The sentence is correct, but I suggest rephrasing it, as it can be misinterpreted when read quickly. 'Buoyancy fluxes' is a general expression and is usually used to refer to surface buoyancy fluxes. Yet the Atlantic water densification is dominated by surface buoyancy fluxes but subsurface mixing contributes as well.

We agree. We have rephrased the sentence. Line 28.

Method section: When using acronyms for the first time, please write in full the meaning of the acronym (for example the meaning of ICES).

Thanks for pointing it out. Definitions of all Acronyms are added. Also, we provide these details in a separate table (Table 2)

Result section:

I recommend introducing subsections to better guide the reader and increase readability (maybe by subdomains (SBS, NBS), impact on the outflow of dense water).

Thanks for the suggestion. Yes, we agree. We have divided the Results Section into the above suggested subsections.

Line 117: 'upstream north Atlantic' this expression is hard to understand. Please replace it with a more meaningful one. Does the author mean 'in the northward circulation'?

We agree. We removed the phrase "upstream". The sentence is clearer now. Line 132.

Line 121: please add a justification of the definition of the Barents sea subdomains. Please also add a justification of the decision to analyse the two subdomains separately in the first place (this could be included in the introduction as there is already mention of some difference between the two subdomains). It seems that the latitudes of the northern and southern subdomains have been swapped in this sentence. It would also help the reader to highlight the subdomains using boxes on figure 1.

Thank you for pointing this out. We have added the justification, and corrected the typo the reviewer correctly pointed out. We have also added the subdomains in Figure 1. Lines: 137-138.

Line 129: Mention of Svinoy but the reader does not know where it is located. The caption of figure 2 says it is indicated in figure 1 but I can't find it there (it is actually outside the scope of the map of figure 1). Please add its location in figure 1, if not possible please give a sense of where it is with a description (Feroe Islands).

Thanks for pointing this out. We have added Svinoy location in Figure 1.

Figure 2: The y axis of the panels indicates 'salinity anomaly' (please add unit on panel a for consistency) but the caption only says 'salinity'. Please indicate how the salinity anomalies were computed. Please add after 'in situ observations' "(ICES data)".

The figure label and caption are corrected. Line 142, 145.

Line 165: Please add a reference to support the travel time from the SBS to the NBS.

We have added lag-correlation analysis and also added references supporting it. Lines 183-186.

Line 174-175: This result is very light. It is not really adding much as this figure is from the same dataset used for figure 2 so it is trivial that it shows the same positive trend as the data used is the same (one showing an average, the other the vertical dimension). I recommend removing it or to add a value to it, e.g. by giving information added by the depth layers (e.g. which layers are responsible for most of the positive trend?). In addition, the positive trend is not so evident for me for the ESA CCI SSS data (black curve) as the time period is very short and present strong inter annual variability.

We fully agree with the reviewer. We have removed the text.

Figure 5: I don't understand the caption "between the time periods (2016-2024) and (1993-2015)" and therefore the whole figure. What is represented? Is it the difference between the two periods? Please clarify.

Yes, this is the difference between the two time-periods. The sentence is rephrased for clarity. Line no: 228-230.

Lines 197-199: I disagree with that statement. On figure 6b (SAT), the salinity of the dense water seems to vary fairly little in comparison to temperature which seems to drive the density change as well. However, I agree that in the most recent years (e.g. 2023) the salinity is very low. I recommend rewriting this sentence to be more nuanced (not to say that the pattern is similar, the variability of the density of dense waters crossing SAT is dominated by temperature but that in recent years salinity contributed to form record low density).

We fully agree. We have redrafted the sentence as suggested by the reviewer. Lines: 220-222

Section 4

Line 217 and following: I recommend rephrasing and breaking the sentence into several sentences. It is relatively hard to read.

We agree. For more clarity two separate sentences are made. Line 241-244.

Lines 228-230: I don't understand this sentence. I don't understand "upstream subpolar gyre", "northward in the Norwegian Sea", please rephrase.

The text is deleted.

Lines 252-255: I don't understand this sentence. Which lag are we talking about? During which period? How does it change in time?

We understand the reviewer's concern, and we thank the reviewer for raising it. The lag-correlation analysis show that it is the correlation which changes not the lag. We have now added corrected this new finding into results section. Lines 183-188.

Also redrafted the Discussion section accordingly. Lines 258-274.

Line 266: Please remind at the end of the sentence the figure supporting this conclusion (I think it is figure 6).

We agree, the reference to the figure is added. Line 275

Lines 269-271: “offset the reduction in density”: I think the author wants to say 'increase' in density. Indeed, a temperature decrease (cooling) leads to denser waters. The beginning of this paragraph (lines 266-271) took me a long time to understand because of the way it is written and because the changes in temperature, salinity, and density in time are not readily visible from the TS diagrams. I suggest rephrasing these sentences to increase clarity and to add a third panel on figure 6 showing the temperature, salinity, and density time series of the data represented in panels a, and b. This should make it more straightforward to see the changes in time.

We agree. The sentence has been rephrased as the reviewer suggested. Line 278-280. We have also added two panels (c and d) to show the temporal evolution of temperature, salinity and density as suggested by the reviewer. Figure caption is updated accordingly. Line 236-237

Figure 7: The figure 7 should be referred to at least once in the main text. I recommend modifying it: it should show two contrasting states: the mechanisms prior to the recent freshening versus the freshening. It should also emphasize the different mechanisms between the SBS and NBS. It should also show the limits of your SBS and NBS. The text on the figure should make it clear what has changed between the 'normal state' and the 'freshened' state with comparatives like 'lighter dense water outflow', 'fresher AW inflow', 'reduced vertical mixing'...

We thank the reviewer for the comment. Fig 7 is now referred in the main text Line 270. Please note that the intention of including this figure is to show the mechanisms associated with the recent freshening event. Hence we only focus on the freshening event. This point is made clear by referring the figure in the main text as the reviewer suggested. The limits of the SBS and NBS is added to the figure. In addition, we have added more details to the figure caption. Line 298-302.

Technical corrections

Line 123 and 125, 129, 130, 173, 175, 183, 242 : replace 'increasing' by 'positive' (x5). Replace 'decreasing' by 'negative' (x3). Although grammatically correct, 'increasing trend' is misleading as I don't think that the authors are interested in the change of magnitude of the trend but rather on the sign of the trend.

Thank you. We agree and we have corrected it.

Figure 2: the y-axis has negative values on both sides of the zero value. Please correct.

Thank you. The mistake is corrected.

Line 162-163: this result corresponds to figure 2a not 2b.

Many thanks for pointing this out. Yes we have corrected it. Line: 183

Line 168: the sentence is weirdly arranged. It seems that the propositions have been swapped. Please correct: "Lind et al (2018) attributed the increased salinity in the NBS during the same period to the reduced sea ice import from the central Arctic".

Many thanks for pointing this out. We have corrected it. Lines: 189-190

Line 177: modify 'showed' to present tense.

Corrected. Line 199

217: Please correct the grammar 'during when'.

The sentence is redrafted. Line 242.

Response to Reviewer 2

General Comment

The manuscript addresses an important and timely topic: the recent freshening of Barents Sea waters and its implications for dense-water formation and downstream Arctic–Nordic Seas exchanges. The observational basis of the study is valuable, and the results have the potential to contribute meaningfully to our understanding of regional hydrographic variability. However, the clarity and structure of the manuscript require significant improvement. Many sentences are grammatically awkward, imprecise, or potentially misleading, which at times obscures the key scientific points. In addition, the Abstract does not clearly state what is novel about the work or how the methods lead to the presented conclusions. Several acronyms are undefined, figure elements are missing or mislabeled, and important methodological details—especially concerning data sources, section locations, and lag correlations—need to be clarified. The Results section would benefit from clearer structure, more rigorous quantification, and additional analyses (e.g., lagged correlations, trend estimates). Overall, the study is promising, but substantial revision is necessary to improve readability, scientific rigor, and interpretability.

We thank the reviewer for the positive and constructive comments. We sincerely appreciate the reviewer's effort in providing the detailed feedback. In the revised version of the manuscript, we have included all suggestions and corrections pointed out by the reviewer. A point-to-point response to the reviewer comments are given below (in blue).

Specific line-by-line comments, including styling, typos etc.

Abstract – After reading the Introduction, I would say that the Abstract lacks specific mentions of the methodology used and the novelty of the results. For example, the Introduction states:

(Line 36) “The propagation of temperature and salinity anomalies from the North Atlantic through the Nordic Seas and into the Barents Sea through the BSO is well documented (references).”

A few lines below (Lines 51–52), the 2012–2016 AW freshening event and its propagation to the Nordic Seas is also described as “well documented (Mork et al., 2019).”

Then we read in the Abstract (lines 18-23): *“We present new evidence of the imprint of the extremely low saline waters in recent years in both parts of the Barents Sea resulting from the unprecedented freshening observed in the northern North Atlantic. While the salinity variability in the SBS is found to be affected mainly by the variability of the Atlantic Water salinity transported into the region, the salinity variability in the NBS is additionally influenced by the freshening due to the increased sea ice import from the central Arctic.”*

In my experience, an Abstract is more engaging when it highlights the specific methods used and the novel aspects of the results—what distinguishes this study from previous work, and what gap in our understanding of Barents Sea variability it addresses. To strengthen the Abstract, I suggest restructuring it according to the following logic:

- Briefly introduce the region and the central problem—Barents Sea freshening—as a unique feature that also reflects broader Arctic changes.
- Clarify what data or observational products were used to isolate the sources of the observed variability.
- Indicate which analytical approaches (existing or newly developed) were applied to address the problem.
- Present the key findings concisely, supported by quantitative evidence where possible.
- Conclude with the broader implication, e.g., how the recent freshening has affected the density of water masses exiting toward the Nordic Seas and the central Arctic.

Such a structure would help clarify the scope of the study and better convey the novelty and significance of the results.

I believe that this could clear the scope of the paper and engage more the reader to dig into it.

[We thank the reviewer for the detailed feedback. We have now redrafted the abstract section based on the suggestions. Lines: 11-25.](#)

At lines 25-27: "is found to result in the lowest density of the dense waters exiting, respectively to the Nordic Seas and to the Central Arctic" – there's no ordered pair to map onto with "respectively". So "respectively" has nothing to attach to and it can be corrected to "dense waters exiting to the Nordic Seas and the central Arctic."

Corrected. Line: 25

Introduction

Lines 38–40:

The phrasing "time lag of approximately 2–3 years between the inflow region to the Nordic Seas in the south and the BSO" is clumsy and unclear. I suggest rephrasing it to:

"a 2–3-year lag between the Nordic Seas AW inflow region and the BSO."

Yes, we agree. Corrected. Line number: 41-42.

Lines 42–46:

The sequence "The freshening was attributed..." followed by "On the other hand..." reads as contradictory. It is unclear whether the mechanism is already established or still under discussion. I recommend restructuring this part starting with:

"Holliday et al. (2020) attributed the freshening to anomalous winter..."

and then introducing the contrasting view with "However/On the other hand..."

Yes we agree. Corrected. Lines 43-47.

Figure 1:

The source of the SSS data is missing, as is a reference to Table 1 (which currently has no caption or numbering). Please add the appropriate citation or reference.

The source of the SSS data is now mentioned in the Figure Caption. Line : 57-58.

Caption is added to Table 1.

Lines 74–75:

The placement of “respectively” is unusual. I recommend moving it to the end of the phrase:

“...into the Nordic Seas and into the central Arctic, respectively.”

This construction is more standard.

Thank you. Corrected. Line number: 81

Lines 87–90:

The Introduction does not clearly articulate the specific motivation for this study or explain why answering this question matters for Barents Sea dynamics. Why is it crucial to quantify the potential impact of these changes on dense-water formation and subsequent advection? A clearer statement of the study’s relevance would help anchor the reader.

Thank you. A clearer statement is added. Line number: 31-35.

Data and Methods

Line 93:

The text refers to “Table 1,” but the table currently has no caption or numbering. Please add a proper caption and table numbering throughout the manuscript.

Thank you for pointing this out. We have added a Table Caption and numbering. Line: 123-124. Also we have checked the entire manuscript.

Line 97:

The phrase should read “including such as” or simply “including”. As written, the grammar is incorrect.

Thank you. Corrected. Line :107

Line 101:

There is a missing space between “data:” and “The CCI.” Please correct the formatting.

Corrected. Line 111

Line 101:

ESA, CCI, and SSS appear for the first time here and should be defined upon first use. The same applies to SMOS and SMAP (Line 104) and EASE (Line 106). To avoid repeated explanations and potential confusion, I strongly recommend adding a table listing all acronyms (SBS, NBS, AW, BSO, SAT, etc.) and their definitions. This would greatly improve readability.

All acronyms are defined. In addition, a table (Table 2) listing all acronyms is provided after the Summary and Discussion Section. Line: 303.

Line 110:

ICES is also introduced without definition. Please define it at first mention and/or include it in the acronym table suggested above.

Thank you for pointing out. Definition is added. Line 100 and Table 2.

Table 1:

As noted earlier, the table lacks a caption. Please add one, along with a clear description of the variables, datasets, or products included.

Thank you. We agree. The caption is added. Line 123.

Results

Line 121: Is the division of the Barents Sea into NBS and SBS commonly used in prior studies? If so, please provide an appropriate reference. If not, please add a brief explanation of why these particular boundaries were chosen—e.g., whether they are based on bathymetry, circulation features, or another criterion.

We agree. New text is added explaining the above. Line 134-138.

Line 123: More specificity is needed regarding the described trends. Please clarify:

an increasing trend *until when*?

and/or

a decreasing trend *since what year?*

Are these computed trends or a visually analyzed from the plot?

We thank the reviewer for pointing this out.

Kindly note that, educated from the reviewer comments and suggestions we have decided to use the term “a decrease in salinity/sudden drop in salinity” after the mid-2010s, instead of using the term “decreasing trend” (Line 138-140). The exact year is not mentioned here since there is a lag between the two regions.

The timing is visually inferred from Figure 2a, as is also referred in the text (Line 138-140).

Line 129: The Svinøy section appears without sufficient context. It is not shown in Figure 1 (the map does not extend south enough), and it is introduced only briefly earlier (Line 110).

Thank you for pointing this out. Figure 1 is redrawn with location of the Svinøy (location (63°N, 3°E) added. More details added. Lines 150-151.

Please add the location of the Svinøy section to a figure and describe it in more detail in the Methods section.

As it stands, the reader lacks the necessary information to understand the results shown in Figure 2.

Thank you for pointing this out. Figure 1 is redrawn with location of the Svinøy section added.

General comment on the page 6: Including a lagged correlation analysis between SBS, NBS, and BS salinity anomalies and the observations at BSO and Svinøy would help quantify differences in connection strength between SBS and NBS. Testing different lag times would also allow comparison with previously reported 2–3-year lags (Lines 37–38) and provide measurable, interpretable metrics.

Yes, we agree. We have performed a lagged correlation analysis as suggested by the reviewer. Line 154-160; 183-188

Line 163: I believe you meant Figure 2a, not 2b. Please check.

Yes, that's correct. Thank you for pointing out the mistake. It is corrected now. Line 183.

Line 170 – The description of SSS acronym appears too late in the text. This reinforces the need for an acronym table introduced early in the manuscript.

All acronyms are defined. In addition, a table (Table 2) listing all acronyms is provided after the conclusions.

Lines 174-178 – Please consider adding a plot showing decadal SSS trends from 1992 to 2024. The variations discussed in Lines 174–175 seem to represent part of a decadal pattern rather than a true trend over a short interval. I also note a distinct freshening event around 2013 in the CCI dataset, which should be addressed.

We thank the reviewer for the comment. We recognize the importance of adding trend analysis to the main text. We have added it. Please note that in this paper we are trying to highlight the pause of the long-term trend due to the freshening event. This is discussed in lines: 129-131.

The distinct freshening event around 2013 may be linked to the extreme sea ice melting. lines: 194-196.

General comment: It would greatly improve clarity to divide the Results into subsections, for example:

- **1 SBS (Lines 113–150)**
- **2 NBS (Lines 157–189)**
- **3 Downstream effects (Line 190 onward)**

This structure would make the narrative easier to follow.

Thanks for the suggestion. Yes, we agree. We have divided the results Section into the above suggested subsections.

Lines 179-183 and Figure 5: In the caption for panel (a), a key word such as “difference” seems to be missing. As written, it is unclear what is being shown:

“Winter mean sea ice drift velocity (difference?) ... between the time periods...”

Panel (b) strongly suggests that the metric is the difference between two periods. Please clarify this explicitly.

We thank the reviewer for pointing this out. We have corrected the figure caption and redrafted the sentence. Lines 228-230

Lines 196-197: The phrasing here is awkward. "In the last ten years ... to unprecedented low levels in the 1993–2024 period" implies that the unprecedented lows span the entire period, which is contradictory.

A clearer alternative would be:

"In the last ten years, however, the decrease in salinity has further reduced density to levels unprecedented within the 1993–2024 record."

We thank the reviewer for pointing this out. The sentence is corrected (Lines 219-220).

Figure 6: The temperature, salinity, and density axis labels are too small to read easily. I recommend enlarging them, as well as increasing the size of the colored circles to improve visibility.

We agree. The figure is now redrawn.

Summary and discussion

Line 217: "... 1980s) during when ..." *during* can be eliminated without losing sense.

Yes, we agree. The sentence is corrected. (Line 242).

Line 219: The expression "move in concert" is too informal for the scientific context. I suggest replacing it with a more formal phrasing such as:

"...temperature and salinity changes were previously in phase."

or

"...temperature and salinity previously co-varied."

Yes, we agree. The sentence is corrected. Line 243.

Line 235: The proposed mechanism requires further justification. Additional discussion of advection pathways or supporting transport estimates would strengthen this argument.

Thank you. The section is redrafted. Lines 239-257.

Line 237: As mentioned earlier, a correlation analysis with a clearly defined lag would substantiate this statement. Without such quantitative support, the conclusion appears speculative.

Yes, we agree. We have performed a lagged correlation analysis as suggested by the reviewer. Line 155-161; 184-188

Line 242: A trends figure is needed to support the discussion and referenced trends. Please include a dedicated figure showing the relevant temporal evolution.

We thank the reviewer for the comment. As an alternative we have added the results of trend analysis. Line 182-183.

Lines 279-281: Is the underlying mechanism already established in Midttun (1985)? If so, please clarify the connection and cite the result explicitly. If not, this needs to be explained more clearly.

Thank you. The section is redrafted. Lines 239-257.

General comment for this section: I missed the metric computation and strict comparison, such as lag time, correlation – to show the difference in connection strength, trends, which are discussed but not presented.

Thank you. We have added lag correlation analysis, and trend analysis.