

**Interactive comment on “Bathymetry and oceanic flow structure at two deep passages crossing the Lomonosov Ridge” by Göran Björk et al.**

Anonymous Referee #1

We thank the reviewer for a thorough reading of our manuscript and many insightful and constructive suggestions for revisions.

**Summary**

Referee #1 finds that the detailed bathymetric survey and collection of CTD casts presented in our paper from the Lomonosov Ridge are scientifically interesting and deserves publication, although first after a major revision. It is specifically the “methods”, “results” and “discussion” sections Referee #1 comments on. We have decided to undertake the revision. Referee #1 provided some specific comments that we will address one by one in our revision (The comments by Referee #1 are written in italics with blue text).

**Methods**

Missing information: *Detailed period of the cruise (days, months), explanation about collection and use of silicate and dissolved oxygen data (maybe coming from discrete water samples and laboratory analyses?)*

This information will be added in our revision.

*Moreover, if you compare your 2014 data with previous ones, especially if the latter are taken 10 years before, you should justify your choice, being aware that the comparison of thermohaline properties taken in period much different can raise some criticisms.*

The choice for our data comparison is simple, it is the only data we possess from this very sparsely investigated area of the Arctic Ocean. We strongly believe that a comparison with the older data collected from previous years is important to show since they overlap spatially and support the notion that our observations not only represent anomalous snapshots. However, we agree with Referee #1 in that it is important to emphasize the time differences between the data sets. We will therefore add some clarifying words in the revised paper, and include more clearly from when over the year all data shown in the paper was collected, and not only at what year.

The following will be included:

*“Additional evidence of water mass transport from the Makarov to the Amundsen Basin at the northern end of the southern gap is found in two zonal sections at 81°N acquired by RV Polarstern expeditions ARK-XI/1 and ARK-XII in 1995 and 1996 respectively. The 1995 section was acquired August 20-27 and the 1996 section August 16-20. They coincide with the northern end of the SWERUS-C3 section and include deep stations in both basins. This implies that they may serve as reference stations representative for each year to exclude inter-annual variability and long-term trends that have been identified in the Arctic (Polyakov et al., 2012)..*

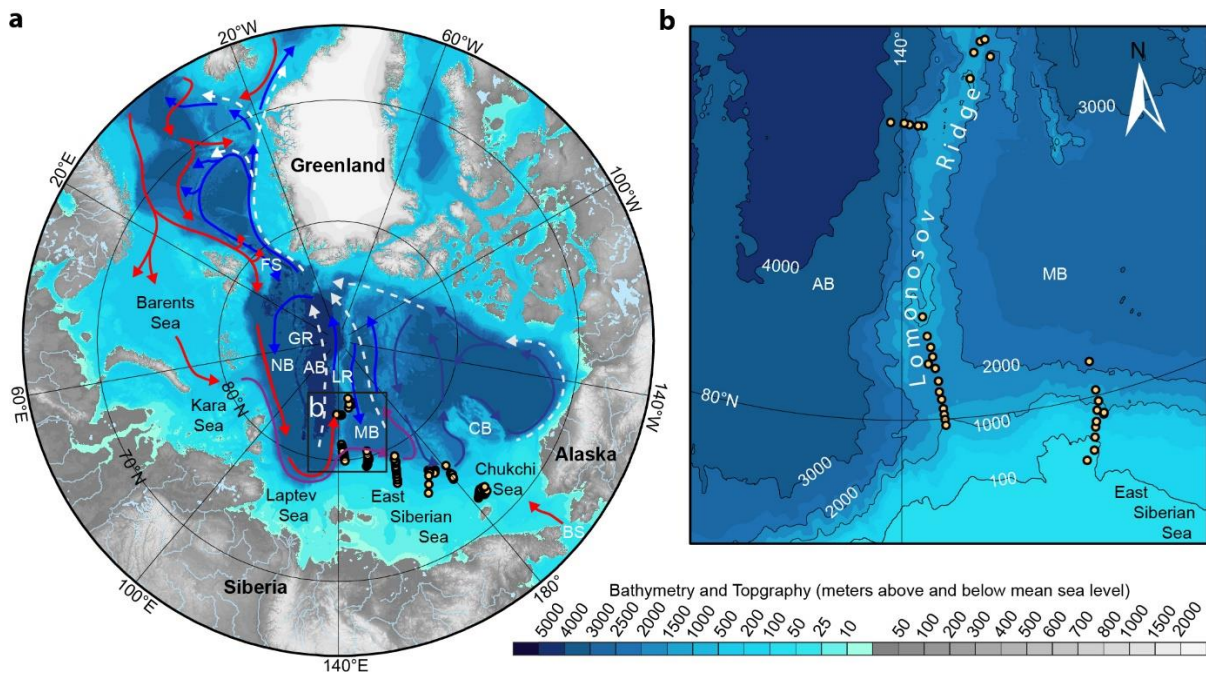
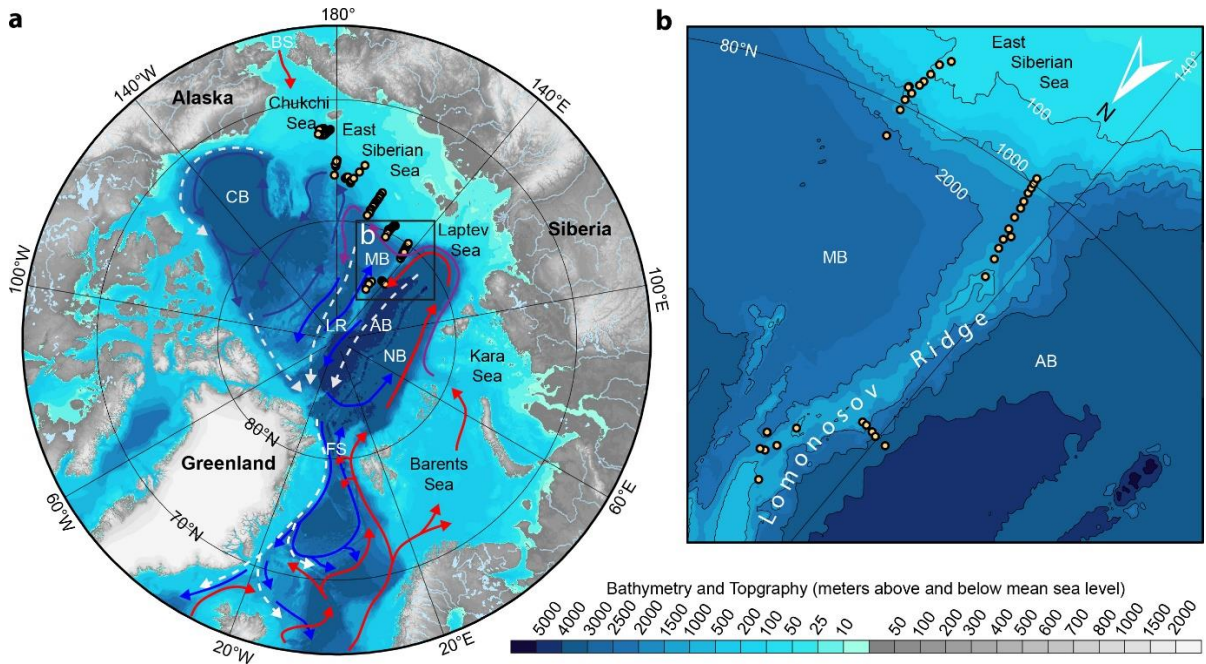
*A minor comment: I suggest the Authors to write somewhere in the methods that they analyze thermohaline properties by using potential temperature, salinity and dissolved oxygen, and define those parameters and their symbols once and for all.*

This will be added as suggested.

## Results

*In section 3.1 the Authors start describing the bathymetry of the region. I had to spend a time to compare figures 1 and 2: I would suggest the Authors to use the same criteria of orientation in panels of figure 2 (a, b) with respect to that in figure 1 (b). It would render easier for the reader to visualize regions and possible pathways of water masses in the study area discussed later within the ms.*

Point taken. We will rotate the main map so 140° is down, implying that it fits with the insets in later figures.



Top: Original map, Bottom: Revised rotated map.

*Page 5: After line 20, Authors describe the hydrological properties. I suggest adding a phrase that could connect the first part of the section 3.1 with its second part.*

We suggest bridging the two sections with:

*“Overall, the new multibeam bathymetry from SWERUS-C3 together with depth information from IBCAO 3.0 provides a spatial context for the north-south hydrographic section across the southern passage (along the ridge crest) close to the Siberian continental slope (Fig. 3).”*

*Line 21: substitute “the section across the passage” with something like “the northsouth hydrological section across the passage. . .”*

This will be inferred in the bridging suggestion above.

*Lines 27-29: Are you speaking about the surface warm core? If so, please move up this phrase within the text, where you are speaking about the surface layer, otherwise it is difficult to follow the description of the thermohaline properties.*

No, this is referring to the Atlantic water, which is subsurface. We have removed “core” in the first sentence to avoid any confusion.

*Lines 31-32: explain why such properties of the bottom layer are “anomalous”. From figure 3, which this part of the text is referred to, the mentioned temperature increase at the very thin bottom layer is not visible. Moreover, cold and salt waters, hence very dense (why you do not add also potential density data?), are normally trapped in the bottom layer of a basin, and lower dissolved oxygen values confirm that they are also pretty old (i.e. not ventilated since a relatively long time).*

Here, “anomalous” simply refers to a slight change in near bottom layer water properties; we will use more clarifying wording. It should be noted that the changes we refer to are also seen in Figure 4, specifically salinity. For this reason, the reader pointed to Figure 4 in this section in addition to Figure 3.

We will also show potential density data. Yes, normally oxygen content reflects age. Here also differences in source waters contribute to the oxygen contrast.

*Line 34: remove double ‘to be’.*

Will be fixed.

*Lines 35-37: please better explain this part and/or support with adequate references (e.g. Chelton et al 1997, JPO). How did you calculate the Rossby radius? Why did you not mention this calculation in the “methods”? Again, did you consider checking satellite images, sea level, or horizontal distribution of potential density to see if any eddies would be visible? It could support the discussion.*

After some further analyze of the special characteristics of station 137 and 138 we have arrived at the conclusion that we probably see some type of interleaving structure between the Barents Sea branch and Fram Strait branch waters which is advected along with the boundary current. We will adjust the text according to this and thus exclude the discussion about eddy and the associated Rossby radius.

*Lines 4-5: remove “matching the salinity and temperature data”. Perhaps, you could discuss the origin of this bottom water masses, and how they accumulated in this part of the ridge, remaining likely isolated from the rest of the water column.*

“Matching the salinity and temp.....” will be removed.

*Lines 6-7: please change this part with “Vertical profiles of  $\theta$  and  $S$  collected in the southern passage of the LR are compared with those collected in the Makarov Basin (Stn. 145 in fig. 2b) and Amundsen Basin (Stn. 148 in fig. ???) and shown in figure 4.”*

This section will be revised for clarity.

*Lines 7-19: this part need to be re-written to render it clearer. I was totally lost reading this part. Please write in more orderly manner about layers, water masses, possible pathways, explain why you chose two reference stations, and so on.*

This section will be revised for clarity.

*Lines 20-36: the same comment as above: re-write this part to be more clear. Authors start introducing silicate data without any previous explanation of them in the “methods”. Additionally, they suddenly refer to mooring data gathered in 1995-1996 but this is not well inserted in the context.*

This section will be revised for clarity and the measurement procedure of silica in water samples will be described in the methods.

*Page 7: Line 2: “upwelling” is a specific oceanographic process, in this case is it driven by what? Maybe Authors mean “upward displacement”*

Yes, it should be upward displacement.

*Line 5: “turbulent diffusion”? ok, but please justify or refer to appropriate bibliography.*

This will be expanded on in a separate sentence with reference included:

*“Using a value of  $5 \cdot 10^5 \text{ m}^2 \text{ s}^{-1}$  for the turbulent diffusion coefficient according to observations at the Lomonosov Ridge (Rainville and Winsor, 2008), it would take about one year to reduce the maximal vertical salinity gradient with 50%.”*

*Lines 8- end of the page: to be re-organized. Again, comparing 2014 thermohaline conditions with those of 1995-1996, after you have written that the variability is large in this region, does not make any sense, unless you justify this approach. Moreover, remove conclusions from this section.*

The approach is now justified and explained with more metadata, as described above.

*Page 8.*

*Lines 1-6: move this part to the “methods”.*

This will be moved to the methods. ”

*Lines 20. . . : the same comment used for the previous page. The description of the thermohaline properties distribution is confusing, and need heavy improvements, in terms of language used and organization of the text.*

This section will be revised for clarity.

*Based on the comments I have provided for the results, I could say that the discussion has to be revised accordingly to the future changes required for the “results”.*

*However, I will provide here some comments: Page 10, Lines 34-35: how do you define the flow “largely barotropic”? Is it reported in literature?*

Yes, the barotropic flow is reported in literature, which we will include in the revised version (Noest and Isachsen, 2003).

*Page 11, line 7: I do not think that “water streaming” is appropriate, please check it.*

Will be changed to “water flowing”.

*Page 11, Line 11: indicate “Gakkel Ridge” in figure 1.*

To be changed in revised figure.

In general, it seems to me that parts of the discussion could be moved to the introduction, while here the Authors should discuss their own data with more detail. Doing so, they could provide some nice conclusions (now they are not clear) on water masses distribution (as they did) and some speculations or hypotheses on the evolution of the thermohaline properties according with previous already published data.

The discussion will be expanded considering the broader implications of our results.

FIGURES: Figure 3: To use different color scales in each layer can be useful to see the variability within each of them, but can confuse the reader because it seems that (e.g.) intermediate and deep layers have different values while they are almost similar with the exception of the very bottom layer. Try to use the same scale in each layer. Figure 4: respect always the same order,  $\theta$  first, S second, Dissolved oxygen third (if you want to show), and then  $\theta/S$  diagram. In general, figure is not clear, all profiles seem bold, and colors between st. 145 and 148 are not clearly distinguishable. Finally, for the exact location of the stations, it is better to refer to figure 2, not figure 1. Figure 5: from this figure, it seems that silicate and dissolved oxygen data comes from discrete water samples. Why the Authors did not described this aspect in the “methods”?

It is actually necessary with different color scales for each depth interval since it otherwise is impossible to see the variability. We will add a note in the figure text to alert the reader about the different scales. We are working on figure 4 in order to make it clearer and will refer to figure 2 for locations. The discrete water sampling data will be included in methods.

**Interactive comment on “Bathymetry and oceanic flow structure at two deep passages crossing the Lomonosov Ridge” by Göran Björk et al.**

Anonymous Referee #2

We thank the reviewer for a thorough reading of our manuscript and many insightful and constructive suggestions for revisions.

**General comments:**

We think that the reviewer points to important general improvements concerning language, clarity and readability of figures, and the benefits of extending discussions on the broader implications of our study; in particular pointing to potential new questions emerging from our work. We will revise the paper based on these overarching suggestions, as will be detailed below.

**Specific comments:**

*P6, Line 11: Could you colour stations 137 and 138 differently so that this statement is clearer on Fig 4? I can just about see what you mean, lower salinities c 500 m, but all profiles being blue it is hard to distinguish from the other profiles for the remaining depths.*

We will introduce different line types for these two stations (solid and dashed lines) to facilitate distinguishing between them.

*P7, line 14 & figures: Please make all multi-panel figures in the paper a,b,c etc. You have done this for some figs but not all. Make consistent across the figures, and also how you label them and the fonts used (some bold with a bracket, some not bold no bracket. . .). You can then refer more easily to the salinity/potential temperature plots in the text.*

We will edit the figures concerning panel labels and fonts as suggested.

*P7, line 27: Any comment on this westernmost station? Makarov water just not reached here or Amundsen signal overwhelming, barrier to W transport/mixing?*

Most likely, the Makarov Basin water in this depth range is deflected along the Ridge bathymetry (in the north-south direction; see Woodgate and Nøst and Isachsen in the reference list) slightly to the east of the westernmost station, where the topography becomes steeper. We will add the following comment in the revised ms.:

“The absence of a Makarov Basin hydrographic signature at the westernmost station indicates that the Makarov Basin waters are deflected along the steep topography on the western side of the Lomonosov Ridge.”

*P9 line 9: Interleaving motions = or could it be a gyre/circulation within the intra basin? Perhaps explain the origin of “interleaving motions” if this is the correct oceanographic term (not my speciality)*

We will rewrite the sentence related to interleaving, providing a reference to Rudels et al. (1999), who in detail review interleaving processes in the Arctic Ocean. The revised sentence reads:

“The profiles suggest that this exchange is not a unidirectional organized flow, but more likely interleaving motions resulting from double-diffusive mixing process, which can create relatively distinct layers with variable flow directions that are intermittent in nature (Rudels et al., 1999).”

*P10, line 25: Label disturbed bottom sediments and transparent lenses on Fig 9*

We will do this.

*P12 line 4-5: I would prefer to see a comment on what kind of data could be used to elucidate the flow exchange rather than a negative comment on the data presented in this study! Otherwise why are we publishing it?*

We will replace the sentence “It is hard to say anything more specific from this type of data.” with “Information on the flow speeds, ideally from moored current meters, would be needed to decide the significance of the cross-ridge exchanges of volume, heat, and salt in this northern passage.”

*P12 line 20-27: The discussion lacks discussion on larger implications of this work plus any comments on unresolved/new questions raised by the study. What is the implication, if any, on seabed temp, for example.*

We will replace the last paragraph in the discussion section with a new one pointing to a few new open research questions (see examples below) which are highlighted by the present study.

1) Our study suggests that the exchange flows across the Lomonosov Ridge have rather different character in the southern and the northern passages. In the southern one, the flow has a more coherent structure, comprised by a few vertical layers with unidirectional velocities. In the northern passage, on the other hand, the flow is broken up into multiple shallow vertical layers with alternating velocity directions. Thus, our results highlight the question of what physical and bathymetrical features that control the nature of the exchange flow through the deep passages cutting across the Lomonosov Ridge.

2) Our survey of the bathymetry and hydrography in the southern passage shows that the detailed saddle bathymetry can have a strong influence on the flow of most dense Makarov Basin waters crossing the LR. Although, our survey does not fully resolve the hydrography and bathymetry over the southern saddle, it indicate that relatively minor topographical features may control if the dense waters reaching the saddle cross over the ridge or return back to the Makarov Basin.

**Technical corrections:**

We appreciate these detailed comments. We will go through the manuscript and address all suggested technical corrections.