Response to RC 1

Thank you for your prompt review of our manuscript.

The paper by Devendra et al. "Postglacial environmental changes in the northwestern Barents Sea caused by meltwater outbursts " attempts to reconstruct the paleoenvironment and the depositional regime from a single core from the trough Kveithola which is located at the western Barents Sea shelf and dates back to about 14.5 ka. To do so they employ quite a number of different proxy data. These include studies in micropalaeontology (benthic and planktonic foraminiferal assemblages and their O-isotopic composition), sedimentology (grain size fractions), geochemistry (XRF), and a suite of biomarker tools. They use all of these data to focus on 3 events, which they identify to be meltwater-triggered, and then, eventually, compare/relate the youngest of those to overregional changes far away.

While the paper is well written, its main focus, namely reconstructing meltwater outbursts during the first ~5ky of the Holocene from these proxies, is fundamentally flawed and therefore not acceptable for publication. The main question, apart from a solid age framework (see below), is to what extent the different proxies add up and can provide a consistently coherent story that also delivers some concrete information on the actual causes of their meltwater events? Instead the authors remain rather vague on this issue, naming all sorts of processes, from far-distance palaeolake drainage of the Baltic basin to tsunami-triggered currents by the Storegga slide to sediment-laden meltwater plumes....

We find the reviewer's comments constructive and helpful, though we kindly disagree that the work is "fundamentally flawed". We are confident in the robustness of the approach and methodology we applied in this study. The interpretations are based on a comprehensive multiproxy analysis, and the conclusions drawn are well-supported by all the presented data. We think the evidence presented in the manuscript warrants our findings and assists in understanding meltwater outbursts during the discussed periods.

One of the main aims was to reconstruct past environmental changes in the NW Barents Sea with an emphasis on meltwater pulses (MPs) during the postglacial period. Reconstructing such events, especially from a single core, obviously poses challenges on its own. Nonetheless, the multidisciplinary nature of our study which includes micropalaeontology, sedimentology, geochemistry, and biomarkers provides a firm ground for interpreting these past events.

*Although each proxy may have its limitations, the strength of our study lies in integrating these different proxy data. By integrating the evidence of different proxies, we recovered a general picture of the paleoenvironmental events and depositional mechanisms in our study area. **This is discussed extensively in the original manuscript** (Lines: 364-368, 477-484, and 516-520), where we integrated our results and compared them with the existing findings to increase the clarity and robustness of our conclusions.*

We understand that the interpretation of the possible causes of meltwater pulses can be complicated. However, in this analysis, we have carefully thought about multiple potential processes. The identification and interpretation of these meltwater events are supported by a combination of different proxies (geochemical and sedimentological), which indicate

substantial inputs of freshwater and sediment during the periods in discussion. Lines: 301-306, 358-364, 392-394, 472-474, 503-505 etc..)

We have proposed that these meltwater pulses could be related to various processes; including regional glacial/sea ice melting, paleolake drainage, and even tsunami-triggered currents. Although it may sound broad, it reflects the complexity of interpreting paleoenvironmental signals in such a dynamic setting. Given the possibility that any of these processes may have been responsible for the observed changes, we aimed to present a range of possibilities rather than oversimplify the interpretation. We are convinced this is an advantage of the presented manuscript, not its disadvantage.

The question the reviewer posed, regarding whether the proxies tell a consistently coherent story. We understand the importance of ensuring that all proxies have to be coherent. In our study, we have carefully examined the data in each proxy to ensure that the data in the various proxies is consistent with one another.

For instance, the biomarker records, benthic foraminiferal assemblages, and their isotopic composition offer independent lines of evidence that indicate changes in water mass properties and meltwater input. The absence of planktic foraminifera during these meltwater intervals confirms our interpretation of sediment-laden meltwater influx. The geochemical data, including XRF measurements, are consistent with this occurrence of meltwater events as indicated by changing elemental compositions associated with significant terrigenous influxes around the meltwater events. All these results agree with the sedimentological data, which suggests a grain size distribution shift consistent with meltwater inputs and associated sediment-laden plumes. Since a major portion of our discussion covers this topic, we have not provided specific line numbers as references in this instance.

Age model and associated problems: The 142cm long core has 10 radiocarbon dates, the lowermost 2 being of similar age. Unfortunately for the interpretation there are also 2 reversals, the lower one covers a huge age range (~4ky), and with 50cm amounts to more than 1/3 of the entire core length. And still, all proxy data from this section are being interpreted, including the YD interval and their MP1.

We built the age-depth model here by using Bayesian statistics with the Bacon package in R (Blaauw and Christen, 2011). Bayesian statistics uses more sophisticated approaches, including constraining the accumulation rates and their variability, hence allowing the detection of "shift outliers" in the radiocarbon data. All this is to ensure that an age-depth model is robust and reliable.

We compared our multi-proxy records from the undated section (dotted area in Fig. 1; including YD and MP1) with the proxy records from nearby (~45 km to east) sediment core JM09-KA11-GC (using a new age model based on the Marine20 dataset). The trends in the multi-proxy records are consistent between the cores. This alignment provides support for our age model, especially in the section where direct dating is unavailable. We will include this comparison figure in the revised manuscript and provide a discussion on this as needed.

We believe the proxy data from this section provide valuable insights. We interpreted the YD interval and MP1 with careful consideration of the age model uncertainties. In particular, we cross-referenced our findings with existing regional records to ensure consistency in the broader context of paleoenvironmental changes. For instance, the timing of this MP1

compares well with the final retreat of the glaciers over the Svalbard and Barents Sea (Svendsen et al., 1996; Hughes et al., 2016), which could release meltwater to the Barents Sea (lines 482-483). Our interpretation is made with an understanding of the potential limitations and is framed within a range of possible scenarios.
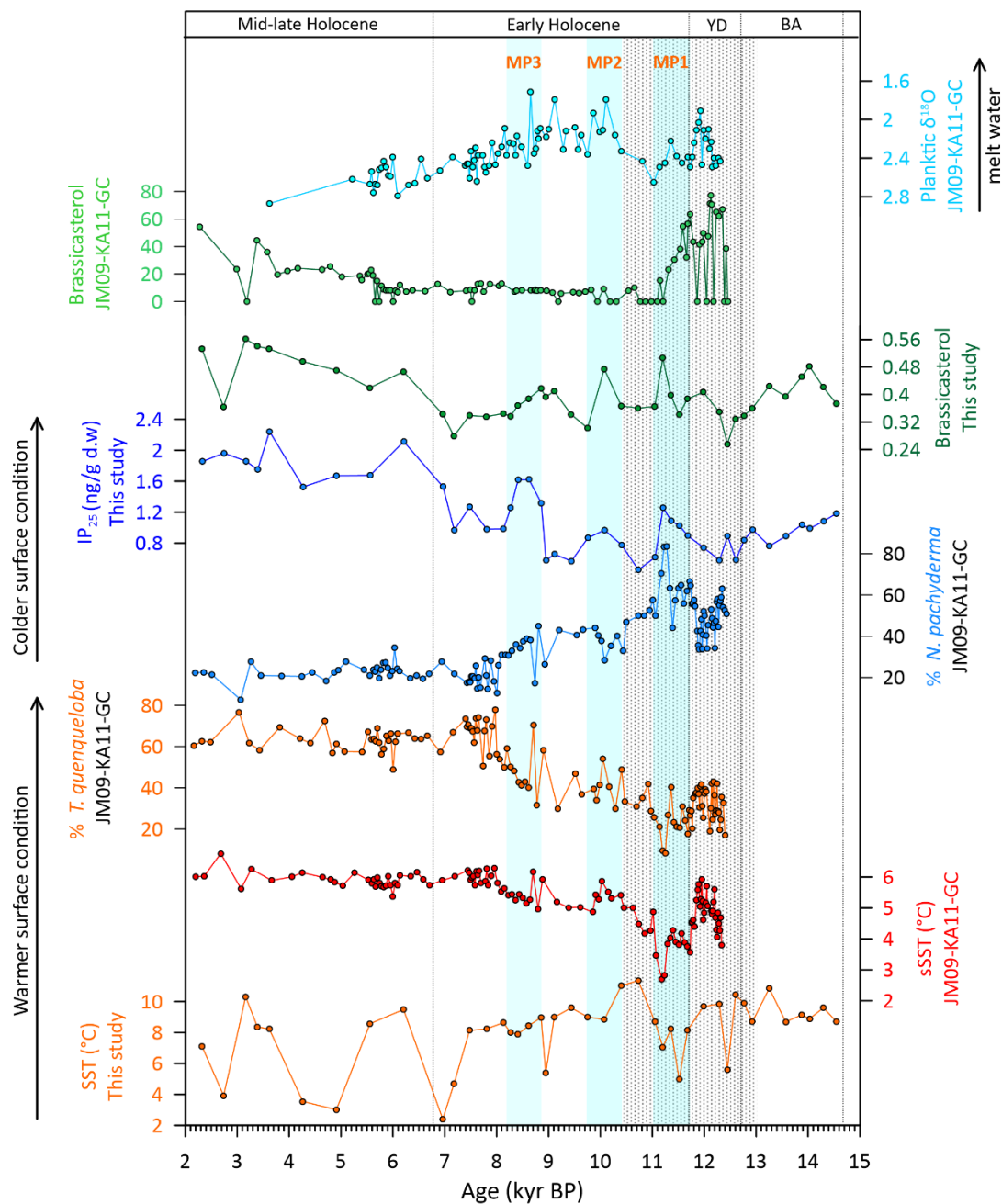

Fig. 1. Comparison between proxies selected from this study and proxy records from sediment cores JM09-KA11-GC (Berben et al., 2014). Blue shadings indicate meltwater pulses.The dotted area indicates the section where direct dating is unavailable. Abbreviations: BA - Bølling-Allerød; YD - Younger Dryas.

The second reversal at depth 53cm is interesting, because of its very old radiocarbon age which deviates from the dates below and above by about 15ky. It indicates that the bulk of forams measured were mostly very old, perhaps 30-40ka, and an admixture of just a few much younger ones caused the final age.

Our data indicate a supply of older sediments from the upper part of Kveithola, which is confirmed by data from nearby core JM09-KA11-GC (Rüther et al., 2012; Groot et al., 2014; Berben et al., 2014).

The crucial thing here is that depth 53 cm is in dead center in their MP3 (around their 8.2ka event), meaning whatever the cause, there was plenty of reworking and delivery of older sediments to the site, including all the fine TOC-rich sediments that would contain their biomarker proxies. The section of MP3 between the 2 acceptable dates is 20 cm long, telling us, together with the first reversal, that half of the 142cm long core (70cm) essentially remained undated. Moreover, the XRF-data (Fig. 4) across MP3 seems to imply that a larger sediment section was affected than indicated by the blueish bar.

The dates used for constructing the age model around the reversal at 53 cm, specifically from 39 cm and 61 cm depths, firmly support our discussion and data interpretation. The meltwater signal, consistently indicated by all proxies, shows that the meltwater events (MP3) in the western Barents Sea occurred before the sediment reworking caused by the Storegga tsunami-induced currents. Therefore, the interpretation of this meltwater signal starting from 8.8 kyr BP is based on biomarkers and corroborated by other proxies, remains robust and well-founded.

Table 1. AMS ^{14}C dates and calibrated radiocarbon ages of JM09-KA11-GC. The calibration is based on the Marine13 calibration curve (Reimer et al., 2013) and a regional ΔR of 67 ± 34. The dates which are not used in the final depth–age model are indicated in italics.

Lab ID	Core depth	Material	^{14}C yr BP (uncorrected)	1σ	cal yr BP	2-σ range	Reference
Tra-1063	4.5 cm	Mollusc dextral part of *Bathyarca glacialis*	925	30	476	397–555	Rüther et al. (2012)
Tra-1064	*4.5 cm*	*Mollusc dextral part of Bathyarca glacialis*	*900*	*35*	*445*	*354–535*	*Rüther et al. (2012)*
Tra-1065	16.0 cm	Mollusc sinistral part of *Bathyarca glacialis*	1880	35	1377	1268–1485	Rüther et al. (2012)
Beta-324049	27.5 cm	Benthic foraminifera *Islandiella norcrossi/helenae*	4820	30	5027	4856–5197	This study
Tra-1066	*33.0 cm*	*Mollusc dextral part of Astarte elliptica*	*1990*	*35*	*1469*	*1347–1590*	*Rüther et al. (2012)*
Beta-315192	40.0 cm	Benthic foraminifera *Islandiella norcrossi/helenae*	5870	30	6211	6108–6313	This study
Beta-315193	44.5 cm	Benthic foraminifer*a Islandiella norcrossi/helenae*	6890	40	7339	7241–7436	This study
Tra-1067	55.0 cm	Mollusc sinistral part of *Astarte sulcata*	7630	45	8038	7919–8154	Rüther et al. (2012)
Beta-315194	80.5 cm	Benthic foraminifera *Islandiella norcrossi/helenae*	9140	40	9790	9573–10 006	This study
Tra-1068	*82.5 cm*	*Mollusc paired shell of Astarte elliptica*	*8140*	*50*	*8541*	*8387–8695*	*Rüther et al. (2012)*
Tra-1069	*82.5 cm*	*Mollusc sinistral part of Nuculana minuta*	*8315*	*50*	*8780*	*8595–8965*	*Rüther et al. (2012)*
Beta-315195	*111.0 cm*	*Benthic foraminifera Elphidium excavatum*	*10 900*	*50*	*12 309*	*12 072–12 546*	*This study*
Tra-1070	134.5 cm	Mollusc paired shell of *Yoldiella intermedia*	10 705	55	11 993	11 668–12 318	Rüther et al. (2012)

Radiocarbon dating from the core JM09-KA11-GC (Berben et al., 2014) also observed age reversal between ~8.1 and 8.6 kyr BP (Table. 1; from Berben et al., (2014)) which is compatible with our findings. Moreover, Rüther et al., (2012) observed the occurrence of mud chips in the sands during this interval, indicating a relatively strong impact, and suggested that the submarine Storegga slide and subsequent tsunami might be the cause. We have discussed this with our findings in the manuscript (Lines: 533-534). Given these similarities, we are confident that our age model is robust and well-supported by independent studies in the region. However, we plan to conduct additional dating between 7.9 and 8.4 kyr BP (between 39 and 61 cm) to better determine the thickness of the redeposited layer associated with the tsunami currents.

In conclusion, We do not agree with the reviewer's assessment regarding our age model. We used the best possible age model for this study. We have made a careful effort to develop an accurate chronology for the core based on radiocarbon dating by the Bayesian age model. This approach has allowed us to integrate multiple radiocarbon dates, account for potential outliers, and reduce the overall uncertainties in the age model. The Bayesian model has reduced error and created a more robust age-depth relationship.

Speaking of the biomarkers, in the polar ocean elevated tetra-unsaturated alkenones (Uk37:4) are traditionally indicative for freshened waters and admixture of sediments which both could be derived from ice rafting. However, what is very critical using these samples with high 37:4 to be cautious when calculating SSTs from the 37:2 and 37:3. Indeed, the SSTs do not provide any consistency for huge temperature drops as claimed by the authors.

The explanation given by the reviewer on $C_{37:4}$ coincides precisely with what we have presented and interpreted (with caution) in our manuscript (lines 288-289, 455-457). The comparison of the SST record with the nearby core shows very similar temperature variations, even though the two studies used different methods to derive SSTs. This consistency, particularly during the MPs (Fig. 1) strongly supports our data and interpretations. We will discuss this in our revised manuscript.

It is necessary to emphasize that our SST reconstructions are based on a careful analysis of the full suite of alkenones, including $C_{37:2}$, $C_{37:3}$, and $C_{37:4}$, with an understanding of the complex interactions in polar environments. Moreover, for the SST calculations, we used different U^{K}_{37} indexes and different calibration equations. Finally, we used the $U^{K'}_{37}$ index, which is calculated as $U^{K'}_{37} = [C_{37:2}]/([C_{37:2}] + [C_{37:3}] + [C_{37:4}]$ (Bendle and Rosell-Melé, 2004). To obtain temperature values, we applied the equation developed by Müller et al. (1998) which provided the most realistic temperature estimates for our dataset.

*We did not claim a **huge** temperature drop during the meltwater pulses or elsewhere in the discussion. Our SST reconstructions do not display significant cooling during the MPs, most importantly during the MP2 and MP3. However, these two pulses occurred in the warmer Holocene conditions and thus the observed drop of SSTs still upholds the story of meltwater discharge. Hence, the variability that was displayed in our SST records is in line with the impacts that could have been subjected to meltwater pulses, ice rafting, and other deglacial activities. Moreover, the SSTs we report are corroborated by other proxies (IP$_{25}$, Atlantic Water indicator proxies… etc.), ensuring that our interpretations are not based on alkenone data alone but on a holistic view of the paleoenvironmental conditions. These issues are discussed extensively in our manuscript, lines: 359-362, 375-387, 395-400, 467-470.*

Foraminifers: The authors claim that the entire core is dominated by planktonics...but my pdf only shows their occurrence after 8ka – incomplete because something wrong with Fig.4? The Barents Sea is known to be prone to massive calcite dissolution and I wonder of the authors noted some drastic changes throughout the core.

We respectfully disagree with the reviewer's comment. We did not claim that planktic foraminifera dominate the entire core! On the contrary, we stated that planktic foraminifera are present in very low abundances throughout the record. The planktic foraminifera assemblages are dominated by three species (Figure 4), the polar species Neogloboquadrina pachyderma, and the subpolar species Turborotalita quinqueloba and Neogloboquadrina incompta as described in lines 130–133 and 258–260 of our manuscript. These species are spread only within the upper ~45 cm of the core. The individual count was quite low before the 45 cm (before 7.9 kyr BP, with about 10-15 individuals per sample) except for the layers between 77 and 85 cm (between 10.2-10.8 kyr BP). Therefore we excluded these samples with fewer than 15 individuals from the calculation. This exclusion has been explained in the manuscript (Lines 130-133).

The foraminiferal-barren layers were detected in the core (emphasized in all figures), which means neither planktic nor benthic foraminifera were discovered here. This barren layer was mentioned in the text (lines: 251, 340-345), and we discussed its implications in the context of environmental conditions such as an anoxic bottom environment, which is indeed a known phenomenon in the Barents Sea region e.g., (Lacka et al., 2020). The occurrence of this barren layer further supports our interpretation of the challenges associated with foraminiferal preservation in this area.

Regarding the visibility of planktonic foraminifera in Figure 4, we would like to clarify that planktonic foraminifera is absent before ~7.9 kyr BP (below ~45 cm; except layers between). Therefore, we keep a dotted background for the area of planktic foraminifera absent.

The oxygen stable isotopes measured on the foraminifers appear very inconclusive with no proper trends over the entire core; the planktonic are only based on 15 samples and measure after MP3. The benthics vary over a 1 permil range and show no relation to any of the 3 MPs in terms of O-depletions. This is somewhat surprising considering that the authors also talk about sediment-laden plumes associated with these meltwater events.

The analyses of stable isotopes in the planktonic foraminifera were conducted only in the layers where these foraminifera were present. Since we do not use the planktic $\delta^{18}O$ results for our interpretation (except line 426, which will be revised in the revised manuscript), we decided to remove the planktic $\delta^{18}O$ curve from Fig. 4. This change does not impact our interpretations of the MPs and the conclusions we made.

The benthic oxygen isotope values vary over a range of approximately 1‰, and in our opinion, this variability is expected in the context of the complex sedimentary and oceanographic processes in the region. In our opinion, it is seen in Fig. 4, especially in MP3 and MP2. The weak relationship between benthic isotopic depletion and all the meltwater pulses (MPs) on the surface reflects the interplay of multiple factors, including varying sources of meltwater, changes in water mass properties, and the dynamic sedimentary environment. Isotopic signals can be influenced by multiple factors masking the direct impact of meltwater events, particularly in records with lower temporal resolution.

Sedimentology: I am puzzled about the use of grain sizes. In Fig. 4 the Coarse Fraction (>63µm), which to my mind is representative of the sand size fraction, does not exceed 5-7%. In Suppl-Fig, there is a completely different "sand" curve shown…

Yes, we agree with the reviewer. The discrepancy between the coarse fraction (>63µm) in Figure 4 and the "sand" curve in the supplementary figure is due to incorrect scales used. We apologize for this oversight and acknowledge that it has led to some confusion. The correct representation of the sand-sized fraction will be included in the revised Figures. However, we would like to point out that this correction does in no way alter the interpretations or conclusions of this study.

Concerning the figures in general there were no plots that would give the reader a better insight and understanding of the main proxies vs. depth (not even in the suppl.). Instead the authors provide all figures vs. the final age model with a rather obscure floating depth scale below.

We respectfully disagree with the reviewer. In our manuscript, in order to provide a better understanding to the readers, we present the data against the final age model to emphasize the temporal relationships of the proxies and to integrate our findings with broader paleoenvironmental records. This approach allows for a more convincing interpretation of the timing of events and their relevance to the regional and global context.

However, the "floating depth scale" in centimeters presented in Fig.3 and Fig.4 as the "depth" has been renamed to "sediment layers". We hope this change clears up any confusion.

In summary, *we respectfully disagree with the argument that our study is fundamentally flawed. Combining multiple proxies, we present a coherent story of postglacial environmental change in the western Barents Sea. We have provided interpretations that are well-constrained by data and careful analysis. All presented proxies thus clearly enhance our story regarding meltwater outbursts.*

Reference

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