Reviewer's comments

Reviewer #1

This paper is well-written and structured. It presents a novel dataset from three multicores along a transect in Kongsfjorden (Svalbard) and provides relative contributions of organic matter sources. To qualify the organic matter, the paper uses bulk parameters (carbon and nitrogen) and lignin phenols. The relative age of the cores is constructed using 210Pb geochronology. I highly enjoyed reading the manuscript and the ideas were easy to follow. The introduction clearly laid out the importance of this study and the methods were succinct and well described. I would have enjoyed a slightly more detailed discussion in section 4.5 about increase surface runoff and impacts on the fjord. The paper suggests important influence from river discharge at the middle site, but does not support/compare with the existing literature on terrestrial OM inputs. Here are some key points that I would like clarification on, followed by minor changes.

Reply: We sincerely thank Reviewer #1 for the thoughtful and constructive feedback. We are pleased to hear that the manuscript was found to be well-structured, with clearly presented ideas and a novel and informative dataset. The comments provided are invaluable in helping us improve the overall clarity and depth of the manuscript. We will carefully address all points raised in a detailed, point-by-point format below. In particular, as suggested, we will expand Section 4.5 to include a more comprehensive discussion of increasing surface runoff and its implications for the fjord system. This will involve a broader comparison with existing literature on terrestrial organic carbon (OC) inputs, especially concerning the riverine influence observed at the middle core site. These additions will aim to strengthen the interpretation of our findings and place them within a broader environmental and climatic context. All changes to the manuscript will be clearly marked and referenced in our responses below.

Main recommendations

- Clarifying how this manuscript builds on from the published work in Kim et al., (2023)

This paper builds on finding from previously published work by the authors (Kim et al., 2023). Due to the similarities in analysis and research location – the present study would benefit from presenting how it builds on the previous findings. I would recommend adding 1-2 sentences in the introduction to present the findings of Kim et al., 2023 and specify how this new manuscript differs and expands from the previous work.

Reply: In the revised manuscript, we will add 1–2 sentences to the Introduction to summarize the key findings of Kim et al. (2023), which examined the sources and characteristics of surface sedimentary organic matter across eight fjords in Svalbard, including Kongsfjorden. That study focused on the spatial distribution of recent OC dynamics based on surface sediments. In contrast, the present study builds upon those findings by analyzing multiple sediment cores along a transect in Kongsfjorden, providing a higher-resolution reconstruction of temporal changes in OC sources and burial over the past centuries. This expanded spatial and temporal framework allows for a more comprehensive understanding of long-term carbon cycling in the context of ongoing climate change.

- Extrapolating N_{org} from N_{tot}

I recommend that the authors further justify extrapolating N_{org} from N_{tot}. How precise is this correlation? The authors describe different sources of OM in the fjord system. Wouldn't these different sources also differ in partition of N? I think it is misleading to present both N_{org} and N_{tot} since N_{org} is just offset by a correction factor (as I understood it). I think this part in the paper deserved a bit more explanation. Also, couldn't the age of the sediment affect the partitioning of N (i.e. is using a correction factor from surface sediment accurate)?

Reply: In the revised manuscript, we will clarify in the Methods section that N_{org} was estimated by using the slope and intercept derived from the correlation between N_{org} and N_{tot}, based on a representative subset of samples. This approach assumes that most N_{inorg} is associated with ammonium-bearing clay minerals, which typically exhibit low variability in similar depositional environments. While we recognize that different organic matter sources may vary in nitrogen content, our dataset shows minimal variation in N_{inorg} across the major sedimentary intervals, supporting the application of a consistent correction factor. We also clarify that N_{org} was used primarily to calculate molar C/N ratios and to complement TOC trends, rather than being interpreted independently. Regarding the potential influence of sediment age and early diagenesis on nitrogen partitioning, we agree this is an important consideration. However, our correction is derived from measurements across multiple depths, not just from surface sediments, which we believe provides a reasonable basis for assessing long-term patterns in N_{org}. These clarifications will be incorporated into the revised manuscript to better justify our approach and address potential limitations.

- Describing the study sites in greater detail

I believe section 2.1 could be made into its own section 2 and methods could be section 3. Would it be possible to showcase the biogeochemistry of Kongsfjorden in more details here? Otherwise, Krossfjorden is discussed quite heavily in the discussion. The study site section would benefit from having 2-3 more sentences describing how Kongsfjorden and Krossfjorden are similar/different.

Reply: In the revised manuscript, we will follow Reviewer #1's suggestion and present the original Section 2.1 as a standalone Section 2, with the Materials and Methods moved to Section 3. We will expand the regional setting section to include a more detailed description of both Kongsfjorden and Krossfjorden. In particular, we will add 2–3 sentences highlighting the key similarities and differences between the two fjords, as these are important for contextualizing our findings. These additions aim to provide a stronger foundation for interpreting the results within a broader regional and environmental framework.

- Discussing the historical/spatial dynamics

Section 4.5 begins to explore the potential OM dynamics at the middle site in a historical context. I think this section would benefit from being expanded a bit. This is the main objective of the manuscript. Why is the middle core seeing the largest changes in OM source. If it because it is more influenced by surface runoff, and therefore glacier dynamics, then perhaps citing

sources of increase river discharge is more relevant than just temperature changes. The argument could be made more convincingly while citing the existing literature. Also, a comment on which change is more significant in Kongfjorden (more surface runoff or Atlantification? Or both and why?) would make a more impactful conclusion. The manuscript only mentions greater terrestrial input and then focuses on Atlantification.

Reply: In the revised manuscript, we will expand Section 4.5 to further develop the interpretation of OC dynamics at the middle fjord site, with particular focus on its sensitivity to recent environmental changes. We will provide a more detailed explanation of why this site exhibits the most pronounced shifts in OC sources, highlighting its proximity to riverine inputs and greater exposure to surface runoff associated with glacial melt. To support this interpretation, we will cite recent studies (e.g., Skogseth et al., 2020; McGovern et al., 2022) that document increasing freshwater discharge and seasonal runoff in response to glacier retreat in Svalbard fjords. Additionally, we will clarify the relative roles of surface runoff and Atlantification in influencing OC inputs, noting that while both processes are important, their impacts may vary spatially and temporally across the fjord system. This expanded discussion will strengthen the overall conclusions and provide a more integrated perspective on the physical and biogeochemical changes shaping the Kongsfjorden environment.

Minor recommendations

Abstract: Perhaps omit the use of acronyms in the abstract for ease of read.

Reply: To improve readability, we will write out full terms upon their first mention in the abstract and use acronyms thereafter. Given the strict word limit, we will aim to balance clarity and conciseness by minimizing acronym use where possible, while still adhering to formatting and length constraints.

Lines 32-34: Please elaborate on this positive feedback loop. How would a greater contribution of AW further amplify AW inflow in fjordal system?

Reply: We suggest that enhanced inflow of Atlantic Water (AW) leads to ocean warming and sea-ice reduction, which in turn weakens the density gradient between shelf and fjord waters. This diminished hydrographic barrier facilitates deeper and more sustained AW intrusion into the fjord. Additionally, reduced sea-ice cover and warmer subsurface conditions promote increased submarine melting of marine-terminating glaciers, contributing to higher freshwater discharge and enhanced water column stratification. The resulting stratification can further stabilize the water column, suppress vertical mixing, and allow AW to persist longer within the fjord system. These interlinked processes create a positive feedback loop, whereby initial AW intrusion enhances conditions that promote further AW penetration and influence. This dynamic has been documented in previous studies, such as Skogseth et al. (2020) and Årthun et al. (2012). We elaborated this aspect in the revised manuscript.

Introduction: Since the scope of study is similar to Kim et al 2023 – perhaps define in the introduction how the present study builds on the previous paper.

Reply: In the revised introduction, we will clearly define how the present study builds on the findings of Kim et al. (2023). While the previous study provided a pan-Svalbard synthesis based on surface sediments from eight fjords to assess spatial variability in recent OC cycling, the current study focuses specifically on Kongsfjorden and employs a high-resolution sediment core approach to reconstruct changes in OC sources over the past several centuries. This temporal perspective allows for a more detailed investigation of the fjord's sedimentary response to recent Atlantification. By combining bulk geochemistry, lignin biomarkers, and radiocarbon signatures, this study provides deeper insight into the mechanisms driving carbon cycle shifts in one of the most extensively studied Arctic fjord systems.

Lines 52-53: "While modern observations have clear limitations in providing long-term datasets" – perhaps reword "datasets" to make this statement more meaningful (i.e. of course modern data isn't old data…)

Reply: In the revised text, we will reword "datasets" as "records" to clarify that modern observational records are limited in their ability to capture long-term historical trends and environmental variability.

Line 57: Change "high-Arctic Svalbard archipelago" to High Arctic Svalbard archipelago

Reply: As suggested, we will revise the phrase to "high Arctic Svalbard archipelago" in the revised manuscript.

Methods: I would recommend adding a sentence at the beginning of each subsection to establish why these analyses were undertaken. This way, readers without prior knowledge of certain methods can understand why certain analyses were done. (i.e. to understand the source of carbon in the fjordal system, we…). Please also describe the indices used in for phenol composition analysis (S/V, C/V and 3,5-Bd/V, (Ad/Al)v).

Reply: As suggested, we will add brief introductory sentences at the beginning of each Methods subsection to clarify the objective of each analytical approach and help guide readers who may be unfamiliar with the techniques. Additionally, we will include descriptions of the lignin phenol indices (S/V, C/V, 3,5-Bd/V, and (Ad/Al)v) in the revised manuscript to ensure their interpretation is clear.

Line 100: AW acronym has already been defined.

Reply: As suggested, we will remove the repeated definition of the AW acronym to avoid

redundancy.

Lines 107-109: Perhaps the types of terrestrial inputs to Kongfjorden could be expanded a bit.

Reply: As suggested, we will expand the description of terrestrial OC sources delivered to Kongsfjorden. Specifically, glacial runoff contributes large volumes of sediment to the seabed, forming turbid plumes that reduce light penetration and suppress primary productivity, particularly in areas close to glacier termini (Ito and Kudoh, 1997; Svendsen et al., 2002). In addition to sediment, glacial runoff transports a variety of terrestrial OC, including petrogenic and soil-derived OC. These additions will be incorporated into the revised discussion to provide a more comprehensive overview of terrestrial inputs into the fjord system.

Line 128: Define KOPRI for readers that are not aware of this facility.

Reply: As suggested, we will define the acronym KOPRI (Korea Polar Research Institute) upon its first mention in the revised manuscript to ensure clarity for all readers.

Line 139: samples were heated to what temperature?

Reply: As suggested, we will include the temperature information in the revised manuscript to enhance clarity.

Line 150: Define HPGe and KBSI.

Reply: As suggested, we will define the acronym HPGe (High-Purity Germanium) upon its first mention in the revised manuscript to ensure clarity for the reader.

Line 173: Replace “carbon isotopes” with “$\delta^{13}C_{org}$” for uniformity

Reply: As suggested, we will revise the terminology in Line 173 to use “$\delta^{13}C_{org}$” for consistency and clarity throughout the manuscript.

Results: Why was the radioisotope analysis not performed at the inner site? This needs to be addressed somewhere in the manuscript.

Reply: As suggested, we will add a statement to the results section, explaining that the inner fjord multicore was excluded from ^{210}Pb dating due to the high sedimentation rates and intense

sediment mixing typically observed near glacier fronts. These conditions are known to limit the applicability of radioisotopic dating by disturbing sedimentary stratigraphy and reducing the resolution of age-depth models (e.g., López et al., 2020; Schirone et al., 2022).

Lines 227-230: What about the inner site? Also, where is the sedimentation rate reported by Zaborska in relation to the present study?

Reply: The sediment core analyzed by Zaborska et al. (2006) was collected in 2000 from a site in the inner part of Kongsfjorden, geographically close to our HH23-1058MUC core. In their study, a sedimentation rate of approximately 0.15 cm/yr was determined using ^{210}Pb dating. While this provides useful context for sedimentation conditions in the inner fjord, we did not perform ^{210}Pb dating on HH23-1058MUC due to extensive sediment mixing, which prevented the development of a reliable age model, as noted above. We will clarify this point in the revised manuscript.

Line 243: Please state what is the significant correlation between N_{tot} and N_{org} derived from previous studies. (see comment in main recommendations)

Reply: As suggested, we will mention that a previous study (Kim et al., 2023) reports a strong linear correlation ($R^2 = 0.89$) between N_{tot} and N_{org} in surface sediments of Svalbard fjords, which supports the use of N_{tot}-based corrections for estimating organic nitrogen content.

Discussion:

Lines 392-394: "The poor sorting observed across all morphological zones highlights fluctuating energy conditions during deposition, likely driven by episodic glacial advances and retreats. These variations suggest that the prevailing climatic conditions in Kongsfjorden were neither stable nor persistent over extended periods" – I am not sure that this conclusion can be drawn from the lack of correlation between TOC and grain-size and poor-sorting. The present study doesn't link specific advance/retreat events to sedimentary behaviour – so I would avoid overinterpretation and just state that poor sorting and lack of correlation between grain-size and TOC are indicative of a glacier-fed system.

Reply: As suggested, we will revise the statement to avoid overinterpretation. We will simply note that the poor sorting and lack of correlation between grain size and TOC are indicative of a glacier-fed system, without attributing these characteristics to specific glacial advance or retreat events.

Lines 492-499: This section could be developed further. Why do the river systems deliver soil-derived OM to the middle site more than the inner site? If this is due to surface runoff – then a map indicating where the river systems are in Kongfjorden would be highly relevant. There is

also a large body of literature on the biogeochemical signature of surface runoff in Kongsfjorden. Perhaps it would be interesting to compare to some of these studies?

Reply: As noted, the main river systems delivering soil-derived OC to Kongsfjorden are located closer to the middle fjord area, rather than the inner site. In the revised manuscript, we will enhance the map in Figure 1 to more clearly show the locations of these river inflows and their proximity to the middle core site. Additionally, we will consider referencing relevant studies on the biogeochemical signature of surface runoff in Kongsfjorden to provide further context.

Lines 502-517: These equations could be placed in the methods section. The discussion loses a bit of momentum when you have to read through how the AR were calculated.

Reply: As suggested, we will move this section to the Methods section to maintain the flow of the discussion.

Figures:

Figure 1: It would be nice to show the elements discussed in section 2.1 on this map. Adding a third panel with labels of the different glaciers and river systems could be helpful to readers that don't have prior knowledge of Kongsfjorden.

Reply: As suggested, we will enhance Figure 1 by adding a third panel that labels the major glaciers and river systems in Kongsfjorden in the revised version.

Figure 2: Change "Water contents (%)" to "Water content (%)" both in caption and in axis title.

Reply: As suggested, we will change the term.

Figure 3: The figure caption states 3 sites (A-C) – but only two are presented (A-B). Please explain in text why inner site is not present here. Add a note in the figure caption to explain the different symbols used in the slopes in the Pb_{ex} panels.

Reply: We thank the reviewer for pointing out this error. We will correct the Figure 3 caption to accurately reflect that only two sites (A and B) are shown. Additionally, we have added a clarification regarding the different slope symbols in the Pb_{ex} panels.

Figure 6: Having a color key, instead of textual annotations, would make the EM identification easier at first glance.

Reply: In the revised figure, we will add a color key to represent each end member (EM), enhancing visual clarity and making EM identification more intuitive at first glance.

Figure 7: The key states that surface sediments have been taken for this study. However, the methods only states multi cores. Please clarify either in the key or in text where the square samples come from. I think that it would be beneficial to differentiate symbols here for the Konsfjorden multicores samples (the present manuscript) over the rest of the dataset to highlight the novelty of this paper of Kim et al., 2023. (see comment in main recommendation)

Reply: In the revised manuscript, we will clarify the origin of the surface sediment samples by adding a statement in the Methods section. Additionally, we will differentiate the symbols for the Kongsfjorden multicore samples (from this study) to highlight the novelty of our dataset compared to previous studies, such as Kim et al. (2023), as suggested.

Figure 8: See comment for figure 7.

Reply: As mentioned above, in the revised manuscript, we will clarify the origin of the surface sediment samples by adding a statement in the Methods section.