

Anonymous Referee #1, 30 Jul 2026:

Reviewer Comment (RC): This manuscript by Tanski et al. addresses the role of Arctic permafrost lagoons as dynamic biogeochemical reactors in the land-ocean transition zone. The study combines shoreline change analysis, sediment core chronology, and bulk geochemistry to trace organic matter (OM) dynamics along a terrestrial–lagoon–marine gradient. Findings from this type of studies have implications for carbon budgeting and climate feedbacks. Overall, I suggest moderate/major revisions.

Authors Response (AR): We thank reviewer #1 for the constructive comments and valuable recommendations and suggestions for improvement of the manuscript.

RC: Below are my comments for consideration:

RC 1: The study provides useful empirical data from a well-characterized system, but the conceptual novelty is limited. The finding that OM content declines along the land-lagoon-ocean gradient is not surprising and has been documented in other coastal systems (e.g., Schreiner et al., 2013; Hanna et al., 2014). In addition, costal erosion and lateral transport have been reported in Beaufort Sea (Ping et al., 2011; Tsai, 2024). The authors should clarify the novelty relative to Jenrich et al. (2021, 2025) and Irrgang et al. (2018).

AR: We acknowledge that the general decline in organic matter (OM) content along land–lagoon–ocean gradients is not a novel observation and has been documented in other coastal systems. Likewise, coastal erosion and lateral transport of terrestrial material have previously been described for the Beaufort Sea. We have therefore revised the manuscript to more clearly distinguish these established patterns from the specific contribution of our study. (See “: While previous studies have documented coastal erosion, land-to-ocean changes in OM characteristics, and carbon dynamics in Arctic lagoons, the quantitative coupling between multi-decadal shoreline erosion and terrestrial OC supply, sediment accumulation, and subsequent OM transformation, burial, and offshore transport within a single lagoon system remains poorly constrained.”)

The novelty of our study lies primarily in quantitatively linking multi-decadal shoreline dynamics and erosion-derived organic carbon (OC) inputs with sediment accumulation, OC burial, and lateral changes in OM characteristics within the same Arctic lagoon system. By combining shoreline change between 1953 and 2018 with estimates of erosion-derived OC fluxes, sediment chronologies and mass accumulation rates, and sediment geochemical properties along the land–lagoon–ocean continuum, we assess how increasing terrestrial inputs are processed and partitioned between retention/burial, transformation, and offshore transport within the lagoon. Thus, the observed decrease in OM content along the land–lagoon–ocean gradient is not presented as novel in itself, but is used together with these independent datasets to constrain the role of the lagoon as an active component of the coastal carbon pathway.

Our study also complements Jenrich et al. (2021, 2025), which primarily investigated thermokarst lagoon systems and their development and carbon dynamics. Kanivaliuraq represents a different geomorphological setting within formerly glaciated terrain, where coastal erosion of Quaternary deposits and sediment redistribution within a semi-open, spit-protected lagoon are important controls on sediment and OM dynamics. This provides an

opportunity to examine whether the role of lagoons as sites of OM processing and sequestration extends beyond the thermokarst-lagoon settings emphasized in previous studies.

Irrgang et al. (2018) provides the regional framework for coastal erosion along the Yukon coast and forms an important basis for our shoreline-change analysis. Our study extends this work by updating the shoreline record to 2018 for Kanivaliuraq and, importantly, by translating shoreline retreat into estimates of erosion-derived OC input and relating these changes to sediment and OC accumulation within the lagoon. In this way, we move from documenting coastal change to examining its consequences for sedimentary OM cycling.

We have revised the Introduction and Discussion accordingly to better acknowledge these previous studies and to clarify that the contribution of this study is the process-based integration of coastal erosion, terrestrial OC supply, sediment accumulation, OM transformation, and burial within an Arctic lagoon rather than the land-to-ocean decline in OM alone.

RC 2: The conclusion that lagoons act as both sinks and reactors for terrestrial OM echoes previous work on thermokarst lagoons (Jenrich et al., 2021, 2025a,b,c). The increase in erosion and sedimentation rates over time is consistent with regional trends already reported by the same research group (Irrgang et al., 2018; Couture et al., 2018). The authors should more clearly distinguish their contributions from those of Jenrich et al. (2021, 2025a,b,c), who have already published extensively on thermokarst lagoon carbon dynamics.

AR: Please see comment above. We agree that the general concept of Arctic lagoons acting as both sinks and reactors of terrestrial OM has previously been demonstrated, particularly for thermokarst lagoons by Jenrich et al. (2021, 2025a,b,c), and we have revised the manuscript to make this previous work and our specific contribution clearer.

Our study complements these studies by examining a semi-open, spit-protected lagoon in formerly glaciated terrain of the western Canadian Arctic and, importantly, by quantitatively linking multi-decadal shoreline change to erosion-derived OC supply, sediment and OC accumulation, and lateral changes in OM characteristics within the same system. Thus, we do not consider the concepts of OM processing and sequestration in Arctic lagoons, or increasing regional erosion rates, to be novel by themselves. Rather, our contribution is the integration of these processes to assess how erosion-derived terrestrial OM is transferred, transformed, retained, and exported across the land–lagoon–ocean continuum.

We also acknowledge that the observed increase in erosion is consistent with the regional changes reported by Irrgang et al. (2018) and Couture et al. (2018). Building on this regional framework, our study translates shoreline retreat at Kanivaliuraq into estimates of OC input and relates these changes to sedimentary records and OM accumulation within the lagoon. We have revised the Introduction and Discussion to more clearly acknowledge the findings of Jenrich et al. (2021, 2025a,b,c) (see “While the role of Arctic lagoons as sites of terrestrial OM transformation and sequestration has previously been demonstrated for thermokarst lagoons (Jenrich et al., 2021, 2025), our results extend this concept to a semi-open lagoon in formerly glaciated terrain and link OM retention and transformation to quantified erosion-derived carbon inputs and multi-decadal changes in shoreline and sediment accumulation” in chapter 4.3) to distinguish these previous findings from the contribution of the present study.

RC 3: The study would benefit from a clearer articulation of what is new beyond confirming existing frameworks. For example, do the authors offer novel insights into the relative importance of degradation versus burial, or the role of wind-driven turbidity in organic matter processing?

AR: Thank you. We added information to explain and acknowledge the focus of this study in the introduction. We more clearly phrased our intentions in this study. As stated above in the changes mentioned.

RC 4: The literature review is comprehensive and appropriately cites key studies on Arctic erosion, permafrost carbon, and lagoon systems. However, there is too much emphasis on local literature (and heavily from their own research network) and too little discussion of broader coastal biogeochemistry. In addition, the authors could cite recent work on DOM dynamics in Arctic nearshore zones to strengthen the discussion of lateral OM export.

AR: The dissolved organic carbon fraction is an important portion of biogeochemical processes along Arctic coasts. Yet, it was not possible in the framework of this study to cover the whole OM spectrum for investigation. We added information to address the biogeochemical processes that are important for the cycling, transport and transformation of OM in the coastal realm such as flocculation, co-metabolization or light exposure. We further added two references to account for the role of DOM (Clark et al., 2022; Bertin et al., 2025).

RC 5: The claim that lagoons will become increasingly important carbon reactors under future warming is plausible but not directly tested. Similarly, the authors suggest that lagoons may be significant greenhouse gas (GHG) sources, but no GHG flux measurements are presented, weakening the direct relevance to the permafrost carbon feedback.

AR: We agree with the reviewer that our data do not directly demonstrate that Arctic lagoons are sources of GHGs or that their importance as carbon reactors will increase under future warming, as we do not provide direct GHG flux measurements or future projections. We have therefore revised the manuscript to clarify that these statements represent broader implications rather than direct findings of this study. We retain this broader context where appropriate and refer to previous studies that have demonstrated seasonal GHG emissions from Arctic lagoon and nearshore environments. In addition, we have revised the relevant passages in the Introduction and Discussion (Section 4.2) to more clearly distinguish between processes demonstrated by our sedimentary data and potential implications for GHG production and the permafrost carbon feedback.

RC 6: The study relies on one-time sediment sampling and does not capture seasonal dynamics, which are critical for understanding OM processing in dynamic lagoons with seasonal and interannual lateral transport. The authors should justify their choice of constant flux-constant sedimentation model and discuss potential uncertainties given the dynamic nature of lagoons.

AR: The CFCS model was used since ^{210}Pb and ^{137}Cs suggest a constant deposition over time. Of course, the upper sediment column can always be affected by processes such as

resuspension, sea ice drag or bioturbation. We addressed these processes in depth e.g. in chapter 4.1.

RC 7: Is there quantitative evidence or reference to support the occurrence of the depocenter and undisturbed sedimentation at the sampling location and thus the interpretation of MAR and OCMAR. In addition, the linkage between physical forcing, sediment dynamics, and OM transformation seems underdeveloped.

AR: Thank you for raising this point. The coring location was selected based on existing geomorphological information from previous studies in the lagoon (Forbes, 1997), complemented by Indigenous knowledge of the channel position and lagoon development. We initially conducted seismic surveys to further constrain the location of the depositional center; however, these data could not be reliably interpreted due to technical limitations related to the shallow water column and acoustic signal quality. We therefore cannot independently confirm the coring site as the lagoon-wide depocenter based on seismic data and have revised the manuscript to avoid overinterpreting this designation. Nevertheless, the sediment chronology and derived MARs provide evidence for continuous sediment accumulation at the coring location and support its use for assessing temporal changes in sediment and OC accumulation.

We further agree that the connection between physical forcing, sediment redistribution, and OM dynamics needed to be more explicit. We have therefore strengthened the Discussion to better link wind-driven resuspension and water exchange, sediment redistribution and accumulation, and the observed lateral changes in sedimentary OM characteristics (see “Together, these observations suggest that wind-driven water exchange and resuspension redistribute fine, OC-bearing particles within the lagoon, thereby linking physical forcing to spatial patterns of sediment accumulation and OM preservation or loss.”).

RC 8: The statement that “most of the OM is derived from terrestrial sources” (Section 4.2) is not supported by the data, as marine OM contribution (based on $\delta^{13}\text{C}$ and C/N) is not quantitatively estimated. A two-end-member mixing model would strengthen this claim.

AR: The coastal realm of the Arctic Ocean and the Yukon coast is overwhelmingly dominated by terrestrial organic matter input, which was shown by numerous studies (e.g. Naidu et al., 2000; Martens et al., 2021). We changed the wording from “most of the OM is derived from terrestrial sources” to “most of the OM is very likely derived from terrestrial sources” in Section 4.2 and added supporting literature (Martens et al., 2021).

RC 9: In Table 1, OCMAR for the lagoon (PB) is higher than expected from MAR (e.g., 0.48 vs. 0.57). This is mathematically possible only if TOC content is > 0.84 or >80%. However, TOC data shown in SI are normally less than 30% in PB lagoon. Please verify and comment.

AR: We checked all the data and made a better approach for the periods, we think the units caused the confusion. In the example highlighted (e.g., 0.48 vs. 0.57) they are not the same units (in the same units the values are 0.048 and 0.57). We corrected the values and updated table 1.

RC 10: To place this study into a broader context, the manuscript would benefit from comparison with recent syntheses on permafrost carbon export and coastal carbon burial.

AR: We added a sentence and put the study into a larger context citing the most recent syntheses literature (e.g., Nielsen et al., 2024; van Crimpen et al., 2025; Vonk et al., 2025).

RC 11: Lastly, the manuscript should explicitly acknowledge limitations on single lagoon, limited number of sediment cores, lack of water-column carbon measurements (no DOC budget), and incomplete carbon mass balance.

AR: Yes, we could unfortunately not cover all carbon compartments and seasons, even though we clearly see the advantage of including them. We agree with the reviewer that these limitations should be stated more explicitly. Our study focuses on the sedimentary OM compartment of a single lagoon system and is based on a limited number of sediment cores and surface sediment samples. Furthermore, we do not include water-column carbon measurements, including DOC, or inorganic carbon and GHG fluxes, and therefore cannot establish a complete carbon mass balance. We have revised the Introduction (“This study focuses on the sedimentary OM compartment of a single lagoon system and does not encompass dissolved OM, inorganic carbon, or GHG fluxes; consequently, the results do not represent a complete carbon mass balance.”) and Conclusion (“While representing a detailed case study of a single lagoon, our integrated sedimentary dataset provides a basis for future studies incorporating water-column carbon dynamics and extending the approach across Arctic lagoon systems. Further and more comprehensive studies are needed taking into account the whole OM spectrum, inorganic carbon compartments and pCO₂ measurements and long-term measurements encompassing the different seasons.”) to clearly acknowledge these limitations and to emphasize that our results represent a detailed case study of sedimentary OM dynamics rather than a complete assessment of the lagoon carbon budget.