R3

I agree with the other reviewers that this is an important, well-conducted study that suits this journal. However, refinement of the figures and conclusion is necessary before publication.

We thank the reviewer for the positive feedback and agree that refining the figures and conclusion improves the clarity and impact of the manuscript.

MAJOR Comments:

147-150: After cutting, were the cores returned to the vertical position? Unclear if you sampled in the field or at the University? Was sampling, especially rhizone sampling, performed with the core vertical? These are critical details to understand how mixed your sampling horizons are, and how well sharp geochemical porewater changes can be measured as a result. Currently the text reads as if the cores were transported horizontally to the university and then rhizone sampled on their sides. Please clarify and consider commenting here or in the discussion about how porewater vertical mixing during collection and sampling can affect your results.

We have clarified in the Methods section that the cores were cut in the field, but due to the very cold weather, they were returned to the lab in Fairbanks vertically for the sampling. The rhizone sampling could be done only horizontally after cutting the corer lengthwise. The diffusion porewater profiles of concentrations and isotopes we obtained suggest no significant vertical mixing during transport. We clarified and discussed this in the revised version.

326-327: Include the uncertainty as a +- next to the absolute value. If I read the supplement correctly, the BTL center estimate would be 7.4 +- 1.8 mol/m2yr. You kept your uncertainties reasonable under challenging sampling conditions, it's good to highlight that in the text.

Thank you for this comment. We have included in the revised version the uncertainty estimates (e.g., ±1.8 mol/m^2/yr for BTL center) alongside all reported methane production values in the Results section and relevant figures.

439-442: I don't follow your logic here. Can this study really tell about methane uptake? Are you assuming your incubation methane production is net between producers and AOM consumers? I think this also relates to another reviewer's comment about what the d13C values imply, you could move it down to this section. I do think you need to discuss methane consumption in the sediment and water column, but possibly as something you can't account for here, with the references you have to support your claim that it's playing a minor role. This would be a great place for future work, especially how AOM rate evolves with age & OM lability.

We measured net production rates from the concentrations changes. We assume that AOM in our batch experiment is not significant based on our previous work on short cores (Lotem et al., 2023 L&O), and that the rates represent mainly methanogenesis. However, the in situ profiles (which show some role for methane oxidation) suggest that this should be further explored and indeed will be very interesting. We clarify it in the revised version.

403/407: directly contradictory statements. A statistically significant difference IS possible to differentiate. Please add numbers and uncertainties to explain what you mean. This paragraph could probably be shortened and combined with the text around it.

We clarified the paragraph and removed contradictory phrasing.

572-582: consider moving figure 9 and its description into a last discussion section, at the author and editor's discretion. I find your first presentation of data of this kind to be an important conclusion and the interpretation (fig 9) not quite as strong, but currently dominates the conclusion section.

We moved figure 9 from the conclusion to the discussion (above the origin part), and emphasized it's a conceptual model (see below).

Abstract/Conclusions: I am not fully convinced that your results support figure 9. From the current text and figures both the young and old lake have similar methane flux in your study and the previously published work shown in Fig 8 panel C has the younger lake with the greatest flux. As per the previous two comments, if you provide more support in the text and address the Pellerin data in the discussion you could still include fig as a hypothesis. If you really are telling a story where the oldest lake has a higher methane flux, I think there are a few places in the text where it sounds like the young/old is the same and that will need to be checked.

Agree. We revised the abstract and conclusion to clarify that figure 9 presents a conceptual model informed by our findings and previous work, rather than a definitive result. We also now explicitly address the apparent similarity in methane fluxes between the young and old lakes.

FIGURE Comments:

Much of what is currently in the supplement needs to be in the main text, in particular when showing a rate or isotopic composition the corresponding concentration also needs to be shown on the same figure. All figure captions need to refer to panel labels, please check throughout manuscript.

We moved key supplementary figures (Fig S1 and Fig. S2) to the main manuscript, as also suggested by the other reviewers, and ensured that isotopic figures include corresponding concentration data.

Consider the format of Figure 5 and S3: filled icons for edge, open for center (I would swap this personally, but not critical), circles for GSL, diamonds for BTL. Keep this convention for all the figures to make it easy for the reader to follow.

Done

Consider dropping redundant y-axis labels if you want to save space or put 4 panels together.

We removed redundant y-axis labels where appropriate to improve figure layout and allow for multi-panel comparisons.

Fig 1: Consider listing the lake ages in the figure caption. Please move the scalebar so it is not covering the other lake feature.

We added lake ages to the caption and repositioned the scale bar to avoid obscuring lake features.

Figure 2 can have one panel per lake per quantity (allows us to easily compare edge to center). Or you can keep all four cores separate but add a second x-axis with DIC concentration (would match more next to figure ¾). Need DIC concentration!

We revised Figure 2 layout to allow easier comparison between edge and center cores and added a second x-axis for DIC concentration.

Figure 3&4 need to be combined, add methane concentrations to the figure, and remove the descriptions from the figure captions into the text. Also add “methane” or “CH4” before “rate” in the axis labels. Possibly 8 panels total: top row with methane in situ concentration and production rate (2 x-axes), bottom row is Figure S2 with d13C of in situ and incubation methane.

We combined Figures 3 and 4, added methane concentrations rates, and revised axis labels and captions accordingly.

Figure 5: Consider putting the equations in the supplement and the legend into the figure caption so you can expand the inset. Currently a busy figure.

We moved equations to the supplement and expanded the figure caption to reduce visual clutter in Figure 5.

Figure 6: what’s the uncertainty of the data in Fig 6? If it’s under the symbols, please add this to the description, otherwise please show error bars or discuss in the text.

We added a note to the text clarifying that uncertainties in Figure 6 are smaller than the symbols and included error bars where appropriate.

Figure 7: Is the 15 m box showing integrated values from 0 to 15 m? Or just from 10 to 15 m? This is confusing in the figure. Perhaps you could write 0-5m, 0-10m, 0-15m, even though it seems a bit redundant. Also need hatch marks on horizontal lines at x-axis values (0,5,…,35): currently too hard to read values in the figure. Consider listing the lake ages as this is a nice summary figure and that could help readers follow your point.

We clarified in the caption that the m box in Figure 7 represents integration from surface to that depth.

Figure 8: Need Methane in axis labels. What are the numbers in the 400s under the y-axes? Please remove.

We updated axis labels in Figure 8 to specify 'Methane production rate' and removed extraneous numbers under the y-axis.

MINOR Text Comments:

64-68, do you not argue later in the manuscript that old lakes are still a large source of methane to the atmosphere if you integrate through the talik? If so, please qualify this statement in the introduction.

We revised the introduction to clarify that while older lakes may have lower surface production rates, their taliks can still contribute significantly to total methane flux.

95-99 Consider moving to methods or shortening.

We moved this background information to the Methods section for better organization.

115: have been described “by” and drop the brackets around Elder et al. (2021).

We corrected the phrasing and removed unnecessary brackets around the citation.

121-122: Confusing to read, consider rephrasing.

We rephrased the sentence for clarity.

125-143: nice descriptions

Thanks.

154-155 extract sediment for what?

We clarified the purpose of sediment extraction in the Methods section.

160-164 how long were the DIC samples stored before analysis? Were they killed?

We added information about DIC sample storage temperature, duration and preservation method.

185: is “total profile methane production rate” the biologic methane flux out of the sediment?

We clarified that 'total profile methane production rate' refers to the depth-integrated microbial methane production rates.

331: Need a reference for talik thaw ages.

We added a reference to support talik thaw age estimates.

343: “roughly calculated”

We revised the phrase 'roughly calculated' to estimated.

389: drop brackets from all but ref date.

We corrected the citation formatting to remove unnecessary brackets.

427-428: drop “which we believe to be most realistic”, and make “reflect” plural

Done

436: add “the” before “low but relatively constant”. Please give an example value here, eg for one core, how much methane is produced in the first meter vs. how much in all the meters below? Could be in percentage rather than absolute value but it will highlight your point, which I do think is an important one. You could reiterate here that a low rate over a larger distance can “outcompete” a high rate over a shorter distance.

We added percentage of methane production in the top meter versus deeper layers to illustrate the importance of depth-integrated rates.

447-453: rephrase this paragraph. It’s arguably your most important finding but difficult to read at the moment. Try writing it in reverse “This study found that as lakes mature, total thawed talik methane production rates will remain similar or even increase bc….”. Rewrite transition to the next section.

We restructured the paragraph to emphasize the key finding and improve readability.

486: Reverse this sentence order so you refer to the in-text figure first and the supplement second (also shallow, then deep).

We reordered the sentence to reference the in-text figure first and the supplement second.

492: drop “in the top meter of BTL” and replace “driven” with “due to”. Could put “available in the top meter of sediment” at the end of the sentence.

We revised the sentence as suggested.

511-516: do you mean that you have to look at age since thaw rather than age since deposition?

Yes, we clarified that we mean to the age since thaw, which is more relevant than age since deposition in this context.

533: “shows” not “showing”

We corrected the verb form to 'shows'.

537: drop “a shift towards”

We removed the phrase 'a shift towards' for conciseness.

541-544: swap these sentences, so your conclusions begin with “This study presents the first empirical data quantifying methane production and organic matter degradation of thermokarst lakes from young to mature” or something like this. Then, “this can be used to test models….

We reordered the sentences to begin with the main conclusion and follow with implications for modeling.

553-557: move to discussion

We moved this content to the Discussion section as suggested.

571-572: “while the highest methane production rates occur in the shallowest sediments of the young lake, the increase in talik depth with age also plays…..”

We revised the sentence.

574: do you mean flux when you say accumulated production rate? Consider having it in brackets? Or use consistent terminology.

Yes, we clarified the terminology and ensured a consistent use throughout the manuscript (as mentioned above to the other reviewers).

582-585: Consider rephrasing, I don’t think it really says what you want it to and people will remember the last sentence.

We appreciate this thoughtful observation and we have rephrased it.