Author revision notes to *Biskaborn et al.: Diatom responses and geochemical feedbacks to environmental changes at Lake Rauchuagytgyn (Far East Russian Arctic)*

Referee #1

General comments to the authors:

This is an interesting and data-rich research paper from a remote region of Chukotka, far eastern Russian Arctic. Here, the environmental history of Lake Rauchuagytgyn was reconstructed during the last 29 ka years, using 14C-dated sediment records of diatoms frustules together with organic carbon, nitrogen and mercury accumulation rates. Diatom assemblages responded to the major Pleistocene and Holocene environmental changes through shifts in species composition and abundance. It appears that organic carbon in lake sediments has largely autochthonous origin, as it is strongly correlated with the diatom frustule accumulation rate. This implies that this type of arctic lake may play an important role as a carbon sink as most organic carbon (OC) is effectively buried in the sediments. However, OC concentrations in the sediments do not reflect the amount of carbon dioxide emitted during the ice melt, and this may be substantial.
I suggest that you change your discussion, conclusions and the abstract reflecting on existing uncertainty regarding the role of arctic lakes in the global carbon cycle.
The age-depth model of the long core, which was based on 23 14C bulk organic carbon dates in a 651.75 cm core, was developed using LANDO modelling. This is in a broad agreement with the earlier published core chronology using different modelling and this gives extra confidence in the results. The short core was dated using 210Pb and 137Cs. The short core chronology is uncertain for the 7-11 cm interval.
Overall, this is a valuable and thorough contribution to the series of recent publications from this remote arctic region, which may play an important role in the global climate change. It deserves a publication. Substantial uncertainty remains, however, regarding the fate of carbon in artic lakes and their role as sinks or emitters of carbon.

Author final response
Dear Reviewer #1
Thank you very much for reviewing the manuscript and your work invested in giving feedback to our study. We are specifically grateful for the comment on remaining uncertainties on the fate CO_2 that is not only accumulated in the sediment but also released after ice-brake up of the lake. We understand that we used misleading wording when using “during warming”, but we actually were addressing millennial scale Holocene warming. We agree that we did not discuss this aspect enough in the manuscript, even though we considered it in the overall study, mainly based on results of the long core record spanning multiple millennia. We now made sure that our findings point to long-term trends, i.e. storage of carbon over millennia in the Holocene interglacial part of the core that is well correlated with diatom valve production and thus primary production.
Accordingly, we included explanations in the abstract:

"We conclude that, if increased short-term emissions are neglected, pristine Arctic lake systems can potentially serve as long-term CO_2 and Hg sinks during warm climate episodes driven by insolation-enhanced within-lake primary productivity."

In the introduction:

"There is an ongoing discussion about the role of Arctic lakes for the carbon cycle. Thermokarst basins are believed to have switched from a net source to a sink during the mid-Holocene ca. 5000 years ago related to permafrost dynamics (Anthony et al., 2014). Glacial lakes are often larger and well oxygenized and thus are considered to strongly contribute to the modern CO2 emission in the Arctic landscape (Tan et al., 2017; Wik et al., 2016). Differences in drivers of bioproductivity, e.g. land-use in Europe (Vihma et al., 2016), accumulation rate and preservation of sedimentary carbon, e.g. during the ice-melt (Spangenberg et al., 2021), still lead to a high sink-source variability across temporal scales. To help gain insights into the fate of carbon accumulated in northern lakes, we provide a high-resolution study of a sediment core from Lake Rauchuagytgyn."

And conclusion:

"From our study we infer that bulk carbon accumulation is represented by climate-enhanced within-lake primary productivity. Thus, pristine boreal lake systems potentially can serve as long-term CO_2 sinks if short-term fluctuations are disregarded. Lake basins also represent disposal sites for heavy metal contaminants."

We think that our edits will sufficiently address the uncertainty related to the modern role of Arctic lakes, especially the methane and CO2 release. Nevertheless, the fact that there is a larger carbon pool preserved - existing - within Holocene sediments (0.15 Mt) than compared to Pleistocene sediments (0.1 Mt), is itself an 'indisputable' evidence of carbon removal during warm episodes, seen at long time scales of course.

Referee #1

Detailed comments to the authors:

The manuscript is well written for the most part, although some of the sentences need clarifying or re-writing. I highlighted those in the attached pdf copy. In addition, there are several minor grammar mistakes which I corrected and highlighted in the attached pdf file. Below I outlined sentences which need re-writing and other comments.

I suggest combining short and long core diatom and biochemistry data to facilitate visual interpretation of the results, please see the details below. This will also reduce the number of figures in this manuscript, which is quite high. My other concern is the way sedimentation rates were calculated. It is not well described in Methods. I give the details below.

Thank you for your help in improving our manuscript. We carefully used your detailed comments to revise the manuscript and provided point-to-point answers and explanations of what we change, listed below. Yes, we now combined long core and short core graphs to reduce the total number of figures, and we described better our calculations using equations.

Abstract:

Line 37. Please change this sentence as uncertainty exists regarding the role of arcitic lakes in the global carbon cycle.

Thank you for the comment – we changed it to "We conclude that, if increased short-term emissions are neglected, pristine Arctic lake systems can potentially serve as long-term CO2 and Hg sinks during warming climate driven by insolation-enhanced within-lake primary productivity".

Methods.

Lines 195-205.

I suggest replacing the text with formulae and short justification of your calculations of sedimentation rates. You need to clearly describe how sedimentation rates were calculated to ensure the validity of the results.

Thank you for the comment. We agree and added the equations used to calculate sedimentation rates SR and mass accumulation rates MAR, and also described all terms used in these equations so that all accumulation rate values of diatoms, carbon, and mercury are reproducible in a mathematical way:

To calculate accumulation rates, we first computed dry mass accumulation rates (MAR, in g cm^{-2} a^{-1}) using equation 1.

$$\mathrm{MAR} = \mathrm{DBD} \times \mathrm{SR} \qquad (1)$$

where DBD is dry bulk density (in g cm^{-3}) and SR is sedimentation rate (in cm a^{-1}). We derived SR from age-depth modelling in a standard procedure according to equation 2 (Pfalz et al., 2022).

$$\mathrm{SR}\ (\mathrm{x_i}) = \frac{\mathrm{depth}(\mathrm{x_i}) - \mathrm{depth}\ (\mathrm{x_{i-1}})}{\mathrm{age}(\mathrm{x_i}) - \mathrm{age}(\mathrm{x_{i-1}})} \qquad (2)$$

The value $\mathrm{x_i}$ represents the layer of interest within a sediment core for which the SR calculation is necessary, while $\mathrm{x_{i-1}}$ is the previous layers.

Results.

Please combine Figures 5 and 6 into one indicating a gap between two cores. This would facilitate better visualization of the floristic changes.

Similarly, please combine Figures 8 and 9 into one figure, this would ease interpretation of the results.

Line 284. You refer here to Figure 5, not Figure 9.

Thank you for the suggestion to combine the figures associated to the short core and the long core. These cores are from slightly different area of the lake, that explains changes in the floristic mode especially taken into account the high morphological variability of the lake floor. However, we combined the diatom assemblage graphs and the biochemistry plots in a way that the short core is above the long core. This will help the reader to more easily identify the chronology using the y-axes.

We also adopted all Figure numbers to the new (lower) total number of figures used in the manuscript.

Discussion.
Section 5.2.
Consider reviewing this section, it requires clarifying and re-writing. Use combined Figure made from Figures 8 and 9 to describe the changes and correlations between the profiles.

> Thank you very much for pointing this out. Yes, we substantially reviewed and edited this entire section. Your detailed comments helped us very much.

Lines 400-405. You need to re-write this passage about sediment accumulation rates, it is not entirely clear.

> Thank you very much. We changed this paragraph to: "Accumulation rates (AR) in sediment basins are generally uncertain due to limitations in precise age-model interpolations (Sadler, 1981). In addition, diatom concentrations are expressed as numbers of frustules (Battarbee et al., 2001) regardless of the weight and volume of the shells. Accordingly, one cannot directly infer biomass from count-based valve accumulation, as valves vary considerably in size among and within species (Birks, 2010)".

Line 407. This sentence about lake ontogeny (which is lake development) looks incomplete to me. You need to explain how lake ontogeny changes, this is a process.

> Thank you. We changed this sentence to: "We showed above that the Rauchuagytgyn sedimentary record shows a tendency toward successional lake development in response to long-term changes of the landscape and ecosystem adaptation (Brenner and Escobar, 2009). Therefore, unknown deviations in the linkage between the mass of carbon stored and number of diatom valves observed are likely to appear".

Lines 409-410 – Similarly, it is difficult to understand these sentences. You need to think clearly what you are trying to say here, and re-write this passage. I highlighted it in the pdf copy.

> Thank you for pointing this out. We deleted this sentence.

Lines 462-465. These two sentences require reviewing and rewriting, it is not entirely clear what is the meaning there.

> Thank you very much. We agree and deleted one of these sentences and reworded the other to: "Our study revealed a positive feedback mechanism between long-term climate amelioration and diatom-driven sink of organic matter."

Figures.
Figure 10 is not easy to interpret, I do not think that this Figure is necessary, I suggest removing it.
It would be better to combine Figures 8 and 9. The combined Figure can be used to describe and discuss the trends in the profile changes and correlations between them.
If you wish to display the correlations, you can use a table.

> Thank you for your suggestion. We now combined Figures 8 and 9 as suggested. We removed the correlation plots to the supplement material because we believe it

contains important information highlighting the good correlation during Holocene warm and missing correlation in the Pleistocene cold episode.

Please also note the supplement to this comment:
https://egusphere.copernicus.org/preprints/2022/egusphere-2022-985/egusphere-2022-985-RC1-supplement.pdf

Thank you for your additional comments and corrections provided in the PDF. We saw all of them and adopted the corrections. Thank you also for the comment on how we could try to approach biomass by diatom measurements for follow-up analyses. It would definitely be interesting to measure sizes of dominant species and will hopefully be possible to do with increasing use of high-res microscopes and data-science methods. Same for measuring pigments.