Review #2

Dear reviewer,

Thank you very much for your positive and constructive feedback and comments on our manuscript. We tried to incorporate your suggestions into the paper. Please find below your comments in orange and our point-by-point response in black. Updated excerpts of the manuscript are included in blue.

The manuscript by Rehder et al. focuses on the simulation of methane emissions from tundra ponds. The authors tackle an important topic given the unprecedented warming in this part of the world. Consequently, the abundance of such ponds could become even larger in the future. In order to simulate methane emissions the authors classified three types of ponds and applied a process-based model. The tuning of the model was achieved by using previously collected data in the Lena Delta - I thoroughly studied region in the Arctic. Furthermore the model is used to estimate methane emissions with ongoing warming.

The paper is well written and concise and the results are sound. Particularly the classification in different poond types as well as the contribution of different pathways and their subsequent attribution is intriguing. The major concern is the calibration of the model with this single site. I am aware that data, and particularly flux data from ponds are not widely available, however a detailed discussion on how different soil types or vegetation structure would affect the fluxes is necessary. The authors themselfes mention at the beginning of the manuscript (p4, l86) that this is a first order approximation for sandy and organic-rich sediments. Surely this is not the case for many other regions. There are some hints towards the upscaling of the results in the conclusion, however a distinct section on how the model can be used and particularly what is needed to achieve upscaling - more precisely what this would mean for the fluces at regional scale - would be very beneficial.

> Thank you for your comment. To briefly summarize: (1) You wonder how dependent on soil type/vegetation structure the calibration is. Linking this to upscaling (2) you would like to see a section discussing the applicability of the model.
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> Regarding (1), the way MeEP was set up, the soil type will have a stronger influence on the thermal structure of the pond and only indirectly influence methane emissions. However, the soil type might influence the microbial community, and in this way the base productivity, one of our tuning parameters. When applying MeEP to larger regions, in a first step an average $P_0^{v/b}$ determined with measurements from several regions will already give new insights on the impact of vegetation on methane emissions from small waterbodies, especially when paired with information about the overgrown area of ponds. So far, plant-mediated fluxes have not been considered when upscaling waterbody emissions, so even a first estimate that does not resolve all regional differences would be a step forward. We added a paragraph on using MeEP for other or larger regions at the end of the discussion:
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> Our model was set up and calibrated for one specific region featuring one specific landscape type. To quantify emissions in other regions and especially other landscape

types, MeEP should be tuned with more and additional data. The magnitude of emissions depends strongly on the base productivity P_0 which is the tuning parameter for the microbial communities and likely differs depending on the structure of the microbial communities. The base productivity for the vegetated pond fraction P_0^v also incorporates the impact of higher substrate availability on the microbial community. Consequently, this parameter is indirectly affected by the vegetation structure in our study region. To apply this model to other regions, special attention should be placed on availability of measurements from the overgrown parts of the ponds, especially plant-mediated transport. One caveat when adapting MeEP for the larger scale is that in our study area ponds do not feature floating mosses like sphagnum which can be found at other sites and reduce methane emissions (Kuhn et al., 2018). While submerged mosses do not impact surface methane concentrations in our study site (Rehder et al., 2021), the same might not be true for floating vegetation.

Two additional specific comments:

I was missing a clear research question and hypothesis

We changed the last paragraph of the introduction, with the research question in the first sentence of the paragraph –

We aim to **explore how pond methane emissions might change in a warmer Arctic** and analyze as many of these interlinked effects on methane cycling in a single study as possible by employing the model MeEP (Methane Emissions from Ponds).

– and the hypothesis in the last sentence of the same paragraph:

While diffusion and ebullition are usually accounted for, the impact of plant-mediated transport on landscape-scale fluxes from ponds is usually not considered but **we expect it to be as important as the other two fluxes**.

Figure 9: the combination of the area in panel b does not necessarily relate to panel a, Also in the caption you write about river terraces, yet in the figure nothing about these is mentioned

Yes, panel (a) is per area of landcover type, panel (b) per area of polygonal tundra. To clarify, we slightly adapted the caption (and substituted ‘river terrace’ with ‘polygonal tundra’, a word we use more often in the manuscript.) The caption now reads:

Impact of pond emissions on landscape methane emissions. (a) **For the hist_all simulation, we compare fluxes from different landscape elements.** The estimate for the overall tundra emissions **(orange bar)** were acquired with eddy-covariance measurements over the growing season of 2003 (Wille et al., 2008) **and are shown for comparison.** Note, that the influence of ponds on these measurements is low. The methane emissions per square meter of open and overgrown water are broken down per pond type. (b) Methane emissions per square kilometer of **polygonal tundra** of each pond type are displayed as stacked bars. We compare these emissions per pond type to the area this pond type covers in the **polygonal tundra** of Samoylov Island (sand-colored bar). This comparison relies on the assumption that the

emissions measured by (Wille et al., 2008) are representative for **polygonal-tundra** emissions.

I hope these comments are useful and I enjoyed reading the manuscript.

Thank you very much. The comments are very helpful.

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