The authors present a study on the evaluation of nine different scenarios of methane (CH4) wetland emissions in the Arctic, obtained by varying two parameters of the JSBACH land surface model: Q10 and fCH4. These scenarios were evaluated using an inverse modeling approach by analyzing the necessary adjustment of the model between prior and posterior CH4 fluxes. The authors found that a Q10 value of 1.8 generally produced the best prior emission scenario in the pan-Arctic region. However, at a regional scale, the optimal parameter set-ups varied, highlighting the importance of using specific parameters of different regions.

In my opinion, this study has been well prepared and carefully thought out, and no major adjustments are required. However, there are three aspects of the description of the study set-up and manuscript structure that could be improved:

1. I would suggest revising the introduction and condensing the information provided slightly. While it is interesting to read, I think it could be shortened slightly to focus more on the research questions being discussed.

2. I would also suggest describing the observation network used more extensively, and properly acknowledging the institutions that provided the observations. In my opinion, the terms currently used in the study, such as "different databases" or "several global and regional networks", are insufficient. Additionally, the limitations of the in situ network, such as the lack of observation sites in Siberia, should be discussed earlier in the manuscript, as these can have a significant impact on posterior CH4 emissions.

3. Please provide a more thorough description of the inversion set-up in section 2.3, as several aspects have not been sufficiently described so far. For example, how did you define the transport error, and which uncertainties were used for the prior emissions? Did you optimize the total CH4 fluxes, or were the fluxes optimized by source category? This is unclear from the description. How were the initial concentrations defined? You could also potentially include one or two more sentences describing the transport model used.

Specific comments

P1, L17:
Would it be possible to already give a short definition of what the Q10 value indicates in the abstract?

P4, L123 and P5, Fig.1:
I would consider renaming the "Europe" region "Europe and Greenland", given that Greenland constitutes a substantial part of this region (even though it belongs to Denmark, it is politically independent and not on the European continent).

P4, L127:
It would be good to mention here that you are using in situ data for the inversion, since "data coverage" could also include satellite data.

P6, L168-169:
Out of curiosity, is the capped fraction of 0.5 a default of the model or a setting of your choice?

P7, L184:
How did you define the ranges of Q10 and fCH4? Are these based on experience and/or other studies?

P7 and P8, Section 2.4
Would it be possible to summarize the described calculations for the evaluation in one or multiple equations?

P11, L290-L 196:
Did the inversion optimize the total CH4 emission or was each emission category optimized separately? In the firs case, how were the wetland emission obtained? (See also general comment 3)

P13, Figure 3a:
So these are the total CH4 emissions from all sources using mean values of all 9 emission scenarios? "using different values of Q10 parameter and baseline fCh4 fraction" is a bit vague and could indicate, that only specific scenarios were used. Also it could be beneficial to plot a pattern in either the prior or the posterior bars since the color difference not always clear (e.g. https://matplotlib.org/stable/gallery/shapes_and_collections/hatch_style_reference.html)

P14, L353-L354:
I think it could be helpful to also provide exemplary maps of the prior fluxes (not just the model adjustment) to better visualize expressions such as "which showed that in high-emission areas, for example the Western Siberian Lowlands…"

Technical corrections

P3, L84-L85:
Please check grammar, e.g. "One big research question now is how high the Q10 value should be for this temperature dependency of the CH4:CO2 production ratio. In order to answer this question, we employ…"

P8, L221-L222
Please check grammar, e.g. "Previous studies have used atmospheric inversion models to evaluate different bottom-up estimates and determine which best reproduces observed atmospheric CH_4 data…"

P8, L239:
Better: maps were created

P12, L325:
Please check grammar: "…best agreed well with…"