Review

Summary

In their manuscript titled "Vegetation structure drives carbon dioxide and methane dynamics in adjacent boreal fen and bog ecosystems", the authors characterize differences in CO_2 and CH_4 fluxes and their temporal patterns on different time scales between adjacent bog and fen ecosystems. They investigate possible explanations for the identified fen-bog differences in carbon fluxes considering biotic and abiotic environmental controls. They found that overall, more CO_2 is taken up and more CH_4 is emitted from the fen than from the bog and that carbon fluxes vary more strongly over the year in the fen than in the bog. They explain these differences by the higher abundance of (aerenchymatous) plants in the fen, which facilitate CH_4 transport, provide substrate for CH_4 production and allow for higher but also more variable rates of photosynthesis over the year.

Relevance

The topic of the presented manuscript is highly relevant and topical as it enhances our understanding of how carbon fluxes can change in the course of both commonly occurring natural fen-bog transitions but also with climate change driven changes in peatland types. The key finding of the important role of vegetation composition will be important to reduce uncertainties in larger scale flux estimates and model predictions.

Overall comments

Overall, the study is highly relevant and the results are presented in a very clear, well-structured and easy-to-follow way, supported by sound data analyses and informative figures. In my opinion, the manuscript is already in a very good state and I only have a few minor comments and suggestions.

The results chapter is quite long and everything presented here is relevant and interesting, I think that the structure could be made a bit clearer to make it even easier to follow. This could be done even just by slightly adjusting the section headings: Mostly, the heading of section 3.3.3 should be changed to include environmental drivers and thereby clarify that it is not merely describe temporal patterns as already done in section 3.2. Furthermore, while I very much like the figures used to support the results, I think that, if necessary, their number could be reduced by combining figures 7, 9, and 10 as they all essentially describe the temperature response of carbon fluxes. The figures could be adjusted to support only the key aspects mentioned in the main text and additional figures could be moved to the supplement. Furthermore, I think that the introductory section of chapter 3.2 could be shortened by focussing only on differences in the overall range of carbon fluxes between fen and bog and keeping the description of seasonal dynamics to section 3.2.2, thereby clarifying the structure and avoiding repetitions.

In the analysis of potential drivers of C fluxes, for the relationship with LAI and photosynthesis-related variables, you refer to results from (linear mixed effects) models. It would be helpful to present model structures and parameters in a table in the supplement.

In the interpretation of your results, you focus very strongly on differences in vegetation structure as explanation for fen-bog differences in carbon fluxes. While an important role of vegetation is also supported by your

data analyses – this interpretation is probably also supported by the fact that LAI is the only variable considered that really differs between fen and bog in your study as climatic conditions are similar. Are there further variables that might differ between the two peatland types that you did not specifically consider in your study but that might also contribute to the observed differences in carbon fluxes? I think this could be an (optional) addition to the discussion chapter.

What I think should be added to the discussion though is a short statement on differences in water table depth as this is the only other variable besides LAI that differs between fen and bog. Could there be direct effects of the differences in water table depth besides its effect on vegetation composition that might contribute to differences in carbon fluxes?

Furthermore, I think you should be a bit careful in calling the bog a "shrub-dominated" ecosystem (e.g., lines 552 and 568). From my experience, shrubs mostly occur on hummocks at Siikaneva bog which are not the dominating microtopographic feature. While LAIaer is higher at the fen site, I would still say that the bog is similarly dominated by sedges. Instead of explaining fen-bog differences in seasonal variation in C fluxes by the dominance of sedges in the fen compared to a dominance of shrubs in the bog (lines 567-571), you could also consider differences in the at the species composition of sedges between fen and bog. For example, Korrensalo et al. (2022) and Jentzsch et al. (2025) different sedge species reach their peak LAI at different times of the year. Differences in sedge species composition and species diversity could therefore contribute to fen-bog differences in seasonal variability in C fluxes.

<u>Specific comments</u>

l. 15 I think that if you say that peatland "increasingly" undergo fen-to-bog transitions, I think that you should also refer to climate change here.

l. 29 You could consider expressing CH_4 fluxes in CO_2 equivalents to evaluate the overall C balance of Siikaneva fen vs. Siikaneva bog (at least for the active season).

l. 41 You could add a transitional sentence here, linking CH_4 production to high water tables.

l. 99 ff. Here, I would be curious to learn a bit more about the reasons for fen-bog differences in CO_2 fluxes identified in the literature. As a first guess I would hypothesize that CO_2 uptake is higher at a fen due to higher nutrient availability, plant productivity and photosynthetic uptake. What processes could your hypothesis of lower CO_2 assimilation at the fen be based in addition to previous observations?

l. 115 The term "aapa mire" has not been introduced before – is it used as an equivalent to fen here? Please add a brief definition or stick to the term "fen" instead.

l. 118 remove the first "and"

Figure 1: consider adding a north arrow

l. 129-130 "Lower lying areas…" Move this sentence to after the next sentence to first introduce microtopography in general and then name the individual microtopographic features.

l. 150 Also add for the LI-7000 whether it is an open- or closed-path gas analyser.

Section 2.4.3: In section 3.2.3, you refer to cumulative sums of CH_4 fluxes – Did you gapfil CH_4 fluxes for theses calculations? If so, how?

l. 260: what did you base your definition of the two seasons on? Increasing v.s. decreasing temperatures, plant activity etc.?

l. 295 Consider adding to the methods section or to the discussion in which microtopographic feature (of the bog) the WTD sensor was installed.

Figure 2: Just out of curiosity (no need to discuss in the manuscript): LAI at the bog in 2012 is very low compared to the other years while climatic conditions seem similar apart from rather high water levels. Do you think that LAI was actually this much lower in 2012 or could it be due to a methodological difference in measurements or something similar?

l. 337-338 Add a figure reference to support the maximum in photosynthetic activity between July and August.

Figure 5: Here you split the active season into 3 periods while in the methods section you define two seasons. Consider changing in the methods in case you do not use the two-season-definition in your data analyses.

Figure 7: Here you define nighttime vs. daytime based on PAR, while in l. 340-341 you use a definition based on the time of day. Please consider using being consistent with this definition throughout the manuscript.

Figure 9: Why did you chose to show correlations with soil temperatures at 5 cm depth instead of at deeper depths where you found stronger correlations at least at the fen?

l. 443 maybe “variation” or “variability” instead of “excursions”?

e.g., l. 466, 467 In several instances you use words expressing a contrast such as “although”, “while”, “but” in sentences that present several but not necessarily contrasting observations. Consider checking the manuscript for this and replacing by “and” or similar.

l. 466 Mean active-season LUE “at the fen”…

section 4.1: could fen-bog differences in cumulative sums of carbon fluxes change when considering the whole year instead of limiting studies to the active seasons? Considering your finding of higher seasonal variability at the fen, I think that considering the full year might at least reduce fen-bog differences unless you assume that photosynthesis is negligible outside of the active season. This might be a point worth discussing.

l. 516 To support the effect of plant-mediated CH_4 transport, you could refer to your own finding of the higher influence of LAIaer compared to LAItot instead of only referring to the literature.

l. 535 “less temporal variability” instead of “more stable temporal variability”?

l. 541: What could be possible reasons for temperature sensitivity being more stable across depths at the bog? Could this be related to differences in water table depth or vegetation species composition/ rooting depths?

l. 575 Why would these special conditions in 2016 result in anomalous C fluxes only at the fen and not at the bog?

l. 602 bog-like

References

Jentzsch, K., Männistö, E., Marushchak, M. E., Rettelbach, T., Golde, L., Korrensalo, A., Hashemi, J., Van Delden, L., Tuittila, E., Knoblauch, C., and Treat, C. C.: Seasonality in Diffusive Methane Emissions Differs Between Bog Microforms, Global Change Biology, 31, e70372, https://doi.org/10.1111/gcb.70372, 2025.

Korrensalo, A., Mammarella, I., Alekseychik, P., Vesala, T., and Tuittila, E.-S.: Plant mediated methane efflux from a boreal peatland complex, Plant Soil, 471, 375–392, https://doi.org/10.1007/s11104-021-05180-9, 2022.