

Review: Year-round methane cycling activity in a European alpine peatland with large spatial and temporal variability

Summary:

In their research article titled “Year-round methane cycling activity in a European alpine peatland with large spatial and temporal variability”, the authors present manual chamber methane flux measurements from an alpine peatland performed during seasonal field campaigns in 2024 and 2025. In an extensive summer campaign in July 2024, the authors measured at a higher spatial resolution. Key findings of the study are that CH₄ fluxes at the researched peatland are much higher compared to CH₄ fluxes reported in previous peatland studies and that both seasonal and (small-scale) spatial heterogeneity in CH₄ fluxes are high. Non-uniform inflow of spring water is mentioned as the most likely reason for spatial heterogeneity in soil properties and microbial communities and consequently in CH₄ fluxes.

Relevance:

The overall topic of the study is interesting and relevant – most of all the discussion of differences between boreal and alpine peatlands and the proposed influence of small-scale variability in water sources on CH₄ fluxes.

Major comments:

While the overall topic and conclusions of the study are interesting and relevant, the study suffers from several conceptual limitations and shortcomings in the presentation of the study results. Conceptual limitations make the study less relevant as a stand-alone study but in my opinion a publication of the manuscript could still motivate further research on the influence of different water sources on the spatial heterogeneity of CH₄ fluxes in sloping peatlands. While conceptual limitations in data collection can hardly be addressed at this point, shortcomings in the presentation of study results should be revised.

A major conceptual shortcoming is that CH₄ fluxes were not measured in the same locations in all sampling campaigns. While the authors mention that “aiming for the same spots was of limited value” (l. 135, 136) I think that the reported high spatial variability in CH₄ fluxes shows that the meaning of seasonal comparisons of flux ranges measured at different locations might be limited. Furthermore, I think that this limitation of the study is not sufficiently discussed in the manuscript (other than claimed in l. 136). Locations of chamber measurements and their numbers should be reported for all measurement campaigns.

Similarly, soil sampling was not performed at the same locations as the flux measurements. The suggested relationships between soil properties and CH₄ fluxes therefore remain purely speculative. To visualize and support the discussed relationships between soil properties that were measured in the same locations (methanogen and methanotroph abundance, TOC, C:N ratio, soil temperatures), scatter plots should be used in addition to the maps in figures 5 and 6. Please specify also during which campaign(s) the soil sampling was performed.

Additionally, the sampling and analysis of spring water is mentioned in the methods section but the measurement results are not reported nor linked to the other data. Results should be reported to potentially support the assumption of “input of redox-active components” (l. 36). I would have been helpful to sample the pore water in the peatland in the same locations as flux measurements and soil sampling and compare the concentrations of components found in the spring water.

Only water composition and temperature are discussed as a potential reason for spatial heterogeneity in CH₄ fluxes. What about water table depth? How did this vary across the peatland?

The section about winter CH₄ fluxes (ll. 494 ff) should be supported by visualizing the relationship between CH₄ fluxes and snow depth as from the text it is difficult to tell whether there is actually a correlation there.

It could be considered to report standard deviations instead of only value ranges to more directly give a measure of spatial heterogeneity.

In my opinion, the result & discussions chapter would benefit from a restructuring: I would be in favour of separating results and discussion. This way key findings can be highlighted more clearly and individual data can be better connected by avoiding repetitions. Furthermore, a Conclusion section should be added, among others containing the information given in ll. 538 ff. The results section could also be made easier to follow by starting with the overall fluxes ranges and the seasonal variation and then going into detail about spatial variation investigated in the extensive summer campaign, following the same order as the abstract.

The manuscript would furthermore benefit from an overall language check to improve reading flow.

Minor comments:

Abstract: Throughout the abstract, in the CH₄ flux unit m² should be changed to m⁻²

l. 24: in l. 33 it is mentioned that chambers were used for flux measurements in the intensive summer campaign. Already in l. 24 it should be mentioned that chambers were used for flux measurements in all campaigns.

L. 26, 27: I think it would be better to be consistent with how to report ranges of values throughout the paper and to use “to” instead of “-“ as the latter might be mistaken as a minus sign.

l. 71-91: This paragraph should be linked more directly to the study objective. Right now it puts the relevance of identifying environmental controls on CH₄ fluxes into the context of climate change while the relevance of environmental controls for this study lies in explaining temporal and spatial variability.

l. 48: Root and shoot length are plant characteristics that may influence the effects of plants on CH₄ fluxes. As potential plant effects in addition to plant-mediated gas transport, also the provision of substrate for methanogenesis through root exudates, plant litter and labile C release through photosynthesis could be mentioned. As it is mentioned in the introduction, the potential effect of spatial heterogeneity in vegetation on CH₄ fluxes reported in this study could also be discussed in more detail in the manuscript.

In the site description, climatic conditions at the site should be characterized by providing annual, winter and summer mean temperatures and precipitation.

l. 115: The sentence about the sources of the maps interrupts the flow of the text. Consider moving this information to the respective figure captions.

l. 116 Which time period does the reported snow cover average refer to? It would be good to give this information specifically for the study period?

Figure 1: Make one line in figure panel A dashed to make it color-blind friendly.

l. 148 CO₂ and CH₄ “concentrations”

l. 175 “depth” or “thickness” instead of “deep”

l. 180 Were those replicate soil samples or repeated measurements of the same soil sample?

l. 204 For how long were the water sampled stored? Were they acidified to conserve DOC concentrations?

l. 213: CH₄ – 4 as subscript

l. 236, 237 Remove this sentence as it is a repetition from the methods section. Instead start by stating the key point of the paragraph such as “Summer CH₄ emissions from the Auenfeld alpine peatland were high compared to CH₄ fluxes reported for other peatlands”

l. 238, 239 Are these spatial and temporal averages?

l. 245 Mention the Wei reference only once

Figure 2: move this figure to part of the text where it is referred to (3.2.2)

Figure 3: mention what cold and warm means in terms of temperatures and in which campaigns this refers to. This information is only given later in the manuscript (3.2.1).

Figures 5 & 6: Create scatter plots of variables that were measured at the same time and at the same location, i.e. methanogens, methanotroph abundance, TOC, C:N ratio, soil temperatures to more directly show discussed possible relationships. Mention in the figure caption when the shown data was collected.

l. 447 remove permill sign, change “dependent” to “dependency”

l. 502 to support the hypothesis with the spring water even more it could be said that (when air temperatures are cold) snow usually has an insulating effect so that soil temperatures underneath the snow cover would be expected to be higher than in snow-free areas

l. 510 does “several locations” refer to snow-free areas only or considering all measurement plots?

Figure A2: where were the measurements taken in the other campaigns?