Reviewer comments for Preprint bg-2023-43 'Temporary stratification promotes large greenhouse gas emissions in a shallow eutrophic lake'

Overall comments

In this study, greenhouse gas (GHG) samples were taken over a 6-month period from a shallow lake in Denmark with the aim of understanding stratification and mixing effects on GHG fluxes. The paper provides an interesting data set, with surface and bottom water GHG concentrations resolved in addition to ebullitive fluxes. The identification of turnover as a highly transient event that can contribute significantly to lake GHG budgets is an important finding.

The paper is well written, the figures are clear and the discussion provides a succinct description of the findings. I have two main points for the author to review, and also provide some minor editorial comments.

The key question of this study was to understand how ebullitive and diffusive fluxes of the key GHGs: CH_4, CO_2 and N_2O respond to temporary thermal stratification. However, N_2O is not mentioned in the discussion in this paper and I therefore do not feel that the question has been adequately addressed. How important was N_2O in the overall lake budgets, and were accompanying nutrient data able to help understand nitrification/denitrification pathways that might result in flux changes through stratification and mixing? I also felt that the discussion was heavily weighted towards CH_4 though the key question concerns all major GHGs. I would have expected that CO_2 undersaturation might have been detected via headspace sampling at times of high algal productivity, as has been observed in shallow lakes in the tropics (e.g. Borges et al. 2022) and that this would mean the lake is a CO_2 sink at some points. That this did not occur is of interest. It is also important to note that in lakes with pH > 7.5 there is a need to further correct headspace derived CO_2 data, as outlined in Koschorreck et al. 2021, to account for chemical equilibration of the carbonate system.

The discussion does not place the fluxes reported in this study in a wider context with the exception of a brief comparison of mean CH_4 fluxes to a global study by Rosenterer et al. (2021). I therefore found it difficult to understand how important or significant the fluxes were from this lake. I think there should be more explicit comparison across all three GHGs with comparative studies from both equivalent climate zones and in a global context.

Minor comments

Line 27-28	Missing 'for' – change to "also the need for high frequency measurements of GHG emission in 28 order to accurately characterise emissions from temporarily stratifying lakes."
Line 35	Should this be 'Freshwaters'?
Line 55	'Identity' is a bit odd in this context
Line 72-74	Add reference here
Line 119	Sampling duration not clear. State start and end point of sampling.
Line 120	Measurement according to 'Danish standard procedures' doesn't mean much for international readers. A brief additional explanation would be beneficial.
Line 128	Did water level changes influence the relative distance between the surface and bottom water sampling points over the sampling duration?
Lines 191-203	This seems like material for discussion rather than methods as it critiques the method applied rather than describes it objectively.
Lines 212-213	The GWPs cited come from two separate IPCC reports. The latest report, AR5 (though AR6 is due imminently…), states the 100 yr time horizon GWPs for

	methane and nitrous oxide as 28 and 265 respectively. Suggest using these for consistency.
Line 230	Remove interpretation from results 'likely limited by nitrogen (Søndergaard et al., 2023)'
Line 231	Change to 'mixing event'
Line 240	Change to 'coincident'
Line 294	Remove 'massive'
Line 302	Remove more from 'more lake-wide driver'
Line 306-307	This sentence is confusing. Do you mean: '6 Thus, whilst we do not have direct evidence it seems more likely that these increased emissions in the littoral zone were driven at least in part by the partial, wind-driven mixing of the GHG rich bottom waters.'?
Line 318	The Wik et al (2013) study was focussed on Arctic lakes and found a seasonal shift in contribution of ebullition to total methane flux whereby the dominance of shallow zone bubble CH_4 fluxes decreased over summer relative to an increase in intermediate and deep zone fluxes. This suggests a strong temperature control. Perhaps a caveat could be added to this comparison for clarity.
Lines 327-335	Agree, and important to state, but equally weekly headspace sampling has some of the same issues whereby GHG fluxes resulting from highly dynamic mixing/stratification processes may not be adequately resolved. I see this caveat has been added later in the discussion (lines 400-401). I suggest adding in that eddy covariance flux measurements are a way to achieve high temporal resolution data to characterise these processes, including the turnover flux that is described as occurring over just a few hours (e.g. Erkkilä et al. 2018; Podgrajsek et al. 2014).
Lines 382-384	Nutrient enriched sediments would likely provide a stable source of organic matter as redox conditions promote internal loading from sediments.
Table 1	Add standard deviations and how many observations (n) informed the mean.
Figure 1	Where is the Aqua troll located?
Figures 3-5	Suggest merging into one figure with multiple panels
Figure 7	I am not sure this works as a line plot. Perhaps just plot the data as points, otherwise huge step changes in ebullition fluxes are implied.

References

Alberto V. Borges, Loris Deirmendjian, Steven Bouillon, William Okello, Thibault Lambert, Fleur A.E. Roland, Vao F. Razanamahandry, Ny Riavo G. Voarintsoa, François Darchambeau, Ismael A. Kimirei, Jean-Pierre Descy, George H. Allen, Cédric Morana Greenhouse gas emissions from african lakes are no longer a blind spot Sci. Adv., 8 (25) (2022), Article eabi8716, 10.1126/sciadv.abi8716.

Erkkilä, K.-M., Ojala, A., Bastviken, D., Biermann, T., Heiskanen, J. J., Lindroth, A., Peltola, O., Rantakari, M., Vesala, T., and Mammarella, I.: Methane and carbon dioxide fluxes over a lake: comparison between eddy covariance, floating chambers and boundary layer method, Biogeosciences, 15, 429–445, https://doi.org/10.5194/bg-15-429-2018, 2018.

Koschorreck, M., Prairie, Y. T., Kim, J., and Marcé, R.: Technical note: CO_2 is not like CH_4 – limits of and corrections to the headspace method to analyse pCO_2 in fresh water, Biogeosciences, 18, 1619–1627, https://doi.org/10.5194/bg-18-1619-2021, 2021.

Podgrajsek, E., Sahlée, E., Bastviken, D., Holst, J., Lindroth, A., Tranvik, L., and Rutgersson, A.: Comparison of floating chamber and eddy covariance measurements of lake greenhouse gas fluxes, Biogeosciences, 11, 4225–4233, https://doi.org/10.5194/bg-11-4225-2014, 2014.