Reply to reviewer #1:

We thank the reviewer for the relevant comments and remarks which considerably improved the quality of the paper. We answered all comments below and we prepared an adapted version of the manuscript in a supplement file where all modifications (suppressions and addings are in red).

1. **Referee:** Fig 4. Assuming that the figure show represent average gas composition in the bubbles being present in the ice, this graph is very interesting because it show a CH4 contribution of at the most 10 % of the bubble content (actually it would be interesting to sum all gases because most of the important gases seem to have been measured).
   Response: Indeed, *this is what the "mixing ratio" is all about: proportion in volume or number of moles of the sum of all gases present*

2. **Referee:** In summertime ebullition CH4 levels are generally much higher so just figure 4 in itself indicate (1) that most gases come from exsolution and (2) that in bubbles caused by ebullition there is substantial exchange with dissolved gases and probably substantial methane oxidation. This should be discussed more in my opinion.
   Response: *A sentence has been added in the last paragraph of section 5.3 to emphasize this pertinent remark!*

3. **Referee :** P 9640 L 17-18: "Most available studies on boreal lakes have focused on quantifying GHG emissions from sediment by means of various systems collecting gases at the lake surface…": Gas collection systems at the lake surface cannot alone say anything about the sediment release because of water column processes. I think it would be more correct to write "Most available studies on boreal lakes have focused on quantifying GHG emissions from water by means of various systems collecting gases at the lake surface…"
   Response: *Adapted in the revised manuscript.*

4. **Referee**: P9642 L5-6: Is it correct that no CH4 fluxes are included in the climate models so far or do you mean that lake CH4 emissions are not included?
   Response*: Yes, we added a reference for this affirmation (Koven et al,. 2011). Citation: "None of the models of C^4MIP accounted for the climate feedbacks of natural CH_4 sources, …"*

5. **Referee:** P9643 Methods section: I find the methods section too brief. Even if there are references for used techniques I think short descriptions of all steps as performed are necessary. The quality of the data crucially depends on very practical work regarding processing of the cores and gas extractions taking pressure, potential leakage and other things into account. It is would be good if the readers (also those not familiar with the techniques and equipment used) can evaluate if all details were considered and successfully addressed without having to read a large number of cited papers. So, I think more details are needed.
   Response: *The methods section has been improved. See the revised manuscript for details.*

6. **Referee:** P9646 L15-20: It is stated that gas concentrations of methane are underestimates because of the sampling procedures. Please provide more method details and explain why and how the samples become underestimates.
   Response: *The methods section has been improved. See the revised manuscript for details.*

7. **Referee:** P9649 – 9652: I am not sure I understand the modelling of water concentrations in this discussion and in Figure 6 and 7.
   Response: *Misleading in the text indeed!...This whole section has been rewritten, the method supported with conceptual diagram, caution taken to dissociate "concentration" and "mixing ratio" concepts.*

8. **Referee:** Some assumptions are clearly wrong because it is well known that at least CO_2 and CH4 surface water concentrations are typically highly supersaturated in systems like those studied and I would not surprise me is such information is available from the studied lakes given the proximity to Stordalen where many GHG studies have been performed throughout the years.
   Response: *The model has been adapted in two ways in the revised manuscript, first, it uses the available local values of CO_2 concentration in water and second, it takes into account the carbonate system (using the CO2Calc software from the USGS).*

9. **Referee:** Hence, even very high concentrations in ice bubbles could indicate exsolution and the actual concentration will be a result of how large water volume that exchange gas with the bubble in the ice (larger water volume means larger concentration) and the water volume will depend on the water mixing under the ice which is difficult to predict because it may vary spatially and over time.
   Response: *The term "high concentration" is misleading here… I guess the reviewer means high ice concentrations in moles gaz/kg of ice. In that case, indeed, the more supersaturated the water at the interface, the higher the ice concentrations, and this will depend on water circulation and mixing rates. Here we clearly state in this very simple study case that no water is advected in the lake (closed system). Mixing on the vertical will clearly be limited by the stable temperature-driven density profile during the whole freezing period. This will therefore hamper homogeneization of rejected gases through the freezing process into the whole remaining water reservoir. Our simple approach therefore indeed potentially underestimates the level of supersaturation at the ice-water interface (since it redistributes implicitely all the moles of gases remaining in the water in the whole reservoir at each step). However, as stated in the new version of this section, this should not affect our results since we used the* ***observed*** *total gas content in the ice to reconstruct the theoretical concentrations and mixing ratios in water and ice.*

10. **Referee:** There are many processes in or under the ice that can affect concentrations of many of the studied gases even after the system was covered by ice. For example, algal growth under clear ice is well known and should affect CO2 and O2 concentrations. Similarly, respiration under dark or snow covered ice cold affect O2 and CO2 as well. Further, CH4 oxidation can affect CH4 concentrations, and possibly to a small extent O2 and CO2 concentrations, in the water and in bubbles underneath the ice.

Response: *Indeed!...This is why the model is only designed as a way to picture what would happen if the gases are only considered as passive tracers! We have insisted on this in the new manuscript*

11. **Referee:** Some of these processes are discussed in relation to the figures, - eg P9651 L14-18 "In our case, the similarity of the reconstructed CH_4 and CO_2 concentration profiles in water in most lakes (Fig. 6, middle and right panels) suggest that acetate fermentation might be the dominant extra CO_2 source at work, as opposed to methane oxidation. This also puts forward acetate fermentation as the source for methane." - but, even if some statements appear likely given fundamental previous findings in biogeochemistry, I cannot see how the available data in figure 6 or 7 support statements about dominating processes and I can see many alternative explanations. In the example above the similarity between CO_2 and CH_4 profiles can simply be related to physics like exsolution and water movements along with ice development. In addition it is not clear why N_2 decrease and O_2 increase with depth in the models (Fig 6 and 7) and such behaviour seems not to be supported by data in Figure 4. ***Response****: This example illustrates, in our opinion, the whole interest of comparing observed mixing ratios in the ice (Figure 4) with theoretical closed system ones (Fig. 7b) and comparing theoretical closed system water concentrations (diamonds in Figure 6) to reconstructed water concentrations from observed mixing ratios in the ice (triangles in figure 6). As far as bubbles mixing ratios are concerned, the increasing trend with depth seen in the theoretical values is globally seen in the observed profiles for the lakes that function in "closed system" (not lake 3), but the level of those mixing ratios, both for CO_2 and CH_4, indicate additional sources of both CO_2 and CH_4, with a positive synergy between the two gases, more clearly seen in the reconstructed water profiles of figure 6b. This synergy supports acetate fermentation, as opposed to methane oxidation that would make both profiles go opposite directions. The curves of figure 6 further allow discussion of the source for the CO_2 when comparing to the O_2 curves, as done in the paper.*
For Figure 7, data are plotted in terms of mixing ratios. Because of lower N_2 solubility, it is included in the bubbles earlier on in the freezing process as compared to all other gases. This means that its relative proportion in the water (Fig 7a) will decrease as freezing progresses, while the relative proportion of all the other gases will increase. This is then also reflected in the mixing ratios trends for the bubbles (Fig. 7b). The more closed the system, the stronger the effect (e.g; hardly any change for lake 3 in Fig. 7b, for example). It is indeed precisely the interest of the comparison to show that the real data go the opposite way, pointing to respiration processes, at least below 20-40 cm depth (Fig. 6a, col. 1 and 2).