December 29, 2014

Response to **Anonymous Referee #2**

We are grateful for this reviewer's comments on our manuscript. Based on their comments and suggestions, we have revised our manuscript in an effort to improve it and address their concerns. Below is our response to each of their comments (reproduced in bold).

The study describes methane and carbon dioxide emissions from lakes in Alaska having differences in their latitudinal location and physical/chemical characteristics. An interesting aspect is that the transect studied allows comparison of yedoma and non-yedoma related lakes. Some comments and suggestions below.

Abstract. In the abstract the relationships between methane emissions and lake characteristics are considered but carbon dioxide is neglected. Carbon dioxide should be included here because this gas is included to the study, and mentioned also in the title.

We have revised the Abstract by adding a new sentence with some suggestions for why we found a weak relationship between carbon dioxide emissions and geographic/limnological parameters.

Introduction/Discussion. When discussing/comparing the atmospheric impact of methane and carbon dioxide emissions, the limitations of the emission measurements could be commented, this is relevant especially for carbon dioxide. The lakes receive organic matter from their catchments and part of that is finally accumulated into the sediments. The C emitted/C accumulated ratio varies a lot (from 4 to 86) between various northern lakes (Global Biogeochemical Cycles 27: 363-374, 2013) and this could be considered when evaluating the real climatic meaning when analyzing only the emissions. In the present study there are great differences between the nutrient status of various lakes and this can have an important effect on their ability to retain carbon. For example, increasing nitrogen availability increases the C emission/C accumulation ratio meaning that nitrogen rich lakes have lower capacity to sequester carbon at landscape level than nitrogen poor lakes (Global Biogeochemical Cycles 27: 363-374, 2013). So, some discussion between lakes (e.g. yedoma and non-yedoma lakes) could be given by considering the real C balance at landscape level.

It is very interesting that nitrate concentration in 82 boreal lakes in Finland was found to be a strong controlling factor of the C emission/C accumulation ratio (Kortelainen et al., 2013). We have revised both the Introduction and Discussion of our manuscript to bring this interesting relationship into light as a potential controlling factor of CO_2 emissions in our Alaskan study lakes and ultimately in the long-term role of lakes in emitting versus sequestering carbon. Please see the following revised sections: New sentence added to first paragraph of the Introduction; New final two sentences in Sec. 4.2; new final sentence added to 4.5 *Climate warming impacts of Alaskan lake emissions*. We also mentioned in the Discussion the limitations of our methods for fully exploring the relationship between nitrate availability in lakes and their ability to sequester carbon since we did not find a significant relationship between CO_2 or CH_4 emissions and nitrate, no differences in nitrate concentration between yedoma and non-yedoma lakes, nor did we measure the long-term carbon sequestration rates in our study lakes. We acknowledge that this relationship should be the subject of more detailed study in the future since nutrients can control the capacity of lakes to sequester (versus emit) carbon.

Discussion. P. 13278 Lines 6-10: There are also earlier observations that area of northern lakes correlates negatively with their methane emissions (Biogeosciences 6: 209-223, 2009).

We thank the Reviewer for the reference. We have revised the manuscript to include this reference (Juutinen et al. 2009) as well as reference to a new relevant study (Rasilo et al. 2014). We also added to this paragraph a brief comment about small (yedoma) lakes tending to develop more noticeable anaerobic hypolimnia than large (non-yedoma) lakes.

Lines 12-23: Yedoma-lakes had higher DOC content which would favor carbon dioxide production as stated. Some comments on the effects of quality of DOC could be given because there are observations that not only the quantity but also quality of DOC is important for the carbon dioxide emissions from northern lakes (Global Change Biology 12: 1554-1567). Would yedoma derived DOC be more easily decomposable?

We agree with the Reviewer that links between DOC quality as well as quantity could be made with respect to CO_2 production in lakes. We addressed this comment by including in Sec. 4.2 a discussion of the potential importance of both DOC quantity and quality in CO_2 emissions from northern lakes (Kortelainen et al. 2006) as well as an example from a recent study by Vonk et al. (2013). Vonk et al. showed that Pleistocene-aged DOC mobilized in stream water draining yedoma outcrops is exceptionally biolabile among contemporary fluvial systems in the Arctic, suggesting that yedoma-derived DOC in lakes may be more easily decomposed than non-yedoma DOC.

Conclusions. The first sentence concluding that the study shows northern lakes to be net source of methane and carbon dioxide is not very novel, it is generally known, and could be excluded.

As suggested, we removed the first sentence from the Conclusions.

We thank the reviewer for the time and thought they put into their comments, which have helped us improve our manuscript. We hope that our revised manuscript will be considered suitable for publication in *Biogeosciences*.

<u>References cited</u>

Juutinen, S., Rantakari, M., Kortelainen, P., Huttunen, J. T., Larmola, T., Alm, J., Silvola, J., and Martikainen, P. J.: Methane dynamics in different boreal lake types, Biogeosciences, 6, 209-223, 2009.

Kortelainen, P., Rantakari, M., Huttunen, J. T., Mattsson, T., Alm, J., Juutinen, S., Larmola, T., Silvola, J., and Martikainen, P. J.: Sediment respiration and lake trophic state are important predictors of large CO2 evasion from small boreal lakes, Glob. Chang. Biol., 12, 1554-1567, 2006.

Kortelainen, P., Rantakari, M., Pajunen, H., Mattsson, T., Juutinen, S., Larmola, T., Alm, J., Silvola, J., and Martikainen, P. J.: Carbon evasion/accumulation in boreal lakes is linked to nitrogen, Glob. Biogechem Cyc. 27, 363-374, 2013.

Rasilo, T., Prairie, Y. T., and Del Giorgio, P. A.: Large-scale patterns in summer diffusive CH_4 fluxes across boreal lakes, and contribution to diffusive C emissions, Glob. Chang. Biol., in press, 2014.

Vonk, J. E., Mann, P. J., Davydov, S., Davydova, A., Spencer, R. G. M., Schade, J., Sobzak, W. V., Zimov, N., Zimov, S., Bulygina, E., Eglington, T. I., and Holmes, R. M. High biolability of ancient permafrost carbon upon thaw. Geophys. Res. Lett. 40, 2689-2693, 2013.