**Interactive comment on "The effect of warm summer 2012 on seasonal and annual methane dynamics in adjacent small lakes on the ice-free margin of Greenland" by Sarah B. Cadieux et al.**

Anonymous Referee #2
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*response from authors is in blue

With a little focusing this interesting study could be a gem. The study demonstrates two mechanisms by which warming temperatures in Greenland could affect methane dynamics in small lakes. The first is during open water, increased stratification of the water column, which would presumably result in greater methane release during fall overturn and less overall methane oxidation. The second mechanism is that greater temps will result in less overall ice cover which would cause less methane storage un- der the ice and presumably more overall oxidation. These two processes or effects of increased temperature would seemingly have contradictory effects. I don't know the extent to which these two processes effects have been expounded in the literature, but this is the first time I've seen them presented. I would thus suggest to the authors that they make more of these observations, highlighting them in the abstract, and particularly in the article titles, which is rather weak right now, in my opinion. Perhaps something like " The contradictory nature of warming effects on lake methane emissions: increased stratification during ice free periods versus reduced ice cover." Needs work, but something along those lines. I would also suggest that these unique observations be expanded into a conceptual model in the discussion and conclusions.

Thank you for this positive review of our paper.

The reviewer has a valid point that the title could be modified to be more compelling. We have taken this into consideration and revised the title to: *"Exceptional summer warming leads to contrasting outcomes for methane cycling in small Arctic lakes of Greenland"*

Specific comments.

1. abstract. See above. ALSO focus on the effects these processes will have on overall annual lake methane emissions. That's what's important. You may not have the data, but speculate, and call for attention to what your have observed so it can be followed up.

We agree with the reviewer that adding more regarding the possible overall methane emissions and highlighting the shift from spring emission to fall emission is important to highlight in the abstract. The later part of the abstract has been revises as follows to include these suggestions: "*In all of the lakes, mean methane concentrations under ice-covered conditions were significantly ($p < 0.0001$) greater than under open-water conditions, suggesting spring overturn is currently the largest annual methane flux to the atmosphere. As the climate continues to warm, shorter ice cover durations are expected, which may reduce the winter inventory of methane and lead to a decrease in total methane flux during ice-melt. Under open-water* *conditions, greater heat income and warming of lake surface waters will lead to increased thermal stratification and hypolimnetic anoxia, which will consequently result in increased water column inventories of methane. This stored methane will be susceptible to emissions during fall overturn, which may result in a shift in greatest annual efflux of methane from spring melt to fall overturn. The results of this study suggest that inter-annual variation in ground-level air temperatures may be the primary driver of changes in methane dynamics because it controls both the duration of ice over and strength of thermal stratification."*

2. page 3, lines 90-95. Your hypothesis. Why did you hypothesize that warmer conditions would lead to higher methane concentrations? Say "increased stratification" here. Explicitly state it. Advance a hypothesis about ice cover. Return to these hypotheses in your discussion.

We hypothesized that warmer conditions would lead to higher methane concentrations, because warmer conditions would lead to increased stratification. This sentence has been revised to increased stratification in order to clarify.

The reviewer makes a good point that a hypothesis should be stated regarding ice cover. Accordingly, the following hypothesis has been added about ice cover: "*The study lakes are ice-covered for 9-10 months of the year, leading us to predict that methane concentrations would be significantly greater under ice-covered conditions as opposed to open-water conditions."*

3. Lines 95-100. Permafrost soil? Anything you can tell us about it? Peat? Mineral soil? OM content? Does it thaw under the lake (thaw bulb) to make the methane you observe?

The soil is composed predominantly of till and glaciofluvial deposits. While there are talics in the area, our observations do not suggest there are talics below any of the study lakes here. In response to this comment, we have added the following sentence to further define soils in the region: *"Soils in the region are not well-developed, composed of till and glaciofluvial deposits (Van Tatenhove and Olesen, 1994)."*

4. line 112. define GIS

GIS stands for the Greenland Ice Sheet, and has been defined in the text accordingly. It is also defined in the introduction.

5. line 126 define EVV

EVV stands for Epidode Vein Valley and is an informal name to describe an outcrop close in proximity to the lakes. We have revised the study area section to include further information regarding the names of the lakes: "*The lake names used herein (EVV Upper Lake, EVV Lower Lake, Teardrop Lake, Potentilla Lake and South Twin Lake) are informal based on local surficial features"*

6. line 211. what is Clinograde?

A clinograde oxygen profile is when dissolved oxygen values decrease with depth. This term is defined in the later part of the sentence:*"wherein DO was saturated and in equilibrium with the atmosphere in the surface waters and became increasingly under saturated down the water column."*

7. line 225. "moderately brackish salinity? What was the salinity in o/oo? Is "brackish" the right term? Like 5-10 o/oo?

These are terms from Stewart and Kantrud paper, which has been added to the references. In terms of salinity, brackish here would be >2 ‰.

8. Line 307-308. confusing. Is the sentence messed up?

This sentence did need to be clarified. It has been revised to state: "*In the water column, $CH_4$ concentrations are directly related to both conductivity and DOC, wherein high $CH_4$ concentrations correspond with both high conductivity and DOC."*

9. Line 308 do you mean figure 8? Not 7?

Yes, thank you

10. Line 315 sulfate reduction not sulfur.

Done. Thank you

11. Line 352. Inversely related?

Yes, this should be inversely related and has been revised.

12. Lines 415-425. I don't follow this too well. How do you know that the % of CH4 oxidized is the same over the two years? Do you have measurements of MOX> ? Doesn't this kind of blow your theory that more temp and more stratification will result in more methane release with fall overturn? How is the MOX the same across years, or even known at all?

The way we determined that the same amount of $CH_4$ was oxidized was by assuming all the methane in the surface water originated from the sediment. By doing that, what is at the surface is a percentage of the initial methane (at the sediment-water interface). Therefore, we don't have the measurements of MOX, just an estimate of the % of methane oxidized. We have revised this paragraph to emphasize that this isn't an estimate of MOX, but an estimate of the amount of methane oxidized.

Even though the amount oxidized at the time of stratification is the same, it doesn't change that under warmer conditions with increased stratification in 2012 there is more methane in the anoxic waters, which is what would be emitted during fall overturn.

13. Develop around line 425-460 the effects of a shorter ice covered period. Make a solid conceptual model centered on your figures. What is the interplay between increased stratification during ice free in contrast with less ice cover? How does this interplay affect annual methane flux as temperatures warm> I would think that there would be less MOX under stratified conditions, and certainly less under ice.

We agree with the reviewers concern and expanded the relevant discussion to better articulate the conceptual model as informed by our results: "*In addition to a decrease in ice cover, our results also suggest an increase in ground-level air temperatures will result in enhanced thermal stability and anoxia in Arctic lakes, as we observed during open-water conditions in 2012. The duration of open-water thermal stratification will also likely increase in concert with the decrease in ice cover. The combined effects of extended season and greater strength of stratification are likely to be development of higher $CH_4$ inventories in the water column during open-water periods. Conceptually, as anoxic zones expand in space and duration, the influence of methanogenic sediments on water column inventories of methane should increase. Currently, small lakes emit substantially more $CH_4$ per unit area than larger lakes during open-water conditions (Bastviken et al., 2004; Cole et al., 2007; Juutinen et al., 2009). Small, shallow likes are more susceptible to thermal change due to increased ground-level air temperatures and will likely continue to be major $CH_4$ contributors to the atmosphere. In fact, our results suggest that increased warming in the Arctic will result in greater summer inventories of $CH_4$ and consequently larger emissions of $CH_4$ to the atmosphere during autumn overturn in small lakes.*"

14. Conclusions. Point out that these two processes are contradictory.

In response to this suggestion, the conclusions have been revised to explicitly point out that these two processes are contradictory, leading to the inclusion of the following sentence: "*We predict that as the climate continues to warm, the greatest annual efflux of $CH_4$ from small arctic lakes will shift from spring overturn to fall overturn.*"