Biogeosciences Discuss.,
https://doi.org/10.5194/bg-2017-566-RC2, 2018
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Biogeosciences Discussions

# *Interactive comment on* "Impacts of temperature and soil characteristics on methane production and oxidation in Arctic polygonal tundra" *by* Jianqiu Zheng et al.

**Anonymous Referee #2**

Received and published: 29 March 2018

The manuscript "Impacts of temperature and soil characteristics on methane production and oxidation in Arctic polygonal tundra" of Zheng and co-authors presents results from incubation experiments of samples from two polygon centres of the arctic tundra in Alaska. The authors sectioned two cores in three layers (active layer, transition zone, permafrost) and incubated samples of these layers under either aerobic or anaerobic conditions. They measured methane (CH4) production in the anaerobic layers and CO2 production and CH4 oxidation in all of the layers at three different temperatures (-2°C, 4°C, 8°C). Furthermore they measured low molecular weight fatty acids and ferrous iron concentrations at three time points of the incubation experiment and gradients of dissolved CO2 and CH4 concentrations at the field sites. From the data of the tem-



perature incubation experiments they calculated Q10 values for CH4 production and oxidation at each depth layer at the two sampling sites.

The manuscript presents potentially interesting data but the study seems not clearly focussed. The main part of the study deals with CH4 production and oxidation but one of the main novel conclusions is that iron reduction is more important for the anaerobic degradation of organic matter than methanogenesis. This would be an interesting result but the methodology and data used to support this this conclusion remain unclear. It is unclear how the authors assessed the importance of methanogenesis and iron reduction. The authors present acetate concentrations and then calculate how much of this acetate was consumed by methanogenesis and iron reduction (Fig. 8). However, it remains unclear how this was done. Acetate concentrations in the soil are a function of acetate production rates e.g. by fermentation and acetate consumption rates e.g. by methanogenesis and iron reduction. Hence concentrations give no information about production rates. Furthermore, the description of the experiments and analysis is in many parts unclear (see also specific comments). It is difficult to follow the incubation experiment and in particular the CH4 oxidation experiment. Samples were incubated at different temperatures to measure the temperature response of CH4 oxidation, but they seem to have been also pre-incubated, but at different temperatures at the different sampling sites. This is confusing and should be clarified. One of the two hypothesis rather states current knowledge than a novel research idea. Furthermore, the aim of some of the presented approaches in the manuscript remain obscure, e.g. the "calculation of net CH4 emissions" (2.5).

specific comments

P1, L23: To my knowledge, high latitude terrestrial ecosystems are a clear CH4 source, even if atmospheric CH4 may be oxidized in dry soils. Please rephrase.

P2, L14: See comment above.

P3, L12: This might be right for the oxidation of atmospheric CH4, but for wetlands,

showing substantial CH4 production, this is not the case. Generally, highest CH4 oxidation is found in wetlands at the aerobic/anaerobic interface, which is close to the water table.

P3, L32: This sentence is unclear. Why is additional research on CH4 oxidation needed to improve estimates on CH4 production? Please rephrase.

P4, L1: Please specify the carbon decomposition pathways investigated.

P4, L5: This is not a hypothesis but well established textbook knowledge.

P5 L24ff: Please clearly explain, which samples were incubated aerobically and which anaerobically. I assume the samples treated in the anaerobic chamber were also incubated anaerobically but this is not stated.

P6 L4ff: Which samples? Are this the same "microcosms" than presented in 2.3.1? and how much is ample?

P6 L9: Why are there two different incubation temperatures for FCP and HCP? I understood from the preceding sentence that the samples were incubated at the tree different temperatures -2°C, 4°C and 8°C. Please clarify.

P6, L20: Please cite the method for Fe2+ measurements.

P6, L25: Table S3.

P7, L3ff: The concept presented here is unclear. What is the aim of these calculations? Do the authors aim to calculate CH4 emissions as stated in the header? Please clarify. Furthermore, some of the assumptions are probably not met. It is unclear why the rate of CH4 oxidation should equal the rate of CH4 production? This would mean zero emission of CH4. Is this likely? And finally the authors assume a certain Km-value for CH4 and O2 and also give a very wide range of reported Km values. It should be explained why these particular Km-values were chosen. And how would a change in the Km-values affect the calculated biomass of methanogens and methanotrophs.



P7, L19ff: It would be interesting to see the water content related to soil volume. The different depth layers show substantial differences in organic carbon concentrations, which likely are also related to substantial differences in bulk densities.

P8, L1ff: Dissolved gas concentrations should be calculated based on volume soil pore water (e.g. as $\mu$M). Relating it to dry weight is misleading considering that gas cannot be dissolved in a solid.

P8, L5: If no CH4 was detected, does this indicate the oxidation of atmospheric methane in the soil? The detection limit was given as 1 ppm, which is below atmospheric concentrations.

P8, L7: Which statistical test was used to test for significance?

P8 L9ff: Better give the carbon concentrations together with the other profile data in Fig. 1. What about the carbon concentrations above 10 cm soil depth? If these are missing, a general comparison between active layer and the other samples is problematic, since generally active layer carbon concentrations are highest at the surface.

P8, L30: What means 0 and 5 days? Were they pre-incubated for 5 days with CH4? Please clearly explain in M&M.

P9, L12ff: The data on the temperature response of CH4 production and oxidation should not be presented only in the text of the manuscript but also as a graph or table as well. According to the title of the manuscript these data are the most important ones.

P9, L18ff: Please explain the meaning of the error for the Q10 values and how this was calculated.

P10, L15ff: Calculating Q10 values from rates derived from different fitting methods (linear and hyperbolic) at the respective temperatures is problematic. I suggest using only one fitting method for all of the incubation temperatures and then use these data to calculate Q10 values.

P10, L18f: Please explain how the Q10 value was estimated.

P10, L19f: This sentence should go to the discussion.

P10, L23ff: Please explain in the M&M how these fatty acids were analysed.

P10, L30: Please explain how significance tests were conducted. There seem to be no replicate analysis before day 90.

P11, L5: please explain this approach in M&M.

P11, L14: Please explain how the rates were calculated. Over the whole incubation period or only for certain incubation intervals?

P11, L15: How were Q10 values “estimated”?

P11, L28: This sentence is unclear. Why does lower active layer than permafrost CH4 concentrations indicate CH4 oxidation in the active layer? Permafrost CH4 is not released from the permafrost since it is frozen. Please clarify.

P11, L29ff: This statement is incorrect. There are numerous studies on CH4 production and CH4 oxidation in the Arctic also showing that CH4 is produced in the anoxic soil layers and oxidized in oxic soil layers. This is an obvious fact, which likely needs no further testing if there is no evidence against it. Furthermore, differences in the temperature response of CH4 production and oxidation has been shown also for Arctic environments and respective studies were also cited by the authors.

P12, L4f: This statement is not completely correct. It is current knowledge and obvious, that CH4 production depends on both CH4 and O2 supply. Therefore, indeed CH4 oxidation depends on oxygen supply but if CH4 is present. Hence, many studies on CH4 oxidation in wetlands (including those in the Arctic) demonstrate that the oxic/anoxic interface is the zone of most intense CH4 oxidation, which are not necessarily the aerobic surface soil layers, since there, as the authors correctly stated, low CH4 concentrations limit CH4 oxidation. Hence the soil water table is often more in-



formative than the gravimetric water content for identifying the zone of maximum CH4 oxidation.

P12, L30f: The meaning of this sentence is unclear. Do the authors assume, that the main oxygen source in the saturated zone is from dissolved oxygen in rain water percolating through the soil and not from molecular transport through the gas phase through unsaturated pores? Please clarify?

P12, L34ff: Which observations? I do not see that the survival of methanotrophs under changing redox conditions argue against highest CH4 oxidation at the water table. I assume the authors mean here in situ CH4 oxidation and not potential CH4 oxidation measured in the laboratory. It has been shown repeatedly that highest CH4 oxidation is found in the soil layer where elevated CH4 concentrations overlap with oxygen. This is in soils generally close to the water table. However, if the water table fluctuates, potential CH4 oxidation rates measured in the laboratory do not need to correlate with the current water table, but likely in situ CH4 oxidation rates do. There is no way to aerobically oxidize CH4 without the presence of CH4 and oxygen.

P13, L13F: Why should this be? Please explain.

P13, L20f: What is meant by “outcompete”? Methanogens and CH4 oxidizers are not competitors. I understand that it is meant that CH4 production is expected to be higher than CH4 oxidation. But why is this likely. It has been shown that even at 8°C the potential CH4 oxidation with the current community size is 7 times higher than methanogenesis. I would rather say that it is highly unlikely that CH4 production will be higher than potential CH4 oxidation.

P13, L21-L29: This part of the discussion is unclear and in part speculative. The purpose of these calculations was not clearly stated in the description in the M&M section (see above) nor is it here. It might be interesting if the authors would have data on the microbial biomass of methanogens and CH4 oxidizers. But as it is now, it gives no substantial additional information.

P14, L1: Which incubations are referred to? The permafrost only or also the active layer?

P14, L4f: To which samples is referred to here? To the FCP samples and the HCP samples?

P15, L5f: The described pattern was obviously not observed for the HCP in this study. What could be the differences to the cited study?

P14, L9f: It is obvious that organic carbon oxidation processes contribute to anaerobic CO2 production, which is the result of organic carbon oxidation. Please rephrase.

P14, L12ff: This sentence should be split into two. Furthermore, the information content is limited. It seem obvious that CH4 isotopes are consistent with either acetoclastic methanogenesis or hydrogenotrophic methanogenesis since these are the mayor pathways of methanogenesis. Does this sentence mean that acetate is mainly oxidized via methanogenesis and not via iron reduction? This seems to contradict the first sentence of this paragraph.

P14, L15: These calculations should be described in the M&M section. The acetate concentrations are rising during the incubations. Hence, there is a net production over time. But how was gross acetate production calculated? This is not possible from the concentration data alone. The data presented in Fig. 8 are not comprehensible.

P14, L29ff: This last paragraph gives the current and well-established view of organic matter decomposition in wetlands. It might fit to the introduction but is not needed at the end of the discussion. The relative importance of iron reduction versus methanogenesis is an interesting issue but the data collected here does not allow a meaningful comparison of these two processes. Hence, I rather suggest omitting Fig. 9.

Fig 5: Please show in the panels which samples were incubated aerobically and which anaerobically.

Fig. 8: Acetate concentrations rather than acetate production are presented in this



Figure. Please rephrase.

Fig S1: This figure is unclear. What do the red circles mean?

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