

1) GENERAL COMMENTS

This methodological, brief communication paper reports on a comparison of different techniques (wet vs. dry extraction, with or without biocide to test microbial contamination) to extract gas (CH₄ and N₂O) from ice wedges of Alaska and Siberia. The authors report that tested methods yield good results for the easily extractable gas fraction (bubbles), but this is not so convincing for the adsorbed phase or gas contained within soil aggregates. One of the main conclusions, therefore, is that current estimates of ground-ice gas budgets are likely underestimated, as a fraction of produced gases are not taken into account. For me, this is the main take-home message.

It appears as an interesting short paper, although the methodology used is not in my immediate field of expertise. To my knowledge, this manuscript does not have major flaws that should ultimately prohibit its publication. It is generally well written and easy to read. I have however a few points to mention that preclude acceptance for publication as is:

- 1) I am not convinced, for now, of the general, broad-audience impact of the manuscript. Does it really « *report new developments, significant advances, and novel aspects of experimental and theoretical methods and techniques which are relevant for scientific investigations within the journal scope* »? (https://www.the-cryosphere.net/about/manuscript_types.html). The authors have not convinced me that this work is new, innovative or represent a major advancement that is relevant to the community at large. They rather suggest that a future, novel extraction method might provide better results. I am also looking forward to that. This work might be useful for a small specialized group, however. Furthermore, the conclusion about underestimation of current gas budgets in ice-wedge terrains is itself interesting and timely.
- 2) I understand that this is a brief communication and that the number of figures/tables is limited. However, it is really unfortunate that there is no map of the many study sites, and no picture or illustration of field sampling procedures, as well as lab instruments (especially the 'needle crushing system'). It would greatly help to have visual support for such investigations.
- 3) Several sentences contained in the results/discussion section are in fact related to methods. I mention examples in the specific comments section below. The structure of the main text should therefore be re-aligned, so that methods sentences are in the methods section.
- 4) Finally, some statements and conclusions in the main text are either not accompanied by a mention to the results or figure(s) they come from, or not supported by literature reference(s).

Overall, I cannot accept this manuscript for publication as is. If the authors are willing to make major revisions (general points above and specific comments below), I would be happy to review a revised version of the manuscript.

2) SPECIFIC COMMENTS AND EDITORIAL SUGGESTIONS

P= page number, L = line number.

P1, L29. To avoid repetition (soil): choose either « Permafrost preserves large amounts of soil carbon and nitrogen... », or « Permafrost soils preserve large amounts of carbon and nitrogen... ».

P2, L30. I suggest adding 'temporarily': «... temporarily removing this frozen carbon... ».

P2, L30-31. (C) and (N) should be put at the beginning of the section (P1, L29), i.e. the first time that the words 'carbon' and 'nitrogen' are mentioned.

P2, L35. « ... which in turn can trigger positive feedbacks... ».

P2, L38-40. This might be true for Yedoma regions (eastern Siberia, Alaska, Yukon), but not all permafrost is necessarily ice-rich. It should be specified in the paragraph, otherwise we have the impression that permafrost all over the Arctic contains 40-90% of ground ice.

P2, L40. I suggest adding 'Pleistocene': « ... volume of Pleistocene ice-rich permafrost, or Yedoma ».

P2, L42. « ... evidence for in-situ microbial aerobic respiration... ». Why just 'aerobic' conditions? This might be relevant for CO₂ production, but CH₄ and N₂O are generally produced under 'anaerobic' conditions, or both oxic-anoxic.

P2, L43-44. « ... detailed information on in-situ biogeochemical processes responsible for GHG production... ». Which biogeochemical processes? Methanogenesis? Respiration? Other processes?

P3, L58-59. «... because ice wedges are one of the most abundant morphological features... ».

P3, L73-79. For the reader not familiar with the study sites and ground-ice sampling protocols in permafrost landscapes, I strongly suggest adding 1) a map of the study sites (Siberia and Alaska); 2) pictures of an outcrop and sample collection (drilling). This way, the reader would have a much better idea of what the samples and sites look like.

P4, L80-97 and L88-95. Again, all these descriptions and distances would make much more sense if they were accompanied by a map (with sampling sites labeled on the map).

P4, L87. «... on the first terrace of the river... ». Do the authors mean the younger (i.e. lower) terrace?

P4, L96. « The ice-wedge ice... ». This phrase is weird. Suggestions: « The ice from ice wedges is different from polar ice cores, in that... », or « Wedge ice is different... ».

P5, L107. «... 8~13 g of ice sample were crushed... ».

P5, L121-123. Which year for this modern air sample? Please specify.

P7, L175. I suggest 'thoroughly' or 'vigorously' instead of 'well'. («... shaken flasks were shaken thoroughly/vigorously... »)

P8, L187-189. What is meant by this statement about the heterogeneous distribution of samples? How is it shown on Fig. 1?

P9, L195-196. This is a busy figure, see comments below (section 3) FIGURES). Some elements could be removed to enhance clarity.

P10, L208-211. This reads more like methods, not a results and discussion section.

P10, L211-212. How about the Eastern Siberia samples? (triangles in Fig1) Did they also « not show significant differences » between the two sets of tests?

P11, L224. «... polar ice core samples... » (remove the 2nd 'ice')

P11, L230-237. This reads more like a paragraph about methods.

P11, L236-237. This information would be better displayed and more appealing in a figure.

P12, L250-252. This statement is based on what result? Can we see this displayed somewhere in a figure/table? If yes, please refer to it in the text.

P12, L255-260. For the reader not familiar with the needle crushing system, a picture or a sketch of what the apparatus looks like might help. The sentences in this paragraph would be more easily understood.

P13, L280-282. Please refer to results (figure or table) to support this statement.

P13, L288-290. Please support this statement by relevant references. In fact, the simple association N_2O =oxic / CH_4 =anoxic is not entirely and always true. For example, N_2O production has been recorded under both oxic and anoxic conditions (Gil et al. 2017; *Global Biogeochemical Cycles*), as well as CH_4 production from oxic waters (Grossart et al. 2011; *PNAS*). It depends on several parameters, including local hydrology (e.g., water-logged soils). This should be acknowledged in the text.

P13, L292 to P14, L298. This statement is highly speculative. Unless I missed something, this was not tested for real in this study. This paragraph should be supported by real data or removed.

P14, L302-303. Again, this is methodology, not results/discussion.

P16, L320-330. Again: methodology, not results/discussion.

P17, L350-352. This is indeed interesting. Do we know why N_2O appears to be more extractable (or less present in the residual adsorbed phase) than CH_4 , at least based on the wet extraction technique? Was this already observed elsewhere and reported in the literature?

P18, L375. «... easy to extract... »

P19, L397. « Our findings indicate that ... »

3) FIGURES AND TABLES

Figure 1, P9.

- a) This is a pretty busy figure. We don't necessarily need the 3 legends (identical) in the middle. By removing them, more space could be created to enlarge the graphs a bit, because for now they are quite small. Also: what is the purpose of the insets (a-b, e-f)?
- b) I don't get the thing about the error bars (in blue). Are these 5x, 100x or 500x larger or smaller in 'real life' than displayed on the graphs? Not clear.
- c) Explain what does 'hit5' mean.

Table 1, P15.

- a) It is not explained why the hit100/hit5 ratios for gas content (6th column) are much lower for most of the central Yakutia samples (Cyuie), compared to the other sites? This is indeed interesting, but why? Less soil aggregates in ice-wedge samples from this site, so relatively more bubbles and thus more extracted gas?

Figure 2, P18.

- a) Where do the samples come from? CYC-02-B and CYC-03-C likely refer to Central Yakutia (Cyuie), but what about the other samples (C-04, C-30, C-10, C-12)? Please specify somewhere.