1) GENERAL COMMENTS

The paper reports novel aspects of experimental methods of gas extraction techniques. Currently, there are no works that conducted such a comparison, which has long been needed due to huge number of gas measurements in permafrost area conducted recently. Unfortunately, there is still no unified method for carrying out gas extraction that leads to the impossibility and impropriety of comparison the results obtained by different research groups.

The authors tested conventional wet and dry gas extraction methods for ice wedges coming to conclusion that current estimates of ground-ice gas budgets are likely underestimated. They found insignificant effects of microbial activity during wet extraction and significant difference in extraction results from polar ice cores and ice wedges. Therefore the manuscript is of big interest for scientific community and contributes to changing our scientific understanding of a subject as it is has to be for TC.

The results are presented in well-structured way and the paper is easy to read.

However, there are a few general suggestions that could improve the article:
1) I suggest adding a map of study sites, maybe some geological sections to get a better idea of the location and structure of ice wedges. Are they all Pleistocene?
2) Besides it is really necessary to include the schemes of gas extraction procedures (both wet and dry techniques as well as the experiment on dry extraction efficiency and on residual gas contents after wet extraction. Due to the limitation of the number of figures both 1 and 2 can be added as supplementary material.
3) Since the article is devoted to the comparison of methods, it would be useful to estimate the limits of applicability of the methods and measurement errors.
4) It is necessary to add initial data on gas content and CH_4 and N_2O mixing ratios as supplementary material to prove you main result about the same effectiveness of wet and dry extraction methods. As I see now from the Table 1 there can be 2 times difference (up to 20000 ppm) for CH_4

So the article is of big interest but needs major revision to be accepted and I would be happy to review a revision of the paper.

2) SPECIFIC COMMENTS AND EDITORIAL SUGGESTIONS

P.2 L50-51 «…ice sample was melted in a saturated sodium chloride (NaCl) solution, in order to minimize microbial activity and gas dissolution (Cherbunina et al., 2018 and references therein)». I found no mention in the article that NaCl was used in order to minimize microbial actvity , is it really there?

P.3 L72. Please specify the size of the samples, add the site map and geological sections with sampling location

P.4 L104. Please include the schemes of gas extraction procedures

P.5 L108 Why it is used precisely 5 times, not 100, can you reason it somehow?

P.6 L144 It is not clear where did you get the dry soil mass before the extraction. «Taking the dry soil mass of the analysed samples (0.33 g) into account, we added 24 µL of saturated $HgCl_2$ solution (at 20°C) to the sample flasks» Were there used the data on dry soil mass from the other

samples? Because later you say « Dry soil content was measured using the leftover meltwater from the control-wet extraction tests. »

P.12 L249. Please specify what do you mean by «ice hardness» here. As in L 249 «the extraction efficiency of the needle crusher not only depends on site characteristics, but also on the individual ice sample hardness», and later L. 251 «no relationship was observed between the dry soil content and the extraction efficiency», but L.274 « soil-rich ice has greater hardness than the soil-poor ice». I guess this is the matter of «soil aggregates» as you mention later, so the hardness in this case is defined by this parameter? Is it posiible to quantify this?

P.12 L255. Please specify the size range for «This is because the large-sized uncrushed soil aggregates or particles may have prohibited the needle crusher from crushing the small-sized ice flakes or grains». As the presence of the aggregates is one of the main limits to use the technique, is it possible to make at least a rough estimate of the amount of gas that can remain there?

P.12 L259. «Therefore, we do not recommend using a needle crusher system to measure gas contents in ice-wedge samples». Can you estimate the efficiency of the method in % in the same way it has been done for polar ice core ice samples (80–90%)(Shin, 2014)? As I see from the Table 1 the procedure « Hit5+Hit100» in most cases allows to extract more gas then the wet method even if uncrushed aggregates still occur. Can you recommend using dry extraction method in this modification?

P.13 L272. Since you talk about gas in bubbles here : «the hit5 CH_4 mixing ratios of the Cyuie samples may more reflect the gas mixing ratios in bubbles, while the hit100 results reflect more of the contribution from gas 2 adsorbed on soil and trapped within soil aggregates than the hit5 results» and further, may be it would be useful to get the data on ice porosity to compare with the results of extracted volume of gas since the volume of gas normalized to layer pressure approximately corresponds to porosity.

P.16 L320. Please explain if I understand correctly the next paragraph:

«To examine how well the gas is extracted by wet extraction, we applied the dry extraction method to refrozen ice-wedge samples after wet extraction. We first prepared degassed ice-wedge samples that had undergone repetitive wet extractions (wet-degassed ice hereafter). Once the wet extraction experiments were completed, we repeated two cycles of melting-refreezing and evacuation procedures to degas the ice melt. After degassing by a total of three cycles of wet extraction and evacuation, the outermost surfaces (~2 mm) of the wet degassed ice were trimmed away in the walk-in freezer at SNU on the morning of experiments. The wet-degassed ice was then inserted into the needle crusher and the crusher chamber was evacuated. A specific amount of standard air was injected. Then, the wet-degassed ice samples were hit 20 or 60 times by the needle crusher.»

After the first freezing-melting cycle the sample gas in the headspace of the flask was collected and gas content, CH_4 and N_2O ratio was measured. Then the two cycles were conducted. (and my question here is what happened to the gas in the flask-was it collected and measured or just evacuated) and next step was measuring the gas content in degassed ice through needle-crusher procedure.

P.16 L328. Explain please why were such parameters chosen if in the previous dry extraction procedure you used 5 and 100 hits: « Then, the wet-degassed ice samples were hit 20 or 60 times by the needle crusher»

P.16 L331. The tests using the wet-degassed ice show an additional gas extraction of 43 to 88% of the amount of gas extracted during the initial wet extraction. I suggest to add this information to the conclusions as it is of big significance as well as if I get it right the best way of degassing the sample according to your manuscript is to combine three cycles of wet extraction with dry extraction for the residual gas. I think this has to be one of the main conclusion.

P.19 L391. Please specify what do you mean by «relatively soft ice wedges».

P.19 L 392 It seems to me that you have very good results of applying the method of three-times wet extractions+residual gas extracted by a needle crusher for N_2O and I don't get why there is in conclusions «Exceptionally, the N2O content in ice wedges may be measured by using repeated wet extractions, but this is not the case for determining the N2O mixing ratio»

3) FIGURES AND TABLES

Table 1. Add a column of dry soil content as in table 2

The table with the data used for Fig.1 need to be added to get the difference between wet and dry method results.