-We thank the reviewers for their positive and constructive comments. Please see below our response to each of the comments.

Lauri Heiskanen, Juha-Pekka Tuovinen, Aleksi Räsänen, Tarmo Virtanen, Sari Juutinen, Annalea Lohila, Timo Penttilä, Maiju Linkosalmi, Juha Mikola, Tuomas Laurila and Mika Aurela

Anonymous Referee #2

Received and published: 1 December 2020

General comments:

This is an impressive study that should be published with minor revisions. The problem addressed is important – what are northern wetlands contributing to the global atmospheric greenhouse? Heiskanen et al. have carried out a very detailed two-year carbon dioxide and methane budget study of a representative 70N wetland in Finland that will give considerable insight into similar wetlands worldwide across the Arctic and sub-Arctic. The study is very thorough and well presented, clearly written and well-illustrated. I would however suggest the addition of a brief final section on the wider applicability of the results, to explain and make explicit what the implications are for our understanding of the impact of strong future warming and climate change.

Specific comments:

1. The manuscript is littered with acronyms, from the abstract all the way through (TT, SM, F, LAI, etc). They are all either standard abbreviations or explained on first contact but I get very lost. Please could a table be added listing all the acronyms, and maybe reminders in the figure captions.

- This is a good point. We added to the appendix a table listing the abbreviations (Table A1). We also included additional acronym definitions throughout the article and figure captions.

Table A1: List of abbreviations.

Abbreviation	Definition
EC	Eddy covariance
ER	Ecosystem respiration
F	Flark
GCC	Green chromatic coordinate
GPP	Gross primary productivity
LAI	Leaf area index
LME	Linear mixed-effects
NEE	Net ecosystem exchange
PCT	Plant community type
PPFD	Photosynthetic photon flux density
ROI	Region of interest
SM	String margin
ST	String top
TT	*Trichophorum* tussock
VPD	Vapour pressure deficit
WTL	Water table level

2. Page 2 line 46 – ‘if anoxia occurs’? – maybe better as ‘where anoxia occurs’.

- Changed to “where anoxia occurs”.

3. Page 3 line 90 maybe more detail on the vegetation. In particular, is it all C3? Or are there C4 plants like Atriplex species present?

- The dominant species are listed in Table 1. There are no C4 plants in the fen, and it seems very improbable they would occur there in near future, as they are presently not found here in any natural boreal vegetation communities.

4. The temperature dependence of respiration flux is taken from Lloyd and Taylor 1994 (P7 L233), and the temperature dependence of methane flux from Kim et al 1999 (P9 L282). Are these assumptions valid? - or is there information in the present study that can add to the older work? In particular, Kim et al were looking at rather different phragmites wetlands, in temperate settings, in Nebraska (43 degrees N whereas Kaamanen is 70N), perhaps more analogous to warmer sub-tropical and tropical systems and with more C4 metabolism present.

- The temperature dependence of respiration is modelled with an exponential (modified Arrhenius) relationship that has been shown to result in an unbiased estimate across a wide range of ecosystem types and soil temperatures (Lloyd and Taylor, 1994). Here, both the base respiration and activation energy parameters were estimated from the local data. For the CH_4 flux, we used a fully generic exponential function with local parameter values. No prescribed parameter values were used, and the function does not involve any assumptions about the ecosystem type. It is true that Kim et al. (1999) studied a temperate marsh, which differs in many ways from our subarctic fen. For the sake of consistency, we changed this citation to Marushchak et al. (2016), which deals with a subarctic ecosystem.

Marushchak, M. E., Friborg, T., Biasi, C., Herbst, M., Johansson, T., Kiepe, I., Liimatainen, M., Lind, S. E., Martikainen, P. J., Virtanen, T., Soegaard, H., and Shurpali, N. J.: Methane dynamics in the subarctic tundra: combining stable isotope analyses, plot- and ecosystem-scale flux measurements, Biogeosciences, 13, 597–608, https://doi.org/10.5194/bg-13-597-2016, 2016.

5. Page 16 line 440. The CO_2 flux being the same for both graminoids and forbs. Is that assumption secure? My question relates to my earlier question about the possible presence of C4 plants? – Are there any C4 plants like Atriplex species present? (and indeed are they likely to become more common?)

- The sentence on lines 440-442 is part of the description of the statistical modelling results and does not imply that the CO_2 flux would be the same for graminoids and forbs; rather, it reports the variables that explain the observed flux variation. As stated in the text, the presence of graminoids and forbs had a similar effect on the CO_2 flux: their coverage correlated positively with both gross primary productivity and ecosystem respiration. This is why only the vascular leaf area index was needed to explain the CO_2 flux variation. For CH_4 flux, however, the relationship with LAI was found to be more complex, as CH_4 emissions increased with increasing graminoid LAI while the opposite was true for the forbs.

6. For future work it would be nice to have some isotopic data.

- We agree with this idea and will consider it for our future work.

7. Page 23 Line 636. It would be good here to have a paragraph or two that is more speculative (or perhaps in warning): we know that the climate in the Arctic and sub-Arctic is warming fast and changing – what is going to

happen? Can this very detailed study give us any pointers to what is going to happen? The work in the paper is careful and well reported, but it needs to be given its wider context – Heiskanen et al are experts – what can they tell us about where these mires are going?

- To keep the conclusions clear and concise, we did not expand this section but added some text to Discussion. This additional discussion makes the connection between heatwaves, studied in the present manuscript, and Arctic warming more explicit; it also supports the final conclusion. We added the following paragraph to the end of Section 4.2.3:

"Heatwaves are predicted to become more frequent in the subarctic region as the climate warms (Masson-Delmotte et al., 2018). However, the impact of heatwaves on the C exchange of northern mires strongly depends on local soil moisture conditions. While drought leads to diminished C sequestration, warming accompanied by sufficient precipitation is likely to support the long-term peat accumulation in the subarctic, non-permafrost mires (Loisel et al., 2020). On the other hand, the vegetation composition and biomass production on these fens are susceptible to lowering water table level (Mäkiranta et al., 2018). Therefore, the functioning of subarctic fens may undergo substantial changes, if the water balance changes concurrently with the warming climate."

Masson-Delmotte, V., Zhai, P., Pörtner, H.-O., Roberts, D., Skea, J., Shukla, P. R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S., Matthews, J. B. R., Chen, Y., Zhou, X., Gomis, M. I., Lonnoy, E., Maycock, T., Tignor, M. and Waterfield T. (Eds.): Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty, World Meteorological Organization, Geneva, Switzerland, 2018.

Loisel, J., Gallego-Sala, A. V., Amesbury, M. J. et al. Expert assessment of future vulnerability of the global peatland carbon sink. Nat. Clim. Change, doi:10.1038/s41558-020-00944-0, 2020.

Mäkiranta, P., Laiho, R., Mehtätalo, L., Straková, P., Sormunen, J., Minkkinen, K., Penttilä, T., Fritze, H. and Tuittila, E.: Responses of phenology and biomass production of boreal fens to climate warming under different water-table level regimes, Glob. Change Biol., 24, 944-956, doi:10.1111/gcb.13934, 2018.