# Reply to Referee 2

This study by Beckebanze et al. seeks to improve estimates of soil organic carbon changes in permafrost-affected soils by estimating both vertical and lateral fluxes of carbon. They aim to achieve this with an extensive measurement campaign in a polygonal tundra ecosystem in Siberia, Russia. The study uses proven methods to estimate the carbon fluxes in a climatologically important area, where such measurements have not been done before. However, I find that the limited temporal coverage of the study (the growing season) puts into question the paper's main conclusions about the negligible importance of DIC and DOC export for the catchment NECB.

**General comments**

It is a bit puzzling to me why the carbon balance was computed for the growing season only. If the goal of the study is to improve estimates of soil carbon change in permafrost ecosystems, then an annual perspective including the highly dynamic spring and autumn seasons is required.

The majority of lateral transport will be in the snowmelt period in spring (65%-100% for dry tundra (palsa and bog habitats) in the study of Olefeldt et al., 2012). The authors state that the majority of the carbon export during the study period was accounted for by part of the spring flood in June, but that only part of the spring flood was covered by their measurements. This implies that the contribution of lateral DIC and DOC export to NECP may not be negligible on an annual basis, which appears to be one of the paper's main conclusions (see my comment about L10). Are there discharge measurements available for the spring season which would enable a rough estimation of the spring export of DOC and DIC? Or else, would it be possible to estimate spring discharge based on the annual water balance?

> *Thank you for your kind words and thorough review.*
> *Based on our limited data availability, we are not able to estimate the complete spring discharge rate. The observation only started on June 2. However, we clearly see in the data of outgoing short wave radiation that the snowmelt started May 14. In case we assume that the DOC flux at our site shows a similar pattern as the DOC flux in Olefeldt and Roulet, 2012 (74% of DOC flux during snowmelt), we would have a max. annual DOC flux of 0.21 g m$^{-2}$. From DIC flux we would only expect a low contribution during the snow melt due to likely high water discharge rates during the snowmelt and the negative correlation between DIC concentration and water discharge rate. Therefore, the inclusion of possible snowmelt-DOC flux and DIC flux would likely not change our conclusion regarding the influence of DOC flux or DIC flux on the NECB.*
> *In combination with the comments from second reviewer, we expanded the section on uncertainty of the measurements in the discussion and included the issue with water from the Lena river flowing out through the weirs. We also included that we do not know when exactly the shift from Lena water to ground- and melt water happened and therefore include observations from the beginning of the observation period:*
>
> Especially at the beginning of the study period, we observe high water discharge rates and high DOC concentration. Most likely, we do not cover the complete melting season with our study period. Relevant lateral C fluxes could have occurred directly at the beginning of the melting period, as it has been observed in a palsa and a bog in Northern Sweden (Olefeldt and Roulet, 2012). However, one could also argue that the

observed high lateral C fluxes at the beginning of the study period should not be included in the NECB. These high lateral C fluxes are likely linked to C-bearing river water which flooded the catchment before the observations started and drained through the catchments' outflows at the beginning of the observation period. In the course of the observation period, the origin of dissolved C in the observed lateral runoff might shift from allochthonous to autochthonous sources. Due to the unknown characteristics of this possible shift in sources for dissolved carbon, we included all available lateral C flux observations in the NECB estimation. This inclusion of lateral C fluxes that are likely not part of the catchments' NECB increases the relevance of lateral C fluxes in the NECB estimation. Because we potentially overestimated the impact of lateral C export on the NECB, our conclusion of a very limited role of dissolved carbon for appears to be an understatement - lateral C export likely plays an even smaller role.

Similar to the previous comment, large methane emissions may occur in the autumn as the gas is expunged from the freezing soil (Mastepanov et al., 2013). It would be interesting to know if such emissions occur on Samoylov Island and if so, they should probably be included in the carbon balance.

*Thank you for this comment. Yes, large methane emissions have been observed at this study site in the freezing period. We added a paragraph in the discussion on this topic and cited the observation data from this study site instead of Mastepanov et al. 2013:*

At our study site, no large methane bursts have been observed during the soil-refreezing period in autumn as described by Mastepanov et al. (2013) for their arctic fen site in Greenland. For a dataset from 2003, Wille et al. (2008) shows that mean daily methane emissions go gradually down between September and November. However, some peaks of higher methane emissions occur during stormy days during the refreezing period (probably triggered by turbulence-induced pressure pumping). However, these higher emissions during very windy conditions are only at maximum about three times higher than base line emissions, thus, much less than the methane flux peaks observed by Mastepanov et al. (2013). An article analyzing a long-term methane flux dataset from Samyolov Island, which includes data from several autumn refreezing periods and furthermore data from deep winter, is currently under revision (Rößger et al. 2022). This so far unpublished more extensive dataset also shows no large autumn methane bursts. However, the article estimates that about 14% of the annual methane budget of the polygonal tundra is emitted during the refreezing period. Accounting for this additional emission would likely increase the relevance of $CH_4$ fluxes in an annual NECB.

**Minor comments**

**L10: “annual fluxes”: are annual totals of lateral fluxes compared to 93-day totals of vertical fluxes?**

*We deleted the word “annual”.*

**L25: greenhouse gases -> greenhouse gases (GHGs)**

*We followed your suggestion and changed accodingly.*

**L34: NECB computations which include lateral transport are also available for the Stordalen Mire in subarctic Sweden (Lundin et al., 2016; Olefeldt and Roulet, 2012).**

*Thank you for this comment. We have missed out the NECB estimation of Lundin et al. 2016 and included it now into the introduction. However, we refrained from including Olefeldt and Roulet, 2012 in the introduction, since the NECB estimation is only mentioned in the discussion of the article without specific numbers.*

**L32: "basic Arctic landscape C balance models" what models are being referred to?**

*We were referring to landscape C models such as Koven et al. 2015 (CLM4.5BGC Model). However, this sentence has already caused some confusion in the internal review process, since this sentence was to unspecific, misleading, and not to the point of our research. Therefore, we decided to take this sentence out.*

**L135: "quantify the impact carbon losses due to lateral transport have on the total carbon balance of Samoylov Island": please describe briefly how the EC fluxes were extrapolated from the EC footprint to the entire island. I wonder whether it wouldn't make more sense to compare the catchment vertical fluxes to the catchment lateral fluxes.**

*Thank you for this suggestion. Our wording was misleading in this case, we do not observe the carbon balance of the whole island, but instead the area surrounding the EC tower. Therefore, we changed* "Samoylov Island" *to* "the chatchment" *and deleted the word* "total".

**L159: "The 2014 spring flood of the Lena River flooded parts of the catchment." Where is this information coming from?**

*This information is based on field observations by the co-author Benjamin Runkle. We added the source in the text.*

**L205: a detailed discussion of Lundin et al., 2016 and Olefeldt & Roulet, 2012 would be relevant here.**

*Thank you for this comment. We added a discussion on Olefeldt & Roulet, 2012 in the discussion and changed the discussion in this part according to a comment from reviewer 1. The new section is as followed:*

Similar to the DIC concentration, we also found a negative correlation between the water discharge rate and the DOC concentration when neglecting the period during the spring flood. This finding suggests that higher discharge rates dilute and decrease the DOC concentration. Therefore, in seasons with higher discharge rates, the DOC flux would not rise linearly and the DOC flux would affect the NECB only to a minor degree. A similar correlation between DOC concentration and the water discharge rate has been reported in a palsa a subarctic catchment (Olefeldt & Roulet, 2012).

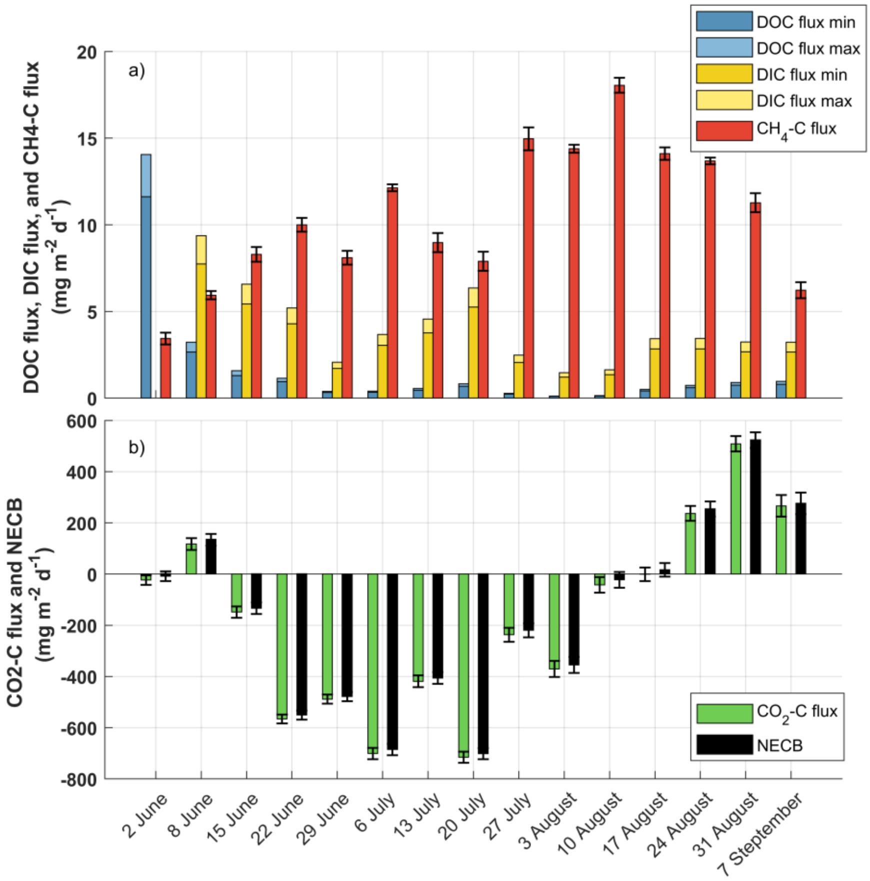
**Figure 1d: Considering the discussion of the representativeness of the tower footprint, it would be helpful to be shown the average tower footprint (i.e. of the 2014 measurement period) on the map.**

*This is a valid point. We added the cumulative footprint representation as we did it in our previous paper (https://doi.org/10.5194/bg-19-1225-2022) and added the description of the different colors in the text of the figure:*

The cumulative footprint is shown in gray shades. 30% of the flux likely originated from within the dark gray area, 50% from within the medium-dark gray area, 70% from within the medium-light gray area and 90% from within the light gray area.

**Figure 5: this is a personal opinion, but I find the artificially coloured background images misleading. The water level and height of the vegetation would change over time.**

*Thank you for this comment. We replaced this figure with a new bar-graph (see below). This graph shows mean daily fluxes with a weekly resolution and allows the reader to see the temporal development of the fluxes during the season.*




## References


Lundin, E. J., Klaminder, J., Giesler, R., Persson, A., Olefeldt, D., Heliasz, M., Christensen, T. R., and Karlsson, J.: Is the subarctic landscape still a carbon sink? Evidence from a detailed catchment balance, Geophys. Res. Lett., 43, 1988–1995, https://doi.org/10.1002/2015GL066970, 2016.

Mastepanov, M., Sigsgaard, C., Tagesson, T., Ström, L., Tamstorf, M. P., Lund, M., and Christensen, T. R.: Revisiting factors controlling methane emissions from high-Arctic tundra, 10, 5139–5158, https://doi.org/10.5194/bg-10-5139-2013, 2013.

Olefeldt, D. and Roulet, N. T.: Effects of permafrost and hydrology on the composition and transport of dissolved organic carbon in a subarctic peatland complex, J. Geophys. Res. Biogeosciences, 117, 1–15, https://doi.org/10.1029/2011JG001819, 2012.