Särkelä et al. describe the carbon balance of the Siikaneva wetland from 2005 to 2021, focusing on the role of the non-growing season. They find that while this fen is in principle a sink for CO2, that it became a source in 2016 due to an unexpected large release of CO2 at the end of the cold season, and they attribute this to the release of CO2 built-up during the winter that remained trapped due to the frozen soil. I find this study well-written and focused, and the proposed mechanism for the large release of CO2 late in the cold season makes sense to me. I have a few suggestions for improvement, but most of them are minor.

We thank REF#1 for the time and effort invested in reviewing our manuscript and for the helpful comments and suggestions, which are very useful in improving the manuscript.

1. My main concern is the use of the word growing and non-growing season, because I'm not sure that the term is correctly used here when using NEE as a threshold. For example, the authors mention that the non-growing season already started on July 30th back in 2018. However, this is a famously warm year with an extensive drought which of course stimulated ecosystem respiration. This is also clear from Figure S3. Did the plants really stop growing in the middle of summer, or did ecosystem respiration simply outweigh GPP? The authors refer to Körner et al. for their definition, but that paper suggests a different term when using NEE as a threshold: the productive season. This is of course an easy terminological fix, and I suggest using the productive season – or productive growing season if need be – to avoid confusion. The term non-growing season would have to be altered accordingly, because the same issue applies there.

Reply 1.

We thank for this useful comment: following REF#1's suggestion, we will change the wording to 'productive season' and 'non-productive season' to follow the definition given by Körner et al. (2023) and to avoid implying that the period is solely based on vegetation growth. We will clarify how this definition affects the season start and end dates, specifically during the extreme years (i.e., that positive NEE does not indicate lack of photosynthesis but rather that respiration outweighs potential photosynthesis, both during the late summer 2018 and spring 2016).

2. Also, it would be good to see what the meteorological growing season would look like. For this, it would be very helpful if a figure similar to Figure 2 could be made that shows air temperature instead of NEE, which is much clearer than what's shown in Figure S1. Similarly, it would be helpful to have such figures for GPP and Reco as well.

Reply 2.

Good suggestion. We will provide a suggested figure in the revised manuscript: a heatmap of air temperature with thermal growing season marked (5 °C threshold, following Ruosteenoja et al., 2016). Our findings suggest that 2016 and 2018 are the years with largest deviations of the productive season from the thermal growing season. We had chosen to focus only on the NEE as it is the direct measurement. However, we now examined GPP during the spring 2016, which is described more in the Reply 3.

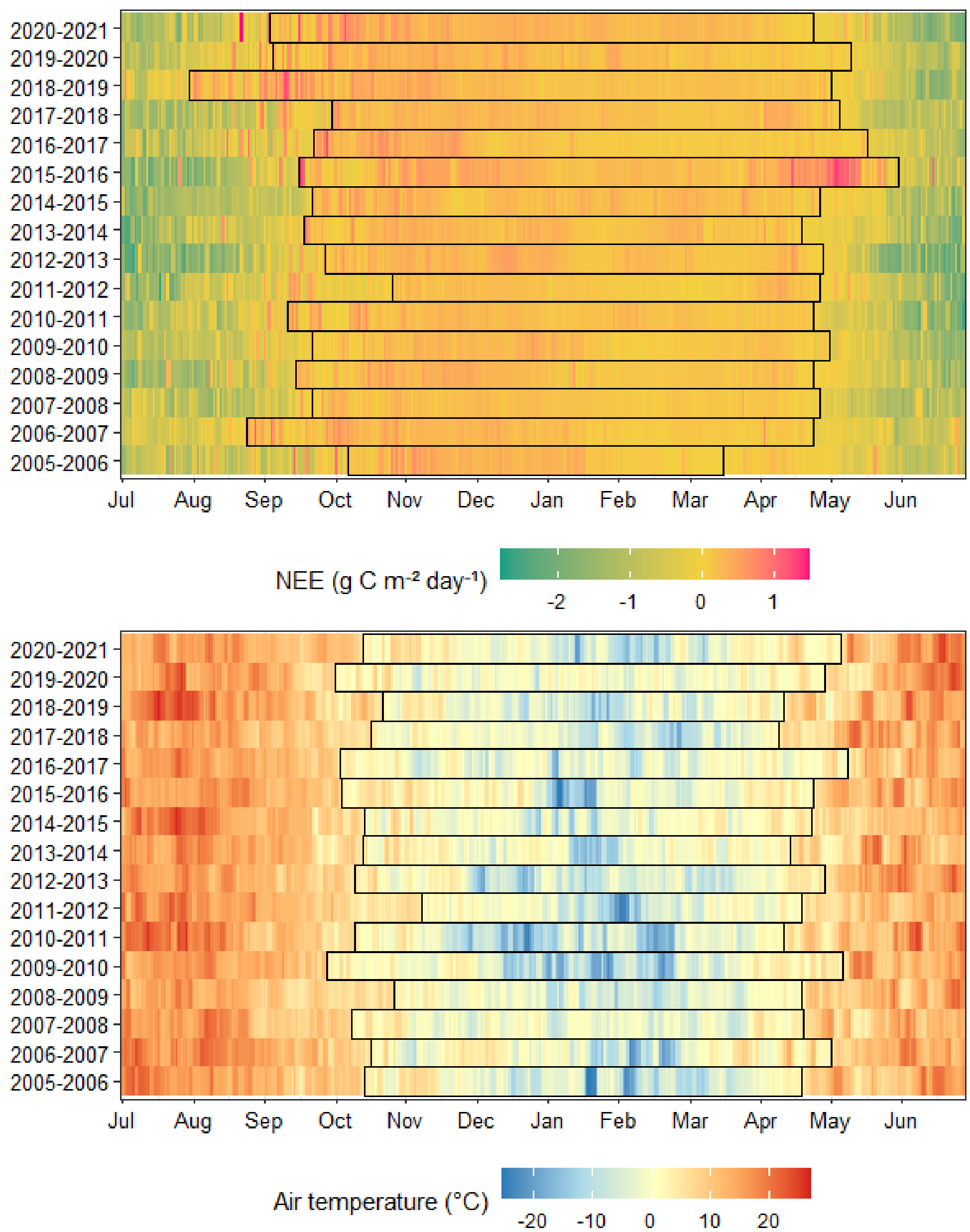

Figure 1. (A) Daily net ecosystem exchange of CO_2 (NEE; g C m^{-2} day^{-1}) in 2005–2021 and the non-productive season (NPS, black rectangular outline) periods centered in the winter. Each row represents one year, beginning in July and ending in June of the following year. Colors indicate daily mean NEE values, where the yellow–green gradient reflects negative values (net carbon sink) and the yellow–pink gradient reflects positive values (net carbon release). Black rectangular outlines mark the NGS periods, defined as the period beginning after the first three consecutive days of positive NEE and ending after the first three consecutive days of negative NEE. On average, the NGS started on September 17th and ended on April 30th.
(B) Daily mean air temperature for 2005–2021, with the thermal non-growing season centered on winter. Each row represents one year, beginning in July and ending in June of the following year. Black rectangular outlines mark the thermal growing season following the definition of Ruosteenoja et al., 2016. The season boundaries are determined from the annual cumulative sum of daily temperature deviations from a 5 °C threshold: the growing season begins when the cumulative sum reaches its minimum and ends when it reaches its maximum, indicating that temperatures remain persistently above or below 5 °C. Reference: Ruosteenoja, K., Jylhä, K., & Kämäräinen, M. (2016). Climate projections for Finland under the RCP forcing scenarios. Geophysica, 51.

3. Otherwise, the event that occurred in early 2016 is very reminiscent of the conditions of a frost drought. This can lead to extensive shrub and tree damage. While the sedges, rushes and mosses present at Siikaneva are probably quite resilient to such events, it is possible that some vegetation got damaged and that this delayed the uptake of carbon after snowmelt. Was the onset of GPP later than in other years when comparing to, for example, growing degree days or a simple temperature sum?

Reply 3.
We thank the REF#1 for this helpful comment. As suggested, we examined the dynamics of GPP in 2016 to evaluate whether reduced photosynthetic activity could explain the spring NEE patterns. We compared the GPP during spring 2016 with the long-term behavior across the study period and found that GPP in spring 2016 closely followed the long-term mean and did not exhibit anomalous behavior (Figure 2.). To further assess the onset of photosynthetic activity, we determined the first occurrence of five consecutive days with GPP exceeding 1 g m^{-2} day^{-1}. In 2016, this occurred on 6 May, five days earlier than the 17-year average. These observations indicate that photosynthetic recovery was likely not delayed, and therefore reduced GPP is unlikely to explain the anomalous NEE patterns.

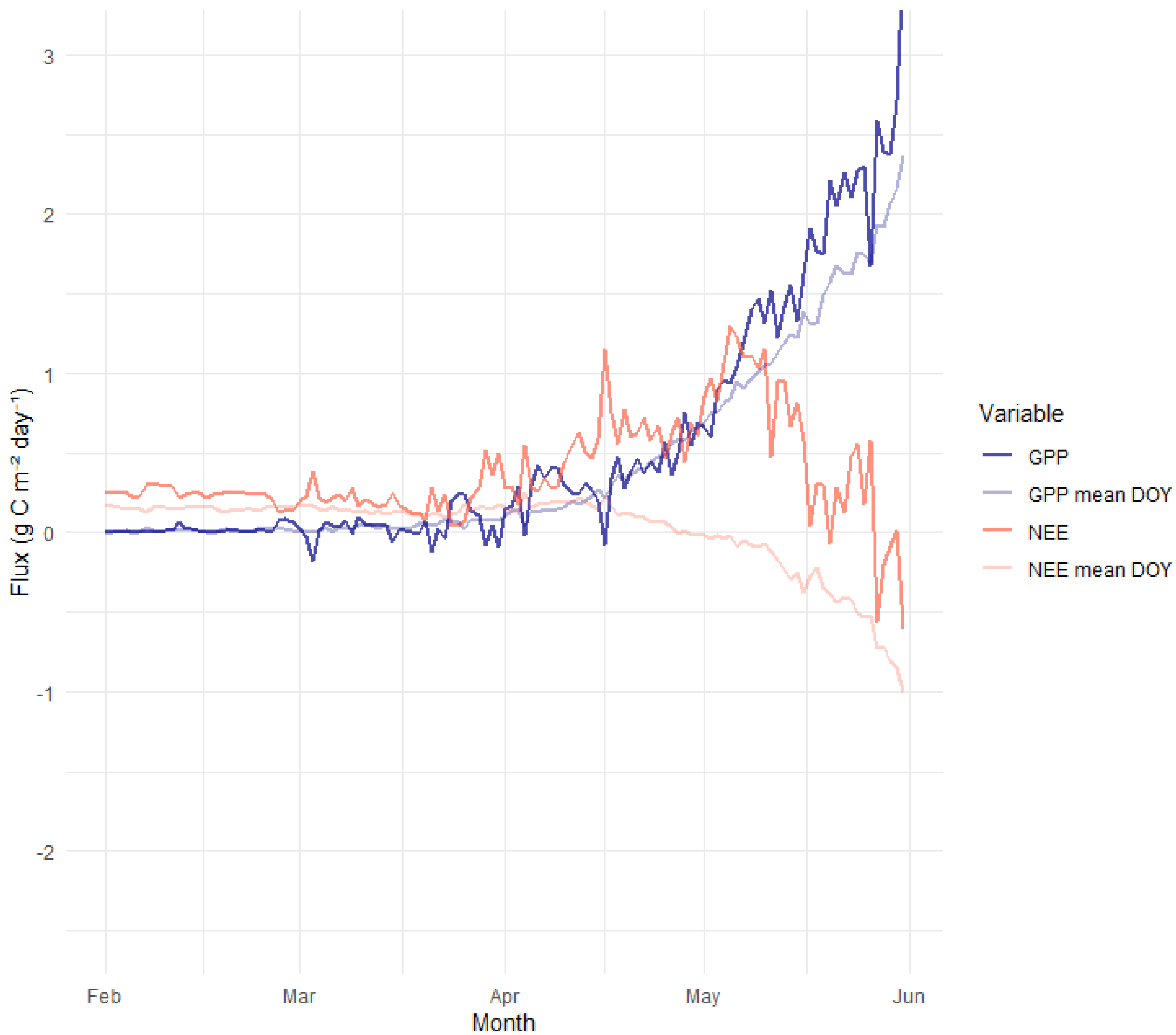

Figure 2. Daily GPP and NEE during spring 2016 (February–June). Solid lines show the observed daily fluxes in 2016, while the semi-transparent lines represent the long-term mean. The DOY mean was calculated by averaging fluxes for each calendar day across the full dataset and is shown to illustrate how the 2016 flux dynamics compare with the typical seasonal pattern.

Based on this, we suggest that the strong spring emissions were instead primarily driven by two complementary mechanisms:

1. Release of CO_2 accumulated under ice: Freezing of the surface layer restricted gas diffusion, allowing CO_2 produced at depth to accumulate. Higher-than-average soil temperatures at depth likely enhanced microbial activity, contributing to a larger pool of stored CO_2 released once transport pathways reopened.

2. Increased instantaneous respiration during thaw: Because GPP did not indicate delayed spring onset, we suggest that the increased respiration is a result of either enhanced decomposition of labile carbon released when ice disrupted the peat matrix and plant

tissues, or by oxygen-rich snowmelt water stimulating aerobic respiration (as suggested by Arndt et al., 2020).

This interpretation will be supported in the revised manuscript by these additional data sources:

- Phenocamera images document an extensive ice layer during winter. The first CO_2 emission peak occurred when the ice layer disappeared while soil temperature at 5 cm remained below 0 °C, consistent with release of accumulated CO_2. A second peak occurred after the zero-curtain period, indicating enhanced instantaneous respiration.
- Methane (CH_4) flux dynamics: CH_4 emissions also increased during snow- and ice-melt and were higher than in other years, supporting the hypothesis of gas accumulation beneath the ice layer (Figure 3, below). However, CH_4 subsequently declined while CO_2 continued to increase (Figure 3, below). We suggest this divergence is likely due to either enhanced decomposition of labile carbon or oxygen-stimulated respiration, as both processes increase CO_2 fluxes but would not necessarily increase CH_4. Comparing CO_2 and CH_4 fluxes thus helps differentiate between contributions of accumulated gas release (transport) and enhanced microbial respiration (production).

These new data sources and interpretations will be included in the revised manuscript, with related images and plots provided.

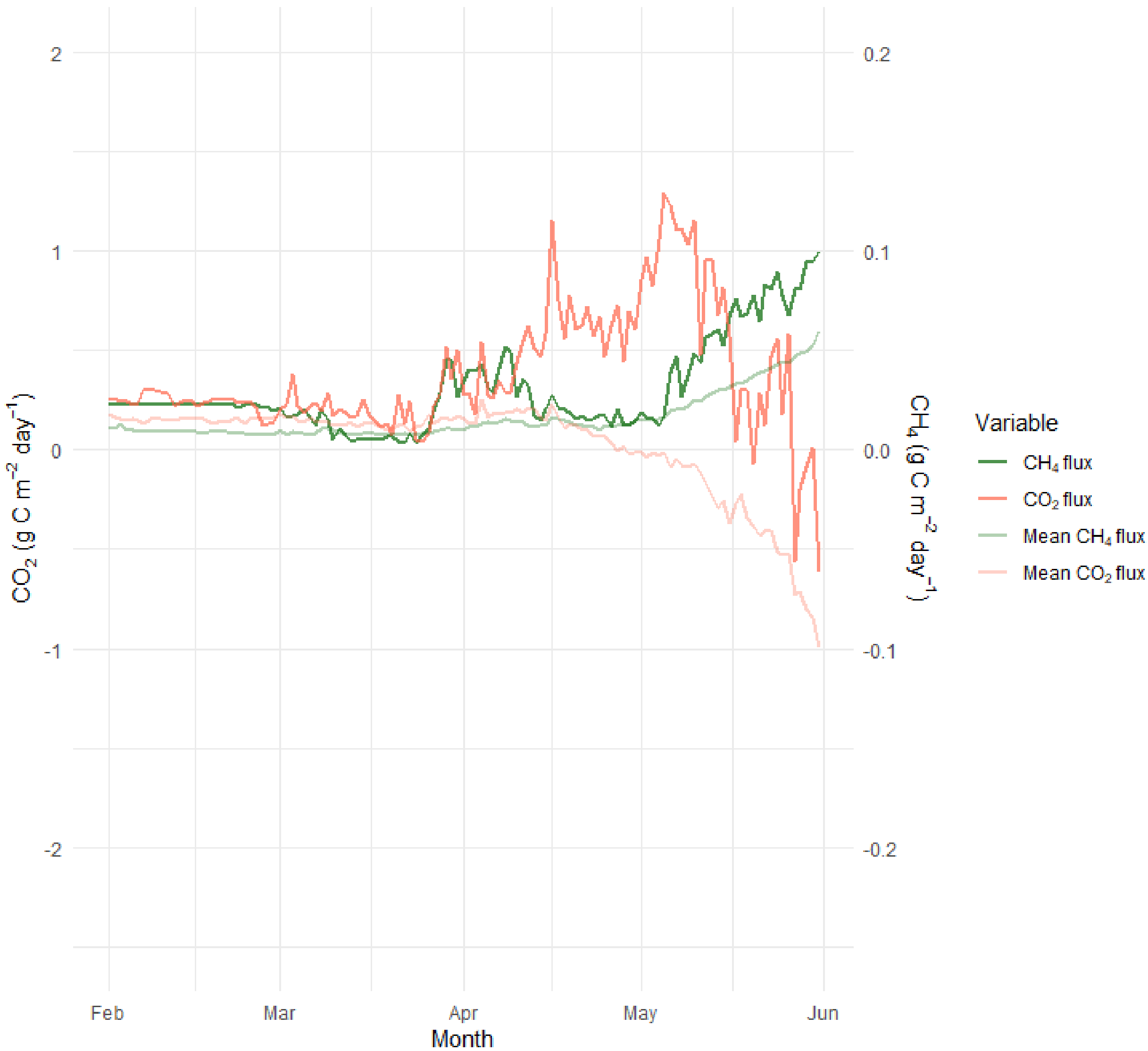

Figure 3. Daily CH_4 and NEE of CO_2 during spring 2016 (February–June). Solid lines show the observed daily fluxes in 2016, while the semi-transparent lines represent the long-term mean. DOY mean was calculated by averaging fluxes for each calendar day across the full dataset and is shown to illustrate how the 2016 flux dynamics compare with the typical seasonal pattern.

4. Detailed remarks:

Line 68: “no-growing” should be “non-growing” (or non-productive)

Line 100: This looks like a sentence remnant that should be removed.

Agreed and will be edited accordingly.