Responses to Reviewer #2

This manuscript investigates the interannual variability of the carbon uptake and carbon release period in Central Siberia. The presented analysis is based on CO_2 observations carried out at the Zotino Tall Tower Observatory (ZOTTO) in central Siberia, during the period 2010 – 2021. This reviewer acknowledges the relevance of the ZOTTO dataset for the scientific community as it is collected in a region that is presently experiencing significant impacts of climate change.

Results based on CO_2 measurements revealed that amplitude and length of carbon release and carbon uptake period increased during the analysed period (2010 – 2021). However, data show that the growth of the amplitude of carbon release period is larger than the growth in carbon uptake period amplitude, suggesting that the enhanced carbon uptake during the growing season was offset by the autumn/winter carbon release.

The manuscript is generally well written, and presented results are an important contribution to the knowledge on the effect of climate change on terrestrial ecosystems.

Thank you for the constructive review and suggestions. We detail our responses below.

However, some aspects of data analysis and related discussion should be clarified:

- Time series of the target tank is used to evaluate the quality of CO_2 mole fraction measured at ZOTTO. This reviewer noted a small jump in the time series of target tank between 2018 and 2019. The average value before the jump seems to be lower than the value for the following period. In the opinion of the reviewer, there could be a potential bias introduced in the ambient measurements. Could the authors comment on this?

Thank you for pointing this out. Unfortunately, we have not been able to find a satisfactory explanation for this jump. The values differ between the 2019-2022 (i.e., after the jump) average of the target tank is 404.67 ppm and the 2009-2018 average is 404.62 ppm. This bias of 0.05 ppm could have been the result of many smaller changes in the measurement set-up. We note that this bias is one order of magnitude smaller than the difference between flask measurements and the continuous in-situ data and three orders of magnitude compared to the averaged amplitude of the seasonal cycle of CO2. We, therefore, believe that this bias is comparatively small and does not have a significant impact on our analysis.

- Lines 122-125. Authors are applying a despiking methodology to remove unreliable CO_2 observations but it is not clear to this reviewer the meaning of “unreliable”: is this the definition assigned to concentrations mainly affected by local sources? Moreover, this reviewer is wondering if the removal of unreliable data is impairing the capability of CO_2mole fraction dataset to detect the effect of extreme events. Finally, this reviewer advises authors to show the percentage of removed observations.

Thank you for pointing this out. This procedure removed “unreliable” outliers that we consider to be caused by local effects and which despite being relatively sparse, do not represent the large-scale seasonal variation that the fitting function should capture. Obviously, by removing those extreme local effects data points, we also removed the extreme events in terms of daily scale. However, our study focuses on seasonal and inter-annual scales. We have checked the removed data points, and they appeared to be random and are not particularly concentrated on

the time of the day or any particular seasons or years. This percentage of the removal data is 2.4% of the total data. After the noisy data removal process, we still could see the abnormal curve shape in 2012 (when an extreme event happened) in Fig. 4b (black line). We, therefore, would say that the removed unreliable data is insignificant in detecting the effect of extreme events in terms of seasonal and inter-annual scales. As suggested by the reviewer, the percentage and "quality" of the removed data points will be added to this section in the revised manuscript.

- Lines 135-136. Has the consistency of the assumption that there are not significant changes in the curve shape of the season over the years been tested?

We have not tested the significance of changes in the curve shape of the season. We mentioned the change in the curve shape of the season over the years is negligible (line 134) but have not addressed why. The ability to isolate changes in the phase and amplitude of the seasonal cycle with fidelity could be determined by using Monte Carlo numerical experiments as in Barlow et al. 2015. Their study shows that the errors associated with independently identifying changes in phase and amplitude that can result in the misinterpretation of seasonal signals are more pronounced when using the detrended CO2 seasonal cycle as opposed to using the time derivative of a time series. This result informed our study. Our use of the time derivative of a time series can provide a more robust estimate of the key dates that define the CUP without taking into account the changes in the shape of the seasonal curve compared to the conventional use of zero crossing date derived from the detrended CO2 seasonal cycle. We will add this discussion and reference to Barlow et al. 2015 study in the revised manuscript.

- Section 2.5. The choice of the threshold value of the spatial root mean square (RMS), used to determine the region of influence, should be explained. Moreover, the impact of different RMS thresholds on the extension of the region of influence should be addressed. Finally, this reviewer suggests including a description of the land cover in the region of influence. This could help readers to get an idea of the type of ecosystems embedded in this area and affecting observations collected at ZOTTO.

Thank you for your feedback. We have tested different RMS thresholds on the extension of the region of influence, but it was not included in the manuscript. We tested varying the threshold between 10% and 50% and decided 40% would be the most presentable for the region of the influence for the ZOTTO station (Figure R2). The ecosystem cover in this region of influence comprises Pinus sylvestris forest stands (about 20 m in height) on lichen-covered sandy soils. As suggested by the reviewer, the description of the land cover in the region of influence will be added to the revised manuscript.

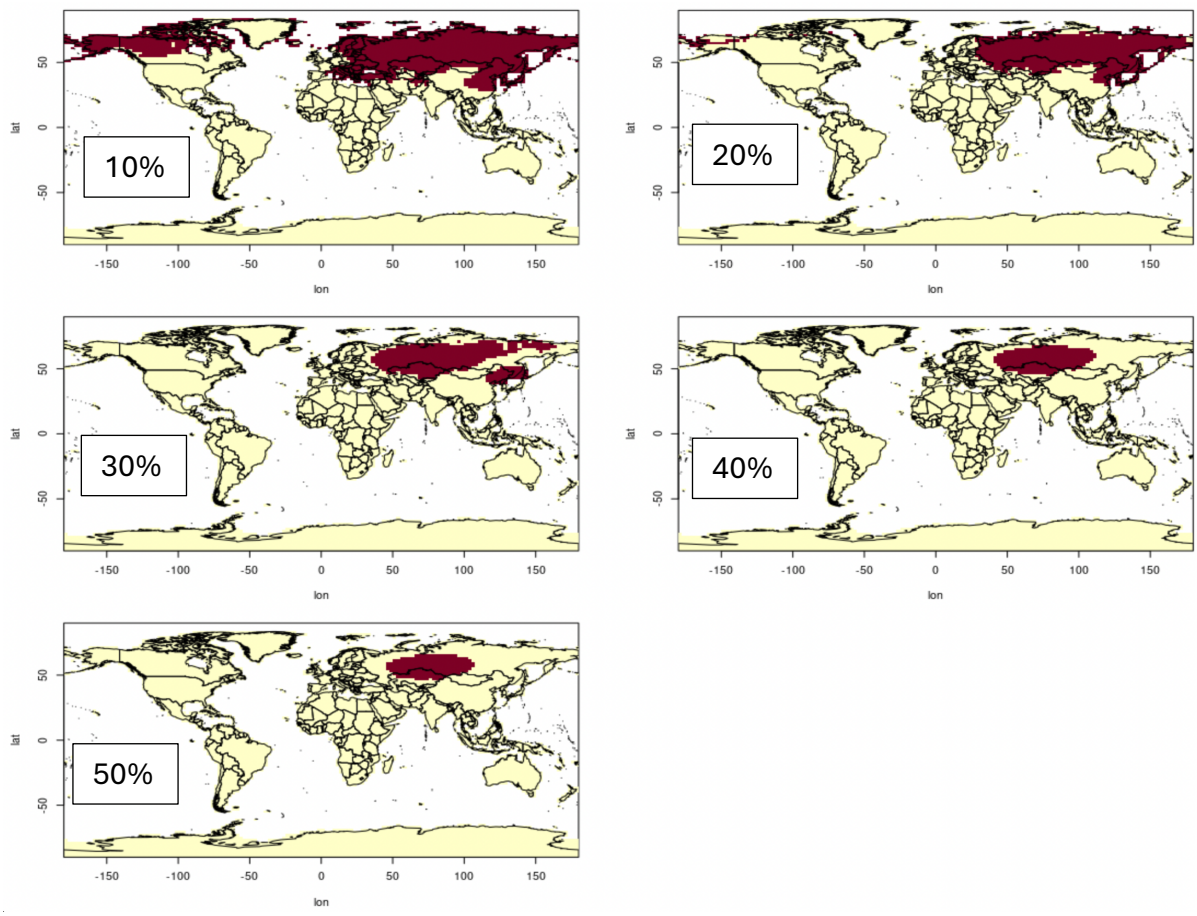

Figure R2. Different RMS thresholds (10-50%) on the extension of the region of influence for the ZOTTO station.

- Section 3.1. Authors found that there is not a significant trend in the timings of CUP, while there is a significant increase of the CUP length. How is it possible to have an increase in the CUP length when the timings (onset and termination) are not changing? Moreover, authors are stating that the heat wave in 2020 induced an early onset of CUP, but the error bar associated to the estimated CUP onset in 2020 (Figure 5) is very large, casting doubt on the author's statement.

One possible explanation for the fact that we did not see a significant trend in the timings (both onset and termination) of CUP but the CUP trend is that: the changes in timings (slight decrease and increase trend for onset and termination respectively) are too small, the time series of 10 years is not long enough to see significant changes. CUP length is the result of both onset and termination. Therefore, slight insignificant changes in both onset and terminations could still result in more visible significant changes in CUP length over 10 years. We also did additional regression of onset and termination timings for both CUP and CRP (Fig. R3 below). There is no clear regression on both cases.

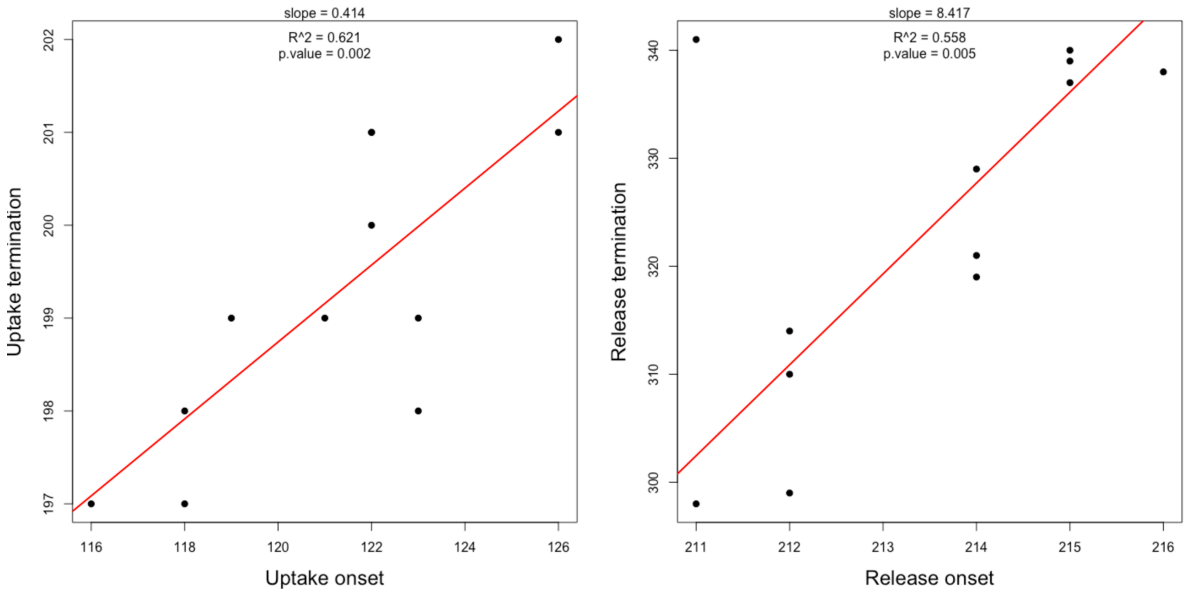

Figure R3. Regression of timing of onset and termination for CUP and CRP.

- Finally, authors are claiming for a significant jump in the CUP length in 2020 but looking at Figure 7 the jump is visible in the CUP amplitude (and CUP rate), not in the CUP length.

We understand that the use of "a significant jump in the CUP length" in line 296 is misleading. What we meant was that during 2020, when the Siberian winter-to-spring heatwave occurred, there was only an increase in the CUP length due to the early spring onset but not in the CUP amplitude. In line 296, "a significant jump" will be replaced with "an increase" in the revised manuscript.

Minor points to be addressed are listed below:

- This reviewer advises authors to cite the data repository where they retrieved the CO_2 mole fractions measured in atmospheric stations used for both inversions s10v2022 and s10v2022+Allstations.
- Lines 120-122. Ranges of short-term and long-term cut-off values tested are different from those reported in Table B1.
- Line 205: change "later" to "layer".
- Caption of Figure 4: change "Thoning et al. (1996)" in "Thoning et al. (1989)".
- Line 374. Add "are" after "s10v2021+ZOT".

We agreed with these minor points and will address them in the revised manuscript.