# Remote carbon cycle changes are overlooked impacts of land-cover and land management changes

## *Response to referee 1*

We sincerely thank the referee for their thoughtful review of our manuscript. We apologize for the confusion caused by the line number references in our previous response. In reply to comment 3, we had indicated Lines 162-166 in the *Author's tracked changes* document (egusphere-2024-2387-ATC.pdf) for the land forcing information. However, we realize we did not clarify this reference in our earlier response, and we apologize for the oversight.

For clarity, we now continue to refer to the line numbers in the current version of the *Author's tracked changes* document for this round of revisions.

We appreciate your understanding and the opportunity to improve the manuscript.

| Referee 1 Comment 1 |
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| The response to my previous comment No. 3 is not clear. This question was regarding the spatial scale of the local and non-local effects. In other words, I wanted to know the effects of big areas being considered local and non-local. The authors can either state in in terms of area (km2) or number of pixels or grid points. It is required but not enough to refer to an old study. These need to be explained step-by-step or included in a flowchart. |

**Response**

We apologize for not fully understanding the requested modifications to the manuscript in our previous response and now provide more information on the scale of local and non-local areas and effects.

We have added the information in terms of area by providing the modeling resolution to Tab. 3. It should be noted that our study does not investigate how far-reaching non-local effects in a specific case are. Such aspects have been addressed by a similar author team looking into 'length scales' of moisture recycling (De Hertog et al., 2024). Instead, our study compares the entireness of non-local effects to those happening at the location of LCLMC. That the distinction between local and non-local areas and effects depends on the application – with the global focus, and thus ESM resolution, in our case – has now been clarified in the introduction by adding the sentence:

> The definition of local vs nonlocal scales depends on the application – while changes in micro- or mesoscale phenomena could be resolved by high-resolution modelling, our study focuses on global impacts of large-scale LCLMCs connected to synoptic scales.

And in the technical implementation in Sec. 2.2, where we reference the new information of Tab. 3:

> As we are interested in global impacts of large-scale LCLMCs at the scale of 100 km upwards, which matches the resolution of the ESMs, we implement the checkerboard pattern at the native resolution of each ESM (Tab. 3).

Additionally, we have accommodated the reviewers' suggestion for a clear step-by-step description for the isolation of the local and nonlocal effects in Sec. 2.2, now explicitly including the information from the referenced literature, even for the first steps where we apply the method in an unaltered way. This should greatly improve clarity.

| Referee 1 Comment 2 |
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| My previous comment No. 15: The response of the authors to this query is not clear. Specifically, the authors state that forests exhibit a larger internal natural variability because of their larger biomass content. I am not sure how these two are linked. |

**Response**

We thank referee for the insightful feedback.

In our study, we define internal natural variability (or noise) as fluctuations in carbon pools driven by natural climate variability. Forests, with their higher biomass density, are more sensitive to these climate fluctuations. For example, when climate conditions become unfavorable (e.g., during droughts), the higher biomass density in forests can lead to higher carbon emissions due to increased carbon decomposition and tree mortality. Conversely, when the climate becomes more favorable, these larger biomasses sequester more carbon, leading to greater carbon uptake. Thus, forests exhibit higher internal variability of carbon pools compared to croplands or grasslands due to their higher biomass density.

However, while forests show larger internal variability (noise), it is not the dominant factor influencing the Time of Emergence (ToE) in forested regions. The earlier ToE is primarily driven by the signal—the amplified response of the carbon cycle to non-local BGP climate changes. In forests, the higher biomass density intensifies this signal, making the response to non-local climate changes more pronounced compared to other land-use types. This stronger signal accelerates the ToE, despite the larger internal variability.

In summary, although the higher biomass density in forests leads to larger internal variability, it is the amplification of the signal due to non-local BGP climate effects that dominantly drives the earlier ToE in forested regions. We have added a sentence in the Sec. 4.1 to clarify this to the reader.