Response Letter to Reviewer #3

CEDAR-GPP: spatiotemporally upscaled estimates of gross primary productivity incorporating CO_2 fertilization

Dear reviewer,

Thank you very much for your thorough review of our manuscript. We greatly appreciate your constructive feedback and comments, which have significantly improved our paper. Below, we outline our responses (in blue) to your comments (in black) and detail the corresponding revisions made to the manuscript (in red). We included line numbers from the "track-change" version of the revised manuscript for your reference.

Thank you once again for the time and efforts you dedicated to reviewing our manuscript. We hope that our revisions have adequately addressed your comments and concerns. We eagerly look forward to any further feedback and suggestions that you may have!

Sincerely,

Yanghui Kang
On behalf of all co-authors

In this manuscript, Kang and colleagues present a novel GPP product that incorporates the CO2 fertilization effect. After several thorough readings over the past two weeks, it has become evident to me that this manuscript is both timely and well-prepared. I have some minor suggestions to enhance its clarity and impact:

1. In the Introduction section, it would be beneficial to provide a more comprehensive explanation of why the authors chose scaling as their approach for global GPP development. Given that there are various other GPP development methods, such as LUE models and SIF retrievals, it's essential to highlight the unique advantages of scaling in comparison to these alternatives.

Response: This is a great point. We have enriched the introduction with a more detailed description of the upscaling approach and its advantages.
Revisions: Line 56 – 64: *This "upscaling" approach provides data-driven and observation-based quantifications without prescribed functional relations between GPP and its climatic or environmental drivers. It offers unique empirical constraints of ecosystem carbon dynamics, complementing those derived from process-based and semi-process-based approaches such as terrestrial biosphere models or the Light Use Efficiency (LUE) models (Beer et al., 2010; Jung et al., 2017; Schwalm et al., 2017; Gampe et al., 2021). In recent years, the growth of global and regional flux networks, coupled with increasing efforts in data standardization, has offered new opportunities for the advancement of upscaling frameworks, enabling comprehensive quantifications of terrestrial photosynthesis (Joiner and Yoshida, 2020; Pastorello et al., 2020).*

2. The concept of "direct CO2 fertilization effect" may not be familiar to all readers. It would be helpful if the authors could provide a clearer explanation of this term and include relevant references in the introduction to ensure a better understanding among readers.

Response: Thank you for the suggestion! We have revised the introduction to provide a clearer description of the direct and indirect CO2 fertilization effect.
Revisions: Line 82 – 19: *Increasing atmospheric CO2 directly stimulates the biochemical rate or the light use efficiency (LUE) of leaf-level photosynthesis, known as the direct CO2 fertilization effect (CFE). Enhanced photosynthesis could lead to greater net carbon assimilation, contributing to an increase in total leaf area. This expansion, contributing to a higher light interception, further enhances canopy-level photosynthesis (i.e. GPP), which is referred to as the indirect CFE. The direct CFE has been found to dominate GPP responses to CO2 compared to the indirect effect, from both theoretical and observational analyses (Haverd et al., 2020; Chen et al., 2022).*

3. Figure 1 effectively illustrates the spatial distribution of flux tower data used in this study. it would be more beneficial to indicate how these flux tower sites represent different biomes. I would suggest adding a Whittaker biome figure within Figure 1 to visually depict the biome types associated with the flux tower locations used in the study.

Response: Thank you for the great suggestion! We have added a Whittaker biome plot to illustrate site distributions in the climate space in Figure 1d. Additionally, we have incorporated a plot showing the site distribution by the actual plant functional types (Figure 1c). We would also like to note that the number of sites in each biome and climate zone was also provided in Figure 4 to assist the interpretation of the results.
Revisions: Line 138 – 140 (Section 2.1): *Despite their uneven geographical distribution, these sites effectively cover a diverse range of climatic conditions and are representative of global biomes (Figure 1c, 1d).*

4. Given the potential wide interest in the various GPP products developed in this work, it would be very useful to include a section that provides guidance on how future researchers and users can effectively utilize these datasets in the future. This could include tips on data access, processing, and interpretation to facilitate broader adoption.

Response: Thank you for the suggestion! In the revised manuscript, we have provided a comprehensive guideline on data usage and selection in the Section "Data availability and usage". We have also incorporated this information into the user guide in the Zenodo data repository.
Revisions: Line 845 – 868 (Section 5): *The CEDAR GPP product offers GPP estimates derived from ten different models. Models are characterized by 1) temporal coverage, 2) configuration of CO2 fertilization, and 3) GPP partitioning approach (Table 2). We provide a structured approach to selecting the most appropriate dataset for research or applications.*

1) Study period considerations: the Short-Term (ST) setup is ideal for studies focusing on periods after 2000. These models are constructed using a broader range of explanatory predictors, offering higher precision and smaller random errors. The Long-Term (LT) datasets shall be used for research assessing GPP dynamics over a longer time period (before 2001). It is important to note that, due to basis in different satellite remote sensing data, trends from the ST and LT datasets are not directly comparable.

2) CO_2 Fertilization Effect (CFE) configurations: the CFE-Hybrid and CFE-ML setups are preferable when assessing temporal GPP dynamics, especially long-term trends. The CFE-Hybrid setup includes a hypothetical trend for the direct CO_2 effect, while CFE-ML is purely data-driven and does not make any specific assumption about the sensitivity of photosynthesis to CO_2. Averaging the CFE-Hybrid and CFE-ML estimates is acceptable, with the difference between them reflecting the uncertainty surrounding the direct CO_2 effect. Note that the Baseline setup should not be used to study long-term GPP dynamics, especially those induced by elevated CO_2. The Baseline setup may be useful to compare with other remote sensing-derived GPP datasets that do not consider the direct CO_2 effect. Differences between these setups regarding mean GPP spatial patterns, seasonal and interannual variations are minor.

3) GPP partitioning methods: We recommend using the mean value derived from both the "NT" (Nighttime) and "DT" (Daytime). The difference between these two provides insight into the uncertainties arising from the partitioning approaches used in GPP estimation from eddy covariance measurements.

5. To streamline the manuscript, consider moving some supplementary materials, such as Table 1 and Table 3, to the supplementary section. This would help maintain a concise and focused main manuscript while still providing access to important supporting information.

Response: Thank you again for the feedback! To streamline the manuscript, we have moved Table 3 and results related to the DT models (i.e. setups based on day-time partitioned GPP) in Figure 3, Figure 5 to the supplementary information. We have opted to keep Table 1 in the main text as it provides essential information on the input datasets, which are critical to our upscaling approaches.