Reviewer Comments
Author Responses

General comments

This manuscript describes an analysis of CMIP6 outputs, specifically presenting a computation of the soil, vegetation, and land carbon sensitivity to CO2 (beta) and climate (gamma) changes. This follows earlier, similar analyses of previous CMIP generations, and is a useful diagnostic of model behavior and to help understand earth system response to anthropogenic CO2 emissions. The ms is well written and interesting, focused, and generally clear; I applaud the inclusion of a link to the analytical code.

We thank the reviewer for their positive and constructive comments.

In addition to some minor issues, my overall concern is that the analysis is quite limited, misses some very interesting possibilities, and doesn't always display its results well. Specifically, a comparison of CMIP5 and CMIP6 values—ideally quantitatively in a figure, but at least treated in the discussion—would add a lot of value. In addition, the bar graphs are not particularly illuminating, and consider better visualization options (e.g. #9 below).

In summary, this is an interesting and valuable contribution, but needs moderate revisions for concision and clarity; to improve how it conveys its results; and, ideally, to expand its scope a bit.

This comment has been taken on board and addressed in our manuscript. Firstly, we now include a comparison of the CMIP6 soil carbon beta and gamma values with equivalent values from CMIP5 models, which are presented in a new table and new figure (**see below**) within the appendix. The following text has been added to the Results:

'**The βs and γs values were also calculated for CMIP5 ESMs (Table A3), which can be compared with a subset of generationally related CMIP6 ESMs considered in this study (Fig. A3). The CMIP6 ensemble means for both βs and γs parameters are found to be lower compared with the CMIP5 ensemble means (Table A3 and Table 2). The relationship of βs and γs values between CMIP5 and CMIP6 however, is not found to be consistent amongst the ensembles. For βs, reductions are seen in *4 ESMs (GFDL-ESM2M Vs GFDL-ESM4, IPSL-CM5A-LR Vs IPSL-CM6A-LR, MPI-ESM-LR Vs MPI-ESM1-2-LR, and HadGEM2-ES Vs UKESM1-0-LL)*, compared to increases in the remaining 2 (CanESM2 Vs CanESM5 and NorESM1-ME Vs NorESM2-LM). For γs, a greater value (closer to 0) is seen in 4 ESMs (CanESM2 Vs CanESM5, GFDL-ESM2M Vs GFDL-ESM4, IPSL-CM5A-LR Vs IPSL-CM6A-LR, and MPI-ESM-LR Vs MPI-ESM1-2-LR), compared to a lower value (greater negative) is seen in the remaining 2 ESMs (NorESM1-ME Vs NorESM2-LM and HadGEM2-ES Vs UKESM1-0-LL).**'.

Also, see comments to #9 that Fig. 4 has been updated from the bar chart to the suggested scatter graph (**see Fig. attached**).

Additionally, the analysis has now been expanded to include a breakdown analysis of the processes driving soil carbon in each simulation. The βs and γs feedback parameters are broken down into sensitivity components due to changes in Net Primary Productivity (NPP) and changes due to soil carbon turnover time (τ_S), which follows the framework presented in Varney et al. 2023 (Biogeosciences). The manuscript will now include a new Methods section '***Processes driving soil carbon change and relation to the βγ formulation***' describing the formulation and how it relates to the βs γs formulation presented here, and a results

section '***Breakdown of the feedback parameters into soil carbon drivers***', including a new figure (**attached below**).

Varney, R. M., Chadburn, S. E., Burke, E. J., Jones, S., Wiltshire, A. J., and Cox, P. M.: Simulated responses of soil carbon to climate change in CMIP6 Earth system models: the role of false priming, Biogeosciences, 20, 3767–3790, https://doi.org/10.5194/bg-20-3767-2023, 2023.


Specific comments

1. Line 11: Jones et al. 2018 http://dx.doi.org/10.1029/2018GL079350 might be a good citation here
   This citation will be added to line 11.

2. 37: "has been"
   This sentence will be changed as stated.

3. 52: This is a long time ago! If any models have been added since then, would it be possible to include them on revision? That said, I'm not trying to make a huge amount of new work for the authors
   Sorry for the confusion here, it has been checked multiple times and there are no more CMIP6 models which provide the required data (https://esgf-index1.ceda.ac.uk/projects/cmip6-ceda/).

4. 141-142: the results section has a certain amount of restating things that have already been defined/said in the introduction and methods; consider trimming. This is one example
   Thank you for pointing this out, the results section can be trimmed to be more precise.

5. 239: do you mean "explicit" here?
   Indeed. Has been changed to "***explicit***".

6. 256: missing word? "that beta and gamma linearity is a valid assumption"?
   Sentence has been changed to include the word "***linearity***".

7. 264: thanks for the code transparency. Adding a README to this repo would be useful, and I suggest permanently archiving it (i.e., generating a DOI) using Zenodo
   A "README" file has been added to the GitHub repository. If the paper is accepted for publication, we will do as suggested using Zenodo.

8. Figure 2: move to SI? Not sure how useful this is; maps are very small
   We feel the maps are useful to show the patterns of change in the different experiments and across the CMIP6 Earth system models so have kept in the main manuscript, and given that this is an online journal, they can be expanded by the viewer to see greater detail.

9. Consider whether Figure 4 could be re-thought for clarity and impact. For example, what about plotting deltaCs (x) versus beta+gamma (y) with a 1:1 line, coloring points by 2xCO2 or 4x? That might be a better way to visualize for readers

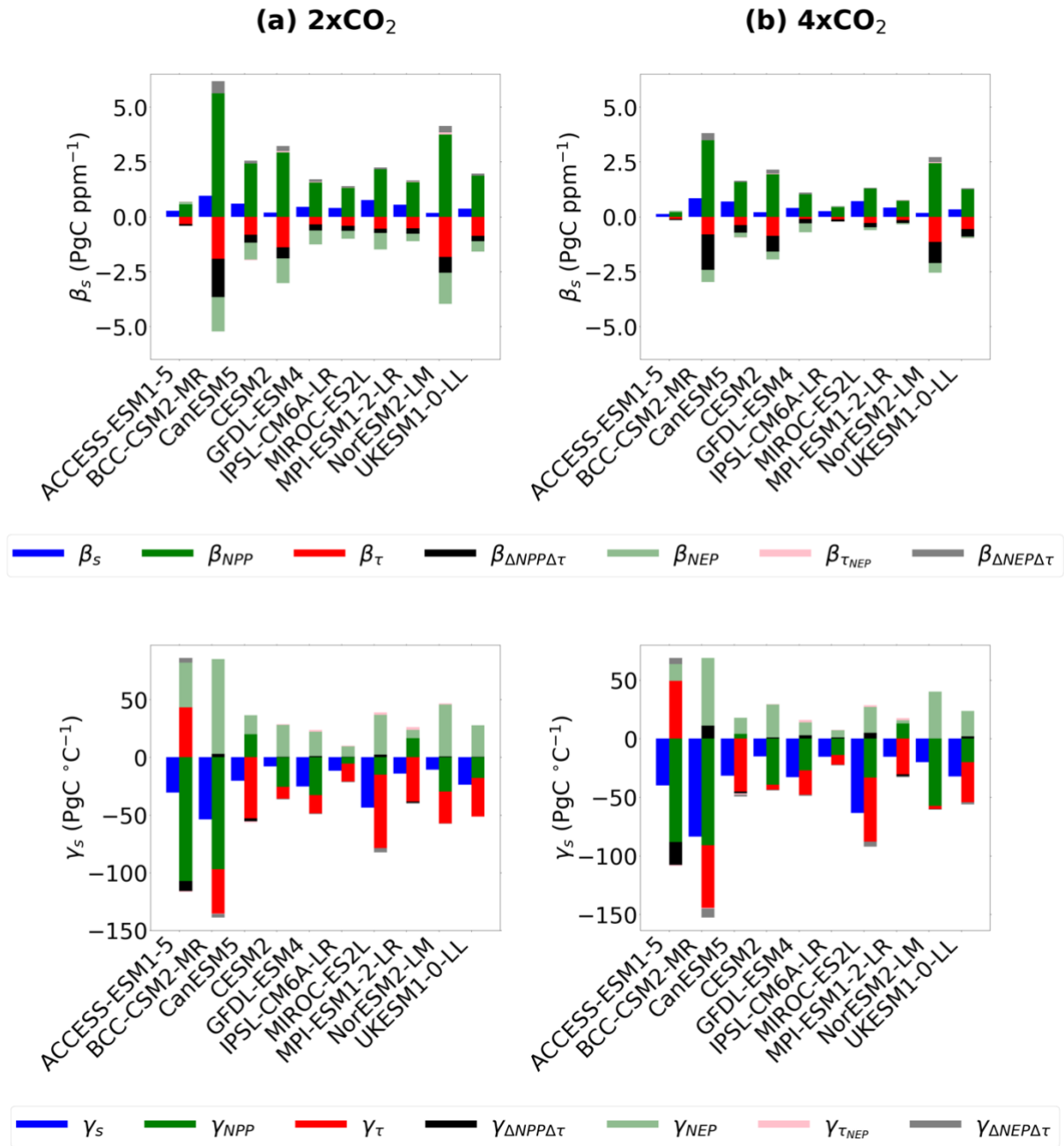   Figure 4 has been remade to follow the suggestion of plotting deltaCs (x) versus beta+gamma (y) with a 1:1 line (**see Figure below**). Though a colour has been used for each ESM (as in Figure 1) so the reader can identify ESMs when comparing to the 1:1 line, therefore a panel is included for 2xCO2 and 4xCO2.

10. You don't need to say "Bar chart", "Maps", etc. in the figure captions. Readers can see what type of plot it is

    The figure captions will be changed to avoid unnecessary information, such as '*bar chart*' and '*table*'.
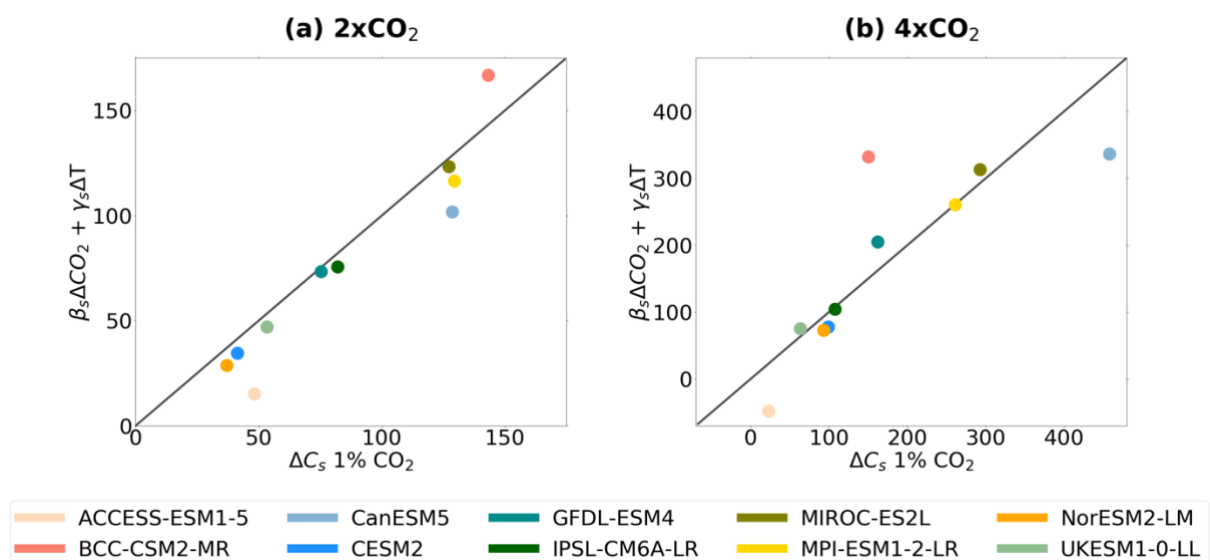
New Fig. 4 caption: '*Comparison of ΔC_s (PgC) in the full 1% CO_2 simulation (x-axis) against the estimated ΔC_s using the calculated β_s and γ_s feedback parameters (y-axis), where estimated $\Delta C_s \approx \beta_s \Delta CO_2 + \gamma_s \Delta T$, for each CMIP6 ESM at (a) 2xCO$_2$ and (b) 4xCO$_2$.*'.

(a) 2xCO₂   **(b) 4xCO₂**

Legend (top): β_s β_{NPP} β_τ $\beta_{\Delta NPP\Delta\tau}$ β_{NEP} $\beta_{\tau_{NEP}}$ $\beta_{\Delta NEP\Delta\tau}$

Legend (bottom): γ_s γ_{NPP} γ_τ $\gamma_{\Delta NPP\Delta\tau}$ γ_{NEP} $\gamma_{\tau_{NEP}}$ $\gamma_{\Delta NEP\Delta\tau}$

New Fig caption: '*Investigating the contribution of individual soil carbon drivers to the soil carbon-concentration (β_s, top row) and carbon-climate (γ_s, bottom row) feedback parameters, for each CMIP6 ESM, for (a) 2xCO2 and (b) 4xCO2. The figure shows soil carbon feedback parameter contributions from NPP (β_{NPP} and γ_{NPP}), τ_s (β_τ and γ_τ), the non-linearity in NPP and τ_s ($\beta_{\Delta NPP\Delta\tau}$ and $\gamma_{\Delta NPP\Delta\tau}$), and the effect from the non-equilibrium term NEP (β_{NEP}, $\beta_{\tau NEP}$, $\beta_{\Delta NEP\Delta\tau}$ and γ_{NEP}, $\gamma_{\tau NEP}$, $\gamma_{\Delta NEP\Delta\tau}$).*'.
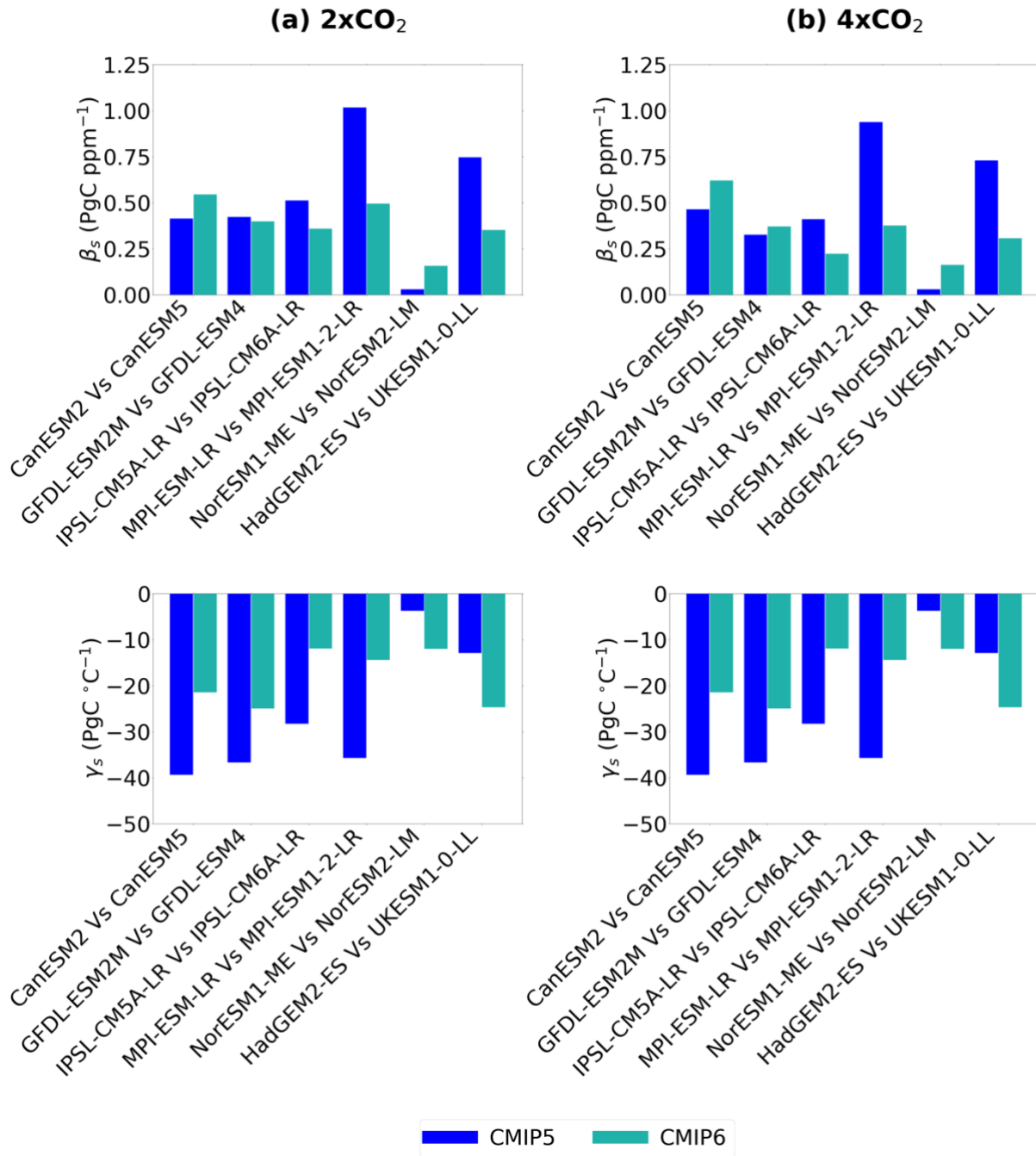
CMIP5 New Appendix Fig: 'Comparison of the soil carbon-concentration (β_s) feedback parameters (top row) and the soil carbon-climate (γ_s) feedback parameters (bottom row) from generationally related ESMs from CMIP5 and CMIP6, for (a) $2xCO_2$ and (b) $4xCO_2$'.