Review for by Soil carbon-concentration and carbon-climate feedbacks in CMIP6 Earth system models by Varney et al., submitted to Biogeosciences (EGUsphere)

The authors present an analysis of soil carbon cycle feedbacks using CMIP6 models forced with the 1pct-CO_2 experiment. Feedbacks are quantified using the integrated flux-based feedback framework from Friedlingstein et al. (2006), referred to here as the $\beta\gamma$ formulation. Feedback parameters are computed from the biogeochemically and radiatively coupled simulations for the carbon-concentration (β) and carbon-climate (γ) feedbacks respectively. The study concludes that the sensitivity of soil carbon to climate change increases with warming and is more dominant than the vegetation carbon response, underscoring the importance of soil carbon in long-term land carbon storage. The manuscript is generally clear, and the text has a logical flow through introduction to conclusion. However, I have two main issues:

1. While this study is a useful contribution, it would benefit from an expansion of the analysis. For example, the processes driving soil carbon change in each simulation could and it would be interesting to discuss why the soil carbon response differs between models, although I understand this may require a substantial amount of additional work. I also notice that some sections of the discussion read as a literature review, which could be remedied by better linking the spatial analysis results to driving mechanisms.

2. The manuscript seems to address two kinds of non-linearities: (1) the non-linearity in the soil carbon responses to CO_2 and temperature, and (2) another form of non-linearity which arises from non-additivity in the responses in the BGC and RAD simulations to that in the full simulation. In the results section, both non-linearities are mentioned, but in the discussion, it appears that the two are combined and given the same explanation.

Minor comments

L3: I suggest replacing the word *feedback* with *response*. The soil carbon responses to CO_2 and climate change give rise to the feedbacks.

L5: Please maintain consistency in the terminology used throughout the manuscript. The feedbacks are mostly referred to as soil carbon-concentration feedbacks (without the word *specific*).

L12: Increases in global temperature are an indicator of climate change, not an impact of climate change. Perhaps, rephrase to “sensitivity to climate change and the associated impacts such as changes in precipitation patterns.”

L23: Yes, the $\beta\gamma$ formulation can be used for calculating feedbacks from both concentration-driven and emissions-driven simulations, but there are issues with using the latter. Land-ocean compensation due to differing timescales of carbon uptake and loss between the land and ocean affects the magnitude of feedback parameters, so to ensure that both land and ocean see the same atmospheric CO_2 concentrations, concentration-driven simulations are used more widely.

L30: Does the first research question also explore the sensitivity of soil carbon to atmospheric CO_2? If so, please clarify.

L32: In the third research question, I suggest changing "land surface response" to "land carbon response". This appears to be more consistent with the results presented, which focus on carbon.

L43: Quick clarification on the length of your simulations: are they 140 or 150 years long? L99 refers to 140 years. Please clarify.

L64-66: In equations 2-4, I suggest using the 'approximately equal to' signs between the integrated flux term and the linearization as in Equation 1.

L67-68: The change in atmospheric CO_2 concentration is consistent in all three simulations, correct? Omitting the RAD simulation from Line 67 implies otherwise. Please address. With that said, I do understand that the point you want to make here is that the carbon cycle in the RAD simulation sees preindustrial CO_2 concentration (no CO_2 change) unlike that in the full and BGC simulations.

L76: Accidental *S* added to the Fig. A1 reference in brackets.

L117-120: According to Figure 1, ΔC_s continues to increase in the GFDL model, whereas in IPSL, the ΔC_s saturates. The sentence here states the opposite. Perhaps the positions of the two models were switched in this sentence or the labels on the figure were switched. Please review.

L121: ΔC_s is used to refer to any simulation (full, BGC, or RAD) in the results section. However, in equations 2 - 4, ΔC_s (with no superscript) is denoted as soil carbon change for the full simulation, and superscripts BGC and RAD are added for the BGC and RAD simulations. It would make the results easier to follow if this is maintained in the results section.

I also suggest using the phrasing "can be approximated by" rather than "is the net effect of" here because responses in the BGC and RAD simulations are not always additive to the response in the full simulation.

L134: Did you mean to say "the *spatial distribution* of ΔC_s seen in the full 1% simulation …"? Please clarify.

L152: I suggest changing the phrase to "increasing range with increased *global temperature*" because, in the RAD simulation, where γ is quantified from, the carbon cycle sees no change in atmospheric CO_2.

L154: Figure 3 is confusing. Please explain how the $2xCO_2$ and $4xCO_2$ β and γ lines were plotted? Could these results be presented differently to improve clarity?

L229: On the other hand, nitrogen mineralization - the temperature-dependent process by which nitrogen in organic matter is converted into inorganic forms that can be taken up by plants – fertilizes soils, countering the limit on productivity.

L259: Missing word *carbon* in “the sensitivity of soil ^ to changes in global temperature”

L262: This could be more concise by phrasing as either “long-term land carbon response under …” OR “long-term land carbon storage under …”