Response to Anonymous Referee #2 on "Identification of linear response functions from arbitrary perturbation experiments in the presence of noise

Part II. Application to the land carbon cycle in the MPI Earth System Model"

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We would like to thank Anonymous Referee #2 for the positive review of our paper and for the useful suggestions. Below we give our point-by-point response to the comments.

General comments

AR#2: **(1) It would be useful to add a section to the introduction explaining why linear response functions are useful.**
5 **This is actually done in the outlook section, but it would be better placed in the introduction so readers understand why all of the dense mathematics is useful.**

Authors: We agree with the reviewer that indeed explaining in advance the applications of linear response functions would better motivate the study. Therefore we will move the applications mentioned in the outlook section to the introduction.

10 *AR#2*: **(2) Throughout the manuscript non-linearities are treated as a annoying problem to to overcome. However, Earth system models were build to study coupled climate carbon cycle feedbacks and to explore for the potential of non-linear behaviour in the Earth system. Thus the manuscript has a bit of a 'we linearized the system of equations and thereafter found everything to be linear' vibe. The manuscript need to be clearer about what non-linearities are and why they are important.**

15 *Authors*: We agree with the reviewer. In the revision we will better explain what we mean by nonlinearities, and what their relevance is.

AR#2: **(3) The manuscript has a bizarre way of referring to subplots as 'subfigure (x)' only giving the letter of the panel as x, without the figure number referred to. Please change these everywhere to the conventional Figure 1a, Fig 2b**

20 **ext.**

Authors: The text will be changed accordingly.

Specific comments

AR#2: **Line 10: The sentence "By taking instead of CO2 the resulting Net Primary Production as forcing, the response is approximately linear until CO2 perturbations of about 850 ppm." confusing, please rewrite.**

25 *AR#2*: **Line 32: Sentence is confusing.**

Authors: We will reformulate the referred sentences.

AR#2: **Line 33: Change 'is' to 'are'**

Authors: Agreed.

30

AR#2: **Line 50: You should include a full explanation in the introduction of what γ and β are. You have assumed the reader knows what they are. In many cases this will be true but including a full explanation means you will lose less people, the paper will be less intimidating and the technique will be more likely to be used.**

Authors: We thank the reviewer for the suggestion. The meaning of γ and β will be fully explained in the revision.

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AR#2: **Line 61: The original C4MIP (Friedlingstein et al 2006) used a modified SRES scenario, not the 1pctCO2 experiment.**

Authors: This is true, but many other studies that followed Friedlingstein et al. (2006) adopted the 1pctCO2 experiment as standard for computing the climate-carbon sensitivities (e.g., Gregory et al., 2009; Arora et al., 2013; Schwinger et al., 2014;
40 Adloff et al., 2018; Williams et al., 2019; Arora et al., 2019). We will be more specific and mention these studies in the referred text.

AR#2: **Line 62: "performed with several" the 1pctCO2 experiment is part of DECK and is a required experiment for admittance to CMIP6.**

45 *Authors*: We will correct the text accordingly.

AR#2: **Line 65 to 69: Confusing long sentence. Break up for clarity.**

Authors: Agreed.

50 *AR#2*: **Line 81: Delete 'But while'. In general do not start sentences, let alone paragraphs, with 'but' in English. 'However' is acceptable.**

Authors: Agreed.

AR#2: Line 113: Most of the audience will not know what 'ansatz' means.

Authors: We will try to think of a better term.

AR#2: Table 1: Clarify that % is compounded to cause and exponential rise in CO2 concentration.

Authors: The clarification will be added in the revision.

AR#2: Line 156: "cursed" is not the correct word to use here.

Authors: We will find a more appropriate word.

AR#2: Figure 2: Is the error metric non-dimensional? If so make this clear. 'Relative prediction error' may be clearer.

Authors: Yes, it is. We will change the naming accordingly.

AR#2: Figure 2: Be careful how you use the word 'forcing'. Many readers will assume radiative forcing unless this is specified otherwise.

Authors: We will try to find a more appropriate term.

AR#2: Equation 12: Lowercase 'c' is terrible notation for atmospheric CO2. C_A or C_{atm} would be clearer.

Authors: The notation will be changed accordingly.

AR#2: Line 291: Why use NPP instead of GPP. GPP is a direct measure of photosynthesis.

Authors: The idea behind the splitting of the overall response of land carbon to CO_2 in two parts ($NPP(CO_2)$, $C_{land}(NPP)$) is to separate off most of the nonlinearities into the the relation $NPP(CO_2)$ whose functional dependence can be guessed as logarithmic. Indeed, alternatively one could use GPP instead of NPP for the splitting, but in this way the nonlinearities arising from the dependence of autotrophic respiration on CO_2 would be part of the relation $C_{land}(GPP)$. Hence, using NPP instead of GPP is a better choice to split off most of the nonlinearities in $C_{land}(CO_2)$.

AR#2: Line 295: "land carbon only via changes in photosyntetic productivity." This is not true. At higher atmospheric CO2 concentration plants are able to close their stoma more often, allowing higher retention of water. This decreases the rate of evapotranspiration, which feeds-back onto ground water supply and atmospheric processes depended of water vapour flux. This is well known and well studied phenomena.

Authors: We agree with the reviewer's comment that CO_2 fertilization consists not only of a direct but also of an indirect effect: rising CO_2 is affecting photosynthetic productivity directly via reduction of photorespiration in the biochemistry of the Calvin cycle, and indirectly by affecting stomatal closure, that via reduced transpiration feeds back on photosynthetic productivity by soil water savings that may e.g. lead to a prolonged growth period. But these two effects are taken into account by our sentence,

which says that "in the 'bgc' setup, perturbations in atmospheric CO_2 affect land carbon only via changes in photosynthetic productivity" – we never claimed that CO_2 acts only via its direct effect. On the other hand, it is true that the reduced transpiration may indeed lead to climatic changes, but these changes are small (e.g., Arora et al., 2013). To make these details clear, we will add a remark in the revision that in the bgc setup these two effects of CO_2 are active, and that in particular the indirect effect of stomatal closure may lead to small climatic changes.

AR#2: 432: This is not a Gregory plot, and calling it a Gregory plot is confusing. Do not refer to these are Gregory plots. Gregory plots are based on simple energy balance, these plots are not.

Authors: We will think of a better name for the referred plots.

AR#2: Line 569 to 570: This is not a complete sentence.

Authors: We will reformulate the sentence.

With best regards,

Guilherme L. Torres Mendonça, Julia Pongratz and Christian H. Reick

References

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