

Review of "Asymmetry in carbon cycle feedbacks and transient climate response under positive and negative CO<sub>2</sub> emissions"

Overall assessment:

The study devises a novel experiment design to assess the asymmetry in positive and negative TCRE. This is done by spinning-up an Earth System Model (ESM) at 2X pre-industrial CO<sub>2</sub> concentration and carrying out positive and negative emissions experiments from climate equilibrium. Biogeochemically and radiatively coupled CO<sub>2</sub> experiments are conducted to decompose the components of the carbon cycle feedbacks. The paper finds that there are substantial asymmetries in positive and negative TCRE driven by complex Earth system responses. Overall the paper is well thought out, thorough and a valuable contribution to negative emissions research. I recommend that the paper undergo minor revisions.

*We thank the reviewer for their positive comments.*

General Comments:

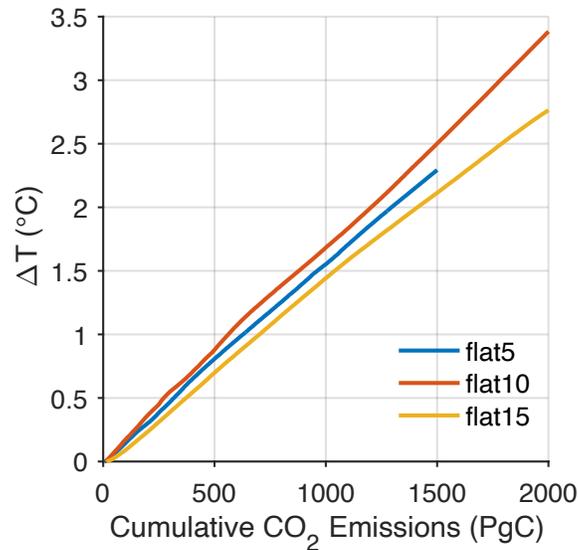
(1) While the need for a new experiment design to quantify asymmetry in TCRE is clearly explained in the introduction, you do not give a clear rationale specifically for your new experimental design. Why is starting simulations from 2X CO<sub>2</sub> a good idea? Why not start at pre-industrial conditions?

While dropping down to zero CO<sub>2</sub> concentration would clearly cause catastrophic strain on any ESMs numerics, you need to explain to the reader why this is a bad experiment design, and why this justifies starting from 2X CO<sub>2</sub>.

*We chose not to initialize simulations from preindustrial because the symmetric negative emissions simulation would span a range of CO<sub>2</sub> concentration of 0 – 280ppm, with most of those CO<sub>2</sub> concentrations below policy relevant levels and could cause instabilities in numerical simulations. Furthermore, this choice allows for comparability to previous work (experimental design from Chimuka et al., 2023). In particular, the symmetric negative emissions simulation from 2xCO<sub>2</sub> to 1xCO<sub>2</sub> here, which represents the response to negative emissions alone, can then be directly compared to the declining limb of the CDR-reversibility experiment (from 2xCO<sub>2</sub> to 1xCO<sub>2</sub>), which represents the response to both prior positive emissions and the subsequent negative emissions. We plan to provide a stronger justification for the experimental design in the revised manuscript.*

(2) You need to establish that TCRE exists in 2X CO<sub>2</sub> world (I highly suspect it does). To do this simple conducted flat-5, flat-10 and flat-15 experiments from the 2XCO<sub>2</sub> equilibrium state to 2000 PgC, and make sure that the cumulative emissions vs. temperature curve is linear and path-independent. You can place the figure in the supplementary and add a sentence or two in the main text saying that you checked this.

*We thank the reviewer for this note. We can confirm that the TCRE relationship is linear and shows little path-dependence for the 2xCO<sub>2</sub> state. The requested figure is included below and will be added to the supplement.*



Specific comments:

Line 25: Change to either 'year 2100' or '2100 CE'

*Corrected.*

Line 112: 'several millennia' be specific, give actual numbers.

*We have made this more specific (6000 years).*

Line 124: Explanation here can be improved. It is unclear what 'symmetrically' means in this context.

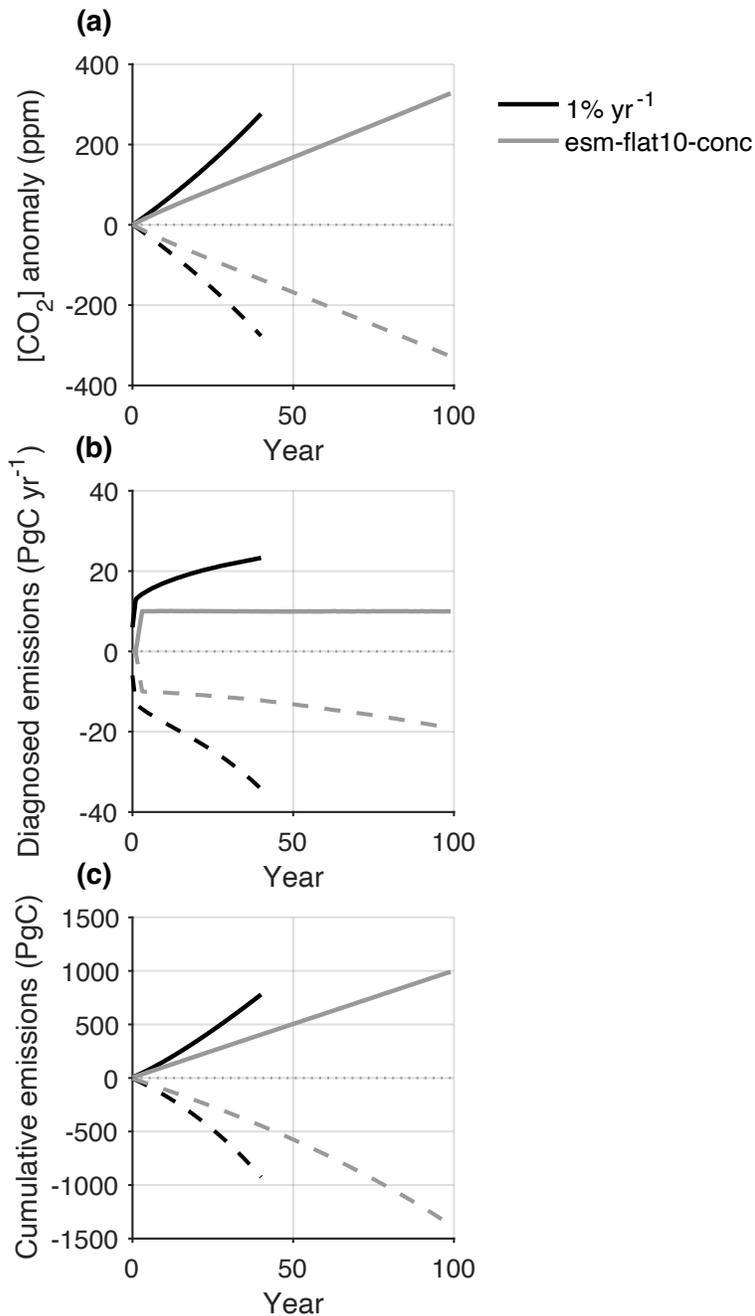
*We have removed this word in this line, and kept it in line 127, where we refer to the symmetric CO<sub>2</sub> trajectories.*

Line 130: Change 'real world' to 'natural world'

*We have corrected this wording everywhere in the manuscript.*

Figure 1b: What are there tails on the flat-10 experiment?

*We noticed that we had the axis shifted forward by a year. The figure has now been corrected and included below. We thank the reviewer for pointing this out.*



Line 183: Should 'modes' be 'models'? If not a typo please explain more.

*Modes here refers to the three fully coupled, biogeochemically coupled and radiatively coupled modes; the last two modes are important for disentangling carbon cycle feedbacks. We will clarify this in the manuscript.*

Line 260: Please write our 'positive emissions' and 'negative emissions'. 'PE' and 'NE' are not improving the readability of the paper.

*We have changed this everywhere in the manuscript.*

Line 261: Change 'logarithmic' to 'approximately logarithmic'

*Corrected.*

Figure 4: Please write out all of the abbreviations in the figure legend.

*We have updated the figure legend accordingly and included it below.*

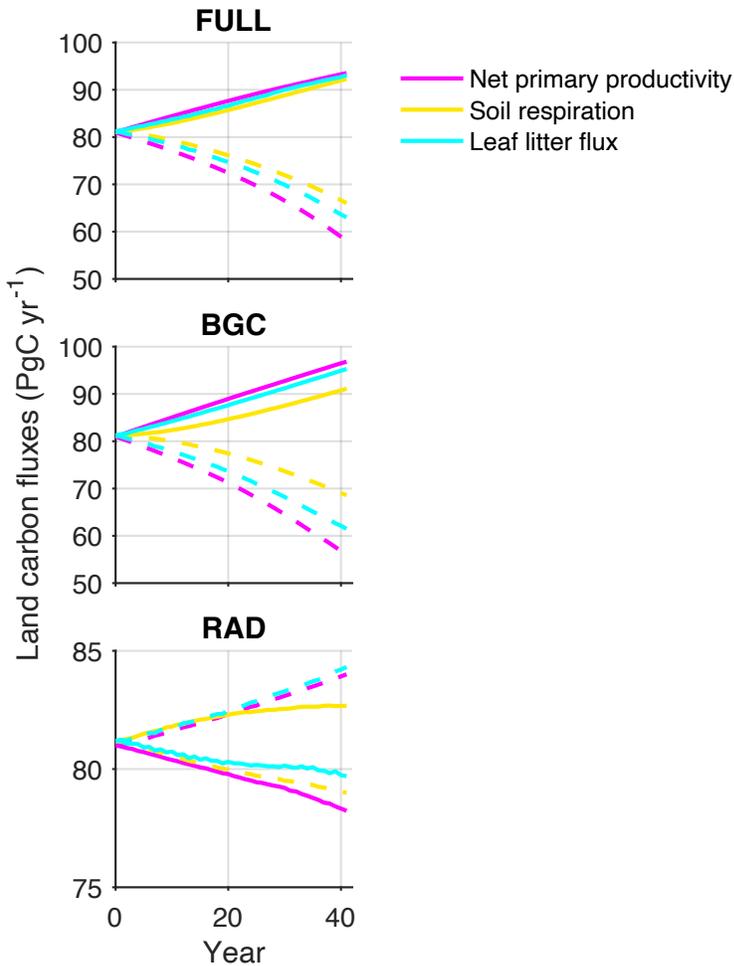


Figure 5: I would suggest using Kelvin units in place of °C. Have C for carbon and °C in the same units can lead to confusion.

Figure 6a: Again Kelvin would be preferable. 'TCRE/TCRR' could be written 'TCRE or TCRR' to avoid readers interpreting the former as a division operation.

*We thank the reviewer for these comments. We chose to keep °C for consistency with the original feedback framework and past carbon cycle and TCRE research studies. We have, however, clarified the meaning of the units in case of confusion in the captions for Figures 5 - 7.*

*We have also replaced all instances of TCRE/TCRR with TCRE or TCRR.*

Line 490: Write out RF and AF. Many readers will read RF as 'radiative forcing'

*We have corrected this wording everywhere in the manuscript.*

Line 496: Change 'real world' to 'natural world'

*We have corrected this wording everywhere in the manuscript.*

Line 503: Change 'real world' to 'present day' or 'pre-industrial world'. Many paleoclimate states have been close to 2XCO<sub>2</sub>.

*Corrected.*

Line 518 to 520: There are versions of the UVic ESCM with fully coupled nitrogen cycle (De Sisto et al. 2024). This should be mentioned here.

*Corrected. We thank the reviewer for this note.*

References:

De Sisto, M.L., C. Somes, A. Landolfi, and A. H. MacDougall, 2024: Projecting atmospheric N<sub>2</sub>O rise until the end of the 21st century: an Earth System Model study, *Environmental Research Letters*, (12), 124036

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