General response:

We would like to express our gratitude to all of the reviewers for the ongoing support and insightful feedback. Their thoughtful and constructive comments have played a key role in refining both the structure and content of the manuscript. Please find our point-to-point responses to the individual comments given by the Reviewers below (reviewer comment in black, our response in blue). The ***line numbers*** and ***page numbers*** in this document refer to the revised mauscript file *with* tracked changes.

Response to RC2:

I thank the authors for their clear and elaborate response to my, and the other reviewers, remarks. All my concerns have been addressed. I have some short new remarks on the revision which should be easy and quick to address. Congratulations on an interesting, well written, paper.
We would like to sincerely thank the reviewer for their positive feedback and thoughtful comments on our paper. We are glad to hear that all of your concerns, as well as those of the other reviewers, have been addressed. We appreciate your additional remarks on the revision, and made sure to incorporate them. Thank you again for your time and constructive input, and for recognizing the work presented in our paper.

Line 152: REF is now introduced in line 182 but could also already be introduced in this line.
Thanks for the suggestion, we have introduced it in the following way as suggested:

Page 7, Line 152*: Added "In the reference [(REF)] experiment, we…"*

Line 195: '… towards to …' I suppose 'to' can be removed here.
Thanks for catching that, it has been changed as suggested:

Page 10, Line 200*: Removed "…temperatures slowly decrease towards [to] pre-industrial levels…"*

Line 228: I'm not sure what is meant with 'generally globally distributed'. Should I interpret this sentence as: 'Most of the globe sees an increase in vegetation carbon with increasing emissions mainly because of increases in NPP. However, there are a few regions that see a decline in vegetation carbon due to a reduction in carbon'. If so, I suggest rewriting the sentence a bit to make it clearer (feel free to use my suggestion, paraphrase it or come up with something yourself).
We have changed the text based on what was suggested, but have replaced "…due to a reduction in [carbon]" with "…due to a reduction in [precipitation]", since we believe that is what the reviewer meant here.

Page 12, Line 233-235*: Changed "Most of the globe sees an increase in vegetation carbon with increasing emissions mainly because of increases in NPP (Fig. 6b,c,e,f). However, there are a few regions that see a decline in vegetation carbon due to a reduction in precipitation (Fig. 11h,i)."*

Line 280: to is missing behind proportional, I think.

Thanks for catching that, it has been changed as suggested:

Page 16, Line 286: *Added "...as it is proportional [to] organic detritus production..."*

Line 339: Now an instantaneous pulse is used in the revision with the PULSE experiments, right?
Indeed, you are correct. We have revised this sentence to better reflect our suite of experiments:

Page 20, Line 345-346: *Added "Unlike previous studies (e.g., Archer et al., 2009a; Joos et al., 2013), we do not deploy an instantaneous pulse [in the REF ensemble], and our fractions of emissions remaining do not start at 1 as carbon sequestration already began during the ramp up of emissions."*

Line 656: 'long timescales' is mentioned several times without a clear definition of what is meant with long. I don't think that's necessarily a problem. However, I do suggest defining it in line 656 as it is a major conclusion. A suggestion on how to do it: '... on long timescales (> 10^3 years).' (or whatever timescale you want to put there).
This is a very good point. In addition to defining "long timescale(s)" in the line as suggested, we have also provided a definition at the beginning of the manuscript.

Page 2, Line 24: *Added "...on the long-term [(>10^3 years)] future."*
Page 35, Line 670: *Added "The methane cycle will likely have a negligible effect on long timescales [(>10^3 years)]."*

Generally: in most of the text the simulations corresponding to the REF experiment are referred to as one ('REF experiment'). I understand that the simulations all fall under one 'experiment', but this is a bit confusing since there are several simulations. I suggest referring in the text to 'REF experiments', so plural. I suggest also doing this for the other experiments. I think this might make it a bit clearer.
This is a good point, thanks. We have changed "experiment" to "experiment[s]", "ensemble", and "ensembles" where appropriate in the revised manuscript.

Response to RC3:

The authors have adequately addressed all the remarks I have raised during the first round of review. Their choice regarding which information (and figures) to add, and which paragraph to remove, in order not to excessively lengthen the manuscript, is relevant. Although there are a few more details I would recommend them to rectify, as far as I concerned, I consider that it can be achieved without needing another round of review.
We would like to sincerely thank the reviewer for their positive feedback and for recognizing the efforts made in addressing the remarks raised during the first round of review. We appreciate the understanding regarding the balance between adding relevant information and maintaining the manuscript's length. We took note of your additional recommendations and made the necessary adjustments accordingly. Thank you once again for your valuable input, and we are pleased to hear that you find that a further review is not required.

Line 165: to be fully consistent, I suggest to change here also "pulse" to "scenario".
Thanks for catching that, it has been changed as suggested:

Page 7, Line 165: *Changed "explore the sensitivity of the results to the duration of the CO_2 emission [scenarios], …".*

Lines 190-195: the cause identified by the authors for the CO2/temperature decoupling in the 500 PgC appears consistent. But the description the authors provide is somewhat awkward, and reads as "global temperature decreases at t = 300yr, except in the 5000 PgC scenario where AMOC declines, resulting in a cooling, preventing further warming".
I believe what the author meant is that the AMOC starts declining around t = 150 yr (not t = 300 yr and the resulting cooling effect truncates the warming peak otherwise observed in all other scenarios (and although CO2 keeps increasing until t = ~300 yr). Hence, there is a global temperature plateau, and global cooling is delayed to t = ~700 yr starts.
This can be explained a bit clearer than currently done.
Thanks for bringing this to our attention. After rereading this section, we agree that it can be interpreted incorrectly, so we have since changed it to the following in the revised manuscript:

Page 8, Line 191-199: *Changed "However, the extended decline in the Atlantic Meridional Overturning Circulation (AMOC; Fig. 7e) in the 5000 PgC scenario results in a cooling effect in the Northern Hemisphere that prevents global mean temperature from further rising, thereby truncating peak warming. After emissions cease (~150–200 years after the start of the simulation, Fig E2), both atmospheric CO_2 concentration and global temperatures decrease as carbon is taken up by the land and ocean pools (Fig. 2a-d). The only exception to this is the 5000 PgC scenario, where there is a global temperature plateau, and global cooling is delayed until approximately ~700 years after the start of the simulation, coinciding with a substantial recovery of the AMOC (Fig. 2b, 7e)."*

The caption of Fig. 12 now gives the impression that panel a (main one) is for the whole time-series, including the ramp up emission, while panels b and c are after the peak CO2 concentration. Whereas the main text says that "The ramp up of emissions is not included in this analysis" (line 338).
Thanks, we understand how this could be interpreted incorrectly. We have since changed this to the following:

Page 21, Fig. 12 caption: *Changed "(a) Fraction of emissions remaining in the atmosphere [after peak CO_2 concentration] for the different emission scenarios in the REF experiment".*

Lines 374-384, Fig 13 and Table E2 : the inclusion of PULSE experiment add some complexity to the understanding of the fit. I am surprise to see that Ai do not sum to 1 for the PULSE case (Fig. 13 and Table E2), and are actually are very similar than for the REF case. It looks as if the fit was performed starting around t = 200yr, and not at peak CO2 concentration, which, in all likelihood, must happen at t = 1yr, where the fraction of emission remaining is still ~ 1 (Fig. 12b). Or maybe is it due to a poorness of the fit for the the very first years, as suggested in caption of Table E2? Meaning that the "n=3" exponential fit cannot reproduce a curve reaching 1 at "t after peak CO2 = 0yr"?
It would be beneficial to say a word or to about why Ai does not sum to 1 in the PULSE case. In this paragraph (lines 374-384) or in the caption of Table E2. Another suggestion would be to specify which year the peak CO2 concentration in the 3 cases (REF, noLAND and PULSE).
As the reviewer correctly noted, the sum of A_i in the PULSE experiment not equalling 1 is due to the relatively poor fit during the first ~100 years. We attempted to address this in the caption of Table E2 (as the reviewer also pointed out). Achieving a more accurate fit would require a

higher number of exponential decay terms to better capture "short-term" (<10^2 years) carbon removal processes such as air–sea CO_2 exchange, dissolution, and land carbon dynamics, as suggested by Lord et al. (2015) and Jeltsch-Thömmes & Joos (2020). By using n=3 for our fit, it does appear as if we have started fitting around $t \approx 200$ years. However, we do fit the entire time series, starting from t=0 (time after peak CO_2 concentration), as one can see in Fig. A1 in the "Additional materials" section at the end of this document. This is also reflected (to a very small extent) in the lower R^2-values as compared to the REF/noLAND experiments, as shown in Table E2 of the revised manuscript.

In our preliminary tests on the PULSE experiment, we found that n=4 to 5 provided the best fit depending of the magnitude of CO_2 emissions, consistent with the findings of Colbourn et al. (2015) and Lord et al. (2015). However, we kept n=3 because (1) ultimately, we are focused on the long-term carbon cycle, and (2) we wanted to remain consistent in our analysis across the different experiments. In saying this, we have clarified in the text that achieving a better fit would require a higher number of exponentials, while also acknowledging the drawbacks of this approach. For the record (since the response is public and this information will be accessible to others), we have included an example of fitting the 500 and 5000 PgC scenarios with a higher-order exponential fit as Fig. A2 the "Additional Materials" section.

Page 22-24, Lines 399-406: Changed "Short-term processes (i.e., sub-centennial timescales) cannot be fit for the REF and noLAND experiments given potential complications with and the removal of the ramp-up period. However, n=3 is already sufficient for examining the long-term uptake of anthropogenic CO_2. It should be noted that, due to this decision, the values for A_i in the REF, PULSE, and noLAND experiments do not sum to 1 (Fig 12b). This is because, for the REF and noLAND experiments, a fraction of emissions was already removed via short-term processes during the excluded ramp-up period. A more accurate fit could be achieved for the PULSE experiment by increasing the number of fitted exponentials, however, we kept n=3 as to remain consistent in our analysis.".

Additional material:

Fig. A1: Multi-exponential fit (n=3) for atmospheric CO_2 concentration in the PULSE ensemble, as shown in the revised manuscript. Colours here correspond to cumulative emission scenarios of 500-5000 PgC (as shown in Fig. E1 of the revised manuscript).

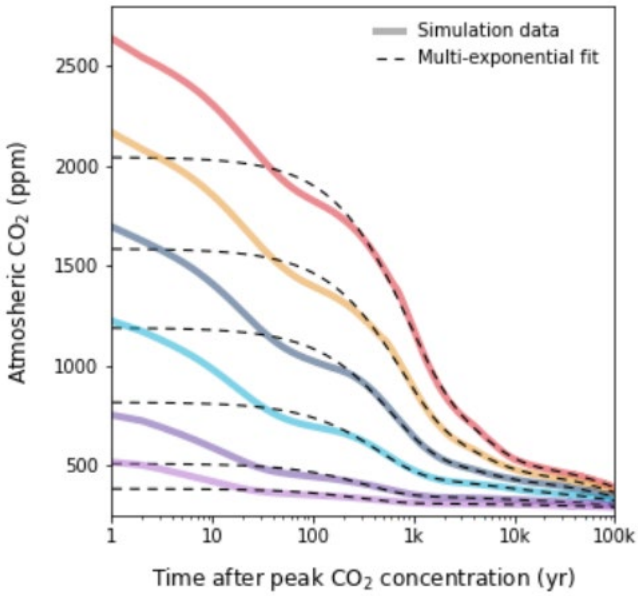
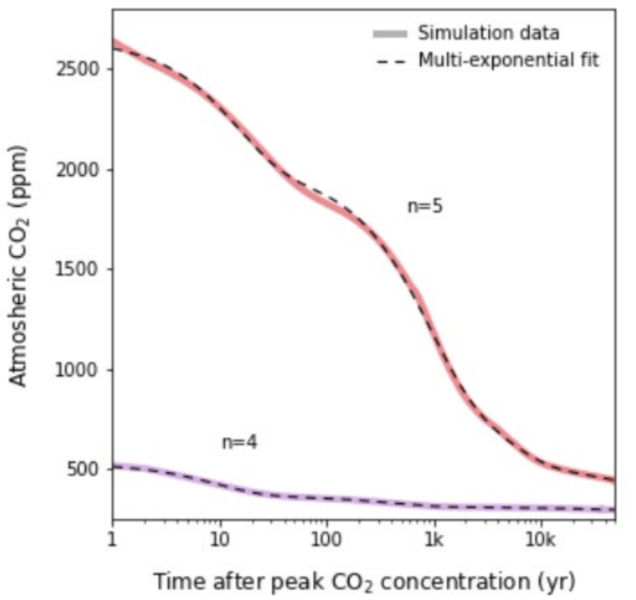


Fig. A2: Multi-exponential fit when using a higher order (n=4 to 5) of fitted exponentials for the PULSE experiment. Colours here correspond to cumulative emission scenarios of 500-5000 PgC (as shown in Fig. E1 of the revised manuscript).



References:

Colbourn, G., Ridgwell, A., & Lenton, T. M. (2015). The time scale of the silicate weathering negative feedback on atmospheric CO_2. *Global Biogeochemical Cycles*, 29(5), 583–596. https://doi.org/10.1002/2014gb005054

Jeltsch-Thömmes, A & Joos, F. (2020). Modeling the evolution of pulse-like perturbations in atmospheric carbon and carbon isotopes: the role of weathering–sedimentation imbalances. *Climate of the Past*, 16, 423–451. https://doi.org/10.5194/cp-16-423-2020

Lord, N. S., Ridgwell, A., Thorne, M. C. & Lunt, D. J. (2015). An impulse response function for the "long tail" of excess atmospheric CO_2 in an Earth system model. *Global Biogeochemical Cycles*, 30(1), 2–17. https://doi.org/10.1002/2014gb005074