Biogeosciences Discussions

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Reviewer comment on bg-2022-168

Anonymous Referee #2

Referee comment on "Quantifying land carbon cycle feedbacks under negative CO_2 emissions" by V. Rachel Chimuka et al., Biogeosciences Discuss., https://doi.org/10.5194/bg-2022-168-RC2, 2022

Authors quantify carbon-concentration and carbon-climate feedback for negative emissions for an idealized scenario and compare the magnitude of these feedbacks for the positive emissions part of an idealized scenario. The manuscript is relatively well written and in principle it all makes sense. However, I would suggest improving the manuscript in the following ways.

- Please include equations in the main text that should clarify your methodology (where you subtract the effect of zero emissions run on quantities considered during the ramp-down phase). If a picture is worth 500 words, an equation is worth at least 200 words. In the absence of the equations, it is difficult to understand your methodology.

- Please introduce your sign notation in the beginning and then use it consistently throughout the manuscript. Recall that carbon-concentration feedback is negative from the atmosphere's perspective because it reduces atmospheric CO_2 If you use the term "when carbon is gained" then please clarify explicitly which component is gaining carbon - land/ocean or the atmosphere.

- Near lines 308-313, I was confused with the sign notation even more because it seems, as you interpret it, sign notation reverses during the ramp-down phase. This needs to be better explained because I am unable to understand why sign notation reversal is needed. If carbon-concentration feedback is negative from an atmosphere's perspective (let's say a value of -1.0 Pg C/ppm) this implies that an increase in atmospheric CO2 concentration will be reduced from its initial amount due to this negative feedback. The corollary of this is that if atmospheric CO2 is reducing then the change in CO2 is negative (say -2 ppm) which when multiplied by -1.0 Pg C/ppm yields +2.0 Pg C implying 2 Pg C is added to the atmosphere. All this makes sense in my mind. So why is reversal of sign notation needed?

- I would also like to note that feedback parameters are most "realistic" or "relevant"

when found using FULL and BGC runs. The real world operates like a fully-coupled simulation. For finding feedback parameters in addition to FULL we need a BGC or RAD simulation. Since the carbon-concentration feedback is the dominant feedback perhaps it makes more sense to use the BGC simulation.

- Finally, my last major comment is that when in the real world we do ramp down emissions then, at that point in time, the land and ocean C cycles won't be in equilibrium with the atmospheric CO2. There will be inertia in the real system, and the response of land and ocean at the time will be affected by this inertia. So is the purpose of attempting to correct the feedback parameters for this inertia on the ramp-down side only to compare them with their ramp-up counterparts?

Minor comments

1. I realize the purpose of Figure 1 is to clarify things but for me text for easier to follow. Perhaps you can try to improve Figure 1.

2. Line 107, "generates permafrost". Please reword this sentence. I think it is incorrect to say "generate permafrost". Permafrost is a state which results from sub-zero temperatures.

3. Lines 145-152 need equations to clarify the methodology used.

4. Line 172. "This temperature change is driven by biophysical responses to increasing CO2". Please add another sentence of explanation at the end of this sentence for completeness.

5. Please put a zero line in Figures 3c,d,e,f, and Figures 4a,b.

6. Lines 258-261 read " … except in the vegetation carbon pool where the width of the hysteresis increases throughout the simulation (figure 5(c)). The land and ocean carbon pools in the RAD mode also exhibit hysteresis (figure 6). The hysteresis in the land carbon pool is dominated by the soil carbon pool (figure 5(d)), and the width of the hysteresis appears to increase throughout the simulation for all carbon pools except the vegetation carbon, which shows nearly constant hysteresis".

I am confused here. Please reword clearly. Hysteresis is defined as the difference in paths going up and down. Isn't hysteresis zero at the point of turn? With this in mind please reword the above sentences.

7. Lines 273-274 read "The ocean holds only 70PgC less than at preindustrial, but unlike the land carbon pool, a miniscule amount of ocean carbon is regained in the ramp-down phase (figure 5d)".

But Figure 5d is the soil C figure. Please refer to the correct figure.

8. Line 308 reads "For positive emissions, feedback parameters are positive (negative) for a gain (loss) of carbon". Please consider not using sentences that use pair of parentheses to note two points. This can get very confusing. Also, please clarify whether the gain or loss is by which component – land/ocean or the atmosphere.

9. Line 309 reads " … resulting in a negative denominator (see supplementary equations 3.3 – 3.6)".

There is no denominator in these equations. I think I know what's implied here but it may not be obvious to other readers.

10. Lines 308 – 313. Please use equations here because the sign convention is becoming confusing.

11. Comparison of Figure 5a and S4a shows there's more hysteresis in BGC run than in the FULL run. Can this be explained? Isn't this a good reason to use the FULL simulation to find feedback parameters on the ramp-up and ramp-down portions?

12. What does "All" means in Figure 7a legend?

13. Zero emissions runs were initialized from the end of ramp-up. What does BGC and RAD mean for these runs? Do the RAD and BGC runs in Figure 7, see and not see temperature change, respectively, relative to end of the ramp-up or relative to the pre-industrial state? Please clarify.

14. Lines 375-377 read "Under negative emissions, the magnitudes of b[eta] and g[amma] from our novel approach are larger compared to those from the "CDR-reversibility" simulation WHEN RAMPING UP (CORRECT?), implying **greater carbon loss** due to the concentration-carbon feedback and **greater carbon gain** due to the climate-carbon feedback under negative emissions".

"Greater carbon loss" and "greater carbon gain" for what component – land/ocean or atmosphere?

15. Lines 383-384 read "… due to the concentration-carbon feedback, carbon pools take up carbon in the ramp-up phase, continue to take up carbon in the early ramp-down phase."

Actually, it's the other way around. Carbon pools don't behave according to the feedbacks but rather feedbacks are derived from the behavior of the C pools. Please consider rewording.

16. Next two sentences …

"Due to the climate-carbon feedback, carbon pools lose carbon in the ramp-up phase, continue to lose carbon in the ramp-down phase, then switch into carbon sinks"

"… suggesting that land and ocean carbon changes due to carbon cycle feedbacks …"

Here too, please consider rewording.

17. Lines 404-405 read " … we subtract the zero emissions simulations from the "CDR-reversibility" simulations …".

Please use equations to show how.

18. Lines 427-428 read "… concentration-carbon feedback parameter is more positive (Table S2)".

Please clarify if this is from the land's perspective. Please use a single notation consistently.

19. Lines 428-429 read … "They [i.e. land models with N cycle] also exhibit greater carbon loss under positive emissions, that is, the climate-carbon feedback parameter is more negative".

This seems incorrect. Note that land models with N cycle typically have a smaller absolute magnitude of carbon-climate feedback because increase in temperature promotes vegetation growth due to enhanced N mineralization which somewhat compensates for increased soil C respiratory losses.

20. Lines 433 – 435 read "With the consideration of nitrogen limitation, the already weakened CO2 fertilization effect under declining CO2 concentrations would be further constrained, exacerbating the carbon loss due to the concentration-carbon feedback".

This seems like a bit of speculation. Why would this be? It could be the other way around too. If increasing CO2 causes C:N ratios to increase and constrain photosynthesis, more than the case when the N cycle is not represented, then decreasing CO2 should lower C:N ratio and help vegetation photosynthesize a bit more (compared to when the N cycle is not represented).

Of course, overall photosynthesis will still be reducing since CO2 is going down but off the top of my head it's difficult for me to imagine the effect of N cycle when CO2 is reducing. Perhaps is prudent to not speculate.

21. Finally, what is the CDR-reversibility simulation? Does this refer to both the ramp-up and ramp-down portions or just the ramp-down portion? Note that the ramp-up portion already has a standard experiment name i.e. 1pctCO2. Please clarify this in the beginning and then use the correct terminology throughout the rest of the manuscript.