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Earth System Dynamics Discussions

Interactive comment on "Earth system model simulations show different carbon cycle feedback strengths under glacial and interglacial conditions" *by* Markus Adloff et al.

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Response to the review comments by Anonymous Reviewer 2:

We thank the reviewer for the comments on the submitted study and especially for the very detailed comments in the scanned paper that will be useful in preparing our manuscript for resubmission.

The main concerns of the reviewer are related to our equations in chapter 2. In the introduction of our equations, we follow Gregory et al. 2009. Just as the reviewer mentioned, I_tot in equation 6 of our paper is "the cumulated carbon influx to the atmosphere until time t consistent with the atmospheric CO_2" (see our remark above eq. 6). I_ext is the cumulated emissions from external sources, as pointed out immediately underneath the equation. One can think of the latter one being the amount of carbon emissions necessary to get the change of atmospheric carbon content that is prescribed in our concentration driven experiments. The difference between I_tot and I_ext is just the amount of carbon that is added/removed via feedbacks. As correctly realized by the reviewer, the quotient I_tot/I_ext is indeed the airborne fraction. But it is as well the feedback strength (Gregory et al. 2009, p. 5238) so that the reviewer's and our interpretation of this quotient are correct. When revising our paper we will point out these alternative interpretations and will take the opportunity to compare with published estimates of the airborne fraction in MPI-ESM and other simulations. – We thank the reviewer for this hint.

From the reviewer's comments we realize that we produced some confusion by incorrectly pointing to Friedlingstein et al 2003 when introducing the feedback factor and gain in the context of eq. 7: our feedback factor and gain are those of Gregory et al. 2009 (the latter named there gC) and not those of Friedlingstein et al. 2003 (Friedlingstein g is called gCC in Gregory et al. 2009) as correctly spotted by the reviewer. The difference is that gC characterizes the feedback induced by the additional radiative forcing and CO_2 fertilization of the CO_2 emissions, while the Friedlingstein g characterizes only the feedback induced by the radiative forcing. Since we are interested in the system as a whole, we prefer to use gC. When resubmitting we will take care to prevent this confusion.

Another concern expressed by the reviewer is that the sharp transition of the dependence of assimilation rate on atmospheric CO_2 concentration shown in figure 7 of our submitted paper cannot be recognized in figure 3c in Arora et al. 2009. This observation does not represent a contradiction between the two studies: Figure 7 in our paper shows the transition between two 'modes' of photosynthetic assimilation as a function of CO_2 concentration. In each 'mode' a different subprocess is limiting the assimilation rate as a whole: carboyxlation or electron transport. In order to assess which of the two limitations presents a larger constraint to the assimilation rate, our model calculates carboxylation rate and electron transport rate and calculates the resulting assimilation rate based on the smaller of the two. This is the same in the CTEM model used by Arora et al. 2009 – see their equations (4) and (5) that describe the two modes. The difference between our figure 7 and figure 3c in Arora et al. 2009 is thus that we display how the assimilation rate resulting simultaneously from both limitations depends on CO2, whereas Arora et al. 2009 show the CO2 dependence of carboxylation and electron transport rate individually. We included figure 7 into our study to point out that assimilation rates are considerably less sensitive to rising CO2 concentration after CO2 has reached the transition point from carboxylation to electron transport rate limitation. With the preindustrial CO2 concentration being closer to the transition point than the glacial CO2 concentration, the regime where the assimilation rate saturates by electron transport limitation is reached much earlier during the scenario starting from pre-industrial conditions, which is the main cause for the smaller sensitivity to rising CO2 concentrations in this case.

As with the first review comment, we take the remarks on language and style very seriously. We will make sure that the next manuscript version is of satisfactory style for native speakers. Here, we intend to clarify exemplarily the criticized formulations explicitly cited by the reviewer:

"fertilization and radiation effect to the different vegetation distribution" -> The following formulation (in the full sentence) might be clearer: "the contribution of the fertilization and radiation effect of different ambient CO2 concentrations to the difference in vegetation distribution during glacial and preindustrial times"

"sensitivity to the fertilization or radiation effect"-> We use this expression because some carbon fluxes are only sensitive to one of the two effects of rising CO2 concentrations. For example, autotrophic respiration is directly affected only by the radiation effect.

“when structural limits are hit” -> The word ‘structural’ refers here to the way carbon pools are set up in the model. Some carbon pools in our model have upper limits of carbon they can contain. When these limits are reached, carbon allocation to these pools stops. We could reformulate this to: “when the upper limit of carbon assumed to be allocatable to these pools is reached”

“physiological limits are hit more frequently” -> This can be reformulated to: “physiological limitations are reached more frequently”

“photosynthetic exploitation of the insolation” -> We use this formulation to speak about the amount of radiative energy in PAR that can be used for photosynthesis under CO2 availability limitation.

“tropical living conditions deteriorate” -> This could be reformulated as: “growth conditions in the tropics deteriorate”

One reason for the linguistic confusion might be that we used a terminology for feedbacks and experiment simulations that is different from previous studies. It is important to mention that there is no agreed, commonly used terminology in the literature yet but we will make sure to introduce our terminology more carefully and to link it to the different terms used in other studies.

Arora, V. K., et al.: The effect of terrestrial photosynthesis down regulation on the twentieth-century carbon budget simulated with the CCCma Earth System Model. Journal of Climate, 22.22 (2009): 6066-6088. Friedlingstein, P., Dufresne, J.-L., and Cox, P. M.: How positive is the feedback between climate change and the carbon cycle?,Tellus, 55B, 692–700, 2003 Gregory, J. M., Jones, C. C., Cadule, P., and Friedlingstein, P.: Quantifying Carbon Cycle Feedbacks, Journal of Climate, 22, 5232–5250, 2009.

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