Clim. Past Discuss.,
https://doi.org/10.5194/cp-2019-107-RC1, 2019

Climate of the Past
Discussions

Interactive comment on "The response to pulse-like perturbations in atmospheric carbon and carbon isotopes" *by* Aurich Jeltsch-Thömmes and Fortunat Joos

Anonymous Referee #1

Received and published: 4 September 2019

This paper describes the long-term evolution of CO_2-pulse experiments in the Bern3D EMIC on CO_2, δ^{13}C, Δ^{14}C. For this aim, especially the airborne fraction of these three variables are analysed, e.g. by a fit of a sum of 5 exponential functions. Furthermore, principal components of EOF are used to investigate the distribution of the signal in the ocean.

The main target is the understanding of atmospheric δ^{13}C of CO_2 as is so far measured in ice cores covering the last 150 kyr. There, an offset in δ^{13}C between the penultimate and last glacial maximum (PGM, LGM) still lacks an explanation (Schneider et al., 2013; Eggleston et al., 2016), but also δ^{13}C during millennial-scale dynamics are also

Printer-friendly version

Discussion paper

briefly discussed (Bauska et al., 2016, 2018).

The paper is on a good way. Its focus is on the evolution of the isotopic signatures following a carbon pulse are to my knowledge new, while the long-term evolution of CO_2 pulses has already been analysed elsewhere (Colbourn et al., 2015; Lord et al., 2016), although with a different model. However, I still have a list of (partly major) points, in which I suggest the draft is revised in order to clarify open issues or sharpen its message. They are in detail:

1. The main aim of this study is to better understand the observed evolution of δ^{13}C in the Earth system (as such explicitly written at the beginning of section 3) with special focus on the atmosphere. I therefore suggest to sharpen (and shorten) the introduction focusing on the available atmospheric δ^{13}C data (Schneider et al., 2013; Eggleston et al., 2016; Bauska et al., 2016, 2018), and delete the lengthly citations/discussion of CO_2 over the last 800 kyr. Maybe, also add a figure, which shows the relevant δ^{13}C data, both on glacial/interglacial and millennial-time scales, to give the reader an idea about the magnitudes of changes and the unsolved problems.

2. At the end of the abstract (and maybe once in the discussion) volcanism is mentioned as a likely cause for the δ^{13}C offset between PGM and LGM. However, I believe no details on volcanism as assumed in the model are given. Is there a (constant?) volcanic CO_2 flux and what is its δ^{13}C signature? This final sentence of the introduction should be backed up with a more in-depth discussion, how this conclusion has been drawn. Right now on page 20 all examples given seemed to be not enough to explain the data, so an imbalance of weathering, volcanic, and burial fluxes seems to be the only possible solution, however the scenario mentioned to be the most likely one is not been investigated in detail. Maybe your insights on δ^{13}C can guide you to prescribe necessary changes in boundary conditions in such a way that the simulated δ^{13}C explains the offset between

PGM and LGM (e.g. how needs volcanism change (in terms of its δ^{13}C signature and/or in its CO_2 release?) to generate the observed offset). This would be a real breakthrough.

3. My understanding of the results here and of Lord et al. (2016) is, that the pulse size (labeled P here and E in the other paper) is also important for the time-dependent airborne-fractions. At least, this is the case for CO_2. For that reason E has been included in the sum of 5 exponential functions that fit to the model results in Lord et al. (2016) (their Eq 3), but E is missing in the fit used here (Eq 4). I believe this needs to be revised. I acknowledge that there is a subsection on the role of pulse size on page 14, but I am wondering why this is not included in the fitting equations. Maybe also compare airborne fraction of CO_2 with results shown in Colbourn et al. (2015); Lord et al. (2016). Any stricking difference?

4. While Lord et al. (2016) and Colbourn et al. (2015) had only future emission in mind (and therefore the starting point has always been the modern carbon cycle), here changs in the past are in focus. One section is missing, which discusses, if (and at best how) everything said here depends on the background state of the carbon cycle. Especially, these detailed changes in δ^{13}C discussed (PGM vs LGM; millennial-scale) happened during more glacial conditions. I understand all pulse experiments have been analysed starting from pre-industrial conditions. At best, everything needs to be repeated from LGM background, but saying that, I realize, that this might double all efforts, and might be too much for the paper at hand. However, it should be shown with at least one perturbation experiment, how things are different when starting from glacial background, in order to give the reader a feeling of the size of such a potential background dependency.

5. Results (Table 2): I would expect the fit parameters also for Δ^{14}C, and for all scenarios and not only for p500. Maybe they can also generalized by the consideration of E in the fitting functions, see point 3 above.

6. When explaining why the airborne-fraction of δ^{13}C sinks at first more rapidly than that of CO_2, I believe this can be explained with the gross gas exchange (atmosphere-ocean), while for the CO_2 the net gas exchange (net oceanic uptake) is relevant, which is, as correctly written, slowed down by the carbonate chemistry (buffer or Revelle factor).

7. Eq 5: Without saying that Eq 5 is wrong, I was intuitively expecting that the pulse size P might be relevant here.

8. I find the detailed discussion of C budget changes in GtC over time for one specific scenario p250 (page 13-14) not that interesting. It would be better, this is expressed in fractional changes (eg expressed as airborne fraction for the atmosphere), and the paper would especially benefit if it can be generalize from one scenario to more (all?), e.g. maybe by including the dependency on the pulse size.

9. Page 14, last sentence (on radiocarbon) does not make sense to me, e.g. the first part seems to say the opposite of the second part, maybe extend with details or revise.

10. Discussion of millennial-scale changes (page 20, line 29ff): My reading of the papers of Bauska et al did not come to the conclusions, that they argue that the changes in CO_2 by 10 ppm and a decrease in δ^{13}C by 0.2‰ can be solely explained by carbon release from terrestrial sources, but they suggest alternative processes. Please revise this discussion of Fig 6 carefully.

11. Fig 1 has in some scenarios some abrupt (and unexpected) changes around 20k in all three variables. I believe, this was shortly mentioned, but I do not think it is entirely explained, especially not for the isotopes.

12. Fig 5: The colorbar on the right hand side is from -30 to +30‰ in changes in δ^{13}C. I hope there is a typo and this is wrong by some order of magnitude, otherwise it

implies that on the local scale the reconstructions are complete off the target and not useful.

Technical issues:

1. Subsection 2.4 Results is empty. Probably this is just the start of section 3 and Discussion is section 4.
2. Fig 2: Hatched area is “sed + wea” in the legend, but “lithosphere” in the caption. Please combine both somehow (e.g. merge to the same). Does this also include volcanism?
3. Fig 3: grey line is called “data”, but this is “modeled”.
4. Fig 5: Please add in the caption the time units when describing the subfigures (“1 (c,d)” into ‘”1000 yr (c,d)” and “10 (e,f)” into “10 kyrs (e,f)” and “50 (g,h) kyrs” into “50 kyrs (g,h)”.
5. page 11, line 1, change “fast” into “faster”
6. page 12, line 6. “additional addition” is a bit too much adding, delete one.
7. page 12, line 19, “long-term removal time scale “ of what?
8. Throughout: I believe figure should be ordered by when they are refered to, but on page 2 a reference to Fig 5g shows up before any reference to Figs. 2-4.
9. Appendix: Maybe consider replacing “$->$” in you subscripts by “2” or “$\rightarrow$” (command rightarrow in LaTeX), e.g. in Eq. A17: change $\alpha_{a->b}$ into α_{a2b} or $\alpha_{a\rightarrow b}$.
10. Reference list needs careful revision, since sub- and superscripts seems to be partly wrong, e.g. CO2 instead of CO_2 etc. Futhermore, AGU paper from the

Printer-friendly version

Discussion paper

time without page numbers need to have their paper numbers included, e.g. necessary for Parekh et al. (2008) where the missing paper number is PA4202, and the page number 1–14 are useless. This is probably the case for all papers from GBC, GRL, P, and from online only journals such as Nature Communcations which start with page number 1. Check Eggleston et al 2016; Köhler et al 2010; Menviel et al. 2012; Ridgwell and Hargreaves 2007; Skinner et al. 2017; Tarnocai et al 2009 Check also, when two links exist and reduce to one (DOI). Lord et al 2015 is incomplete. Last page number is missing in Wanninkhof 1992.

References

Bauska, T. K., Baggenstos, D., Brook, E. J., Mix, A. C., Marcott, S. A., Petrenko, V. V., Schaefer, H., Severinghaus, J. P., and Lee, J. E.: Carbon isotopes characterize rapid changes in atmospheric carbon dioxide during the last deglaciation, Proceedings of the National Academy of Sciences, 113, 3465–3470, doi:10.1073/pnas.1513868113, 2016.

Bauska, T. K., Brook, E. J., Marcott, S. A., Baggenstos, D., Shackleton, S., Severinghaus, J. P., and Petrenko, V. V.: Controls on Millennial-Scale Atmospheric CO2 Variability During the Last Glacial Period, Geophysical Research Letters, 45, 7731–7740, doi:10.1029/2018GL077881, 2018.

Colbourn, G., Ridgwell, A., and Lenton, T. M.: The time scale of the silicate weathering negative feedback on atmospheric CO2, Global Biogeochemical Cycles, 29, 583–596, doi:10.1002/2014GB005054, 2015.

Eggleston, S., Schmitt, J., Bereiter, B., Schneider, R., and Fischer, H.: Evolution of the stable carbon isotope composition of atmospheric CO_2 over the last glacial cycle, Paleoceanography, 31, 434–452, doi:10.1002/2015PA002874, 2016.

Lord, N. S., Ridgwell, A., Thorne, M. C., and Lunt, D. J.: An impulse response function for the long tail of excess atmospheric CO2 in an Earth system model, Global Biogeochemical Cycles, 30, 2–17, doi:10.1002/2014GB005074, 2016.

Parekh, P., Joos, F., and Müller, S. A.: A modeling assessment of the interplay between aeolian iron fluxes and iron-binding ligands in controlling carbon dioxide fluctuations during Antarctic warm events, Paleoceanography, 23, PA4202, doi: 10.1029/2007PA001 531, 2008.

Schneider, R., Schmitt, J., Köhler, P., Joos, F., and Fischer, H.: A reconstruction of atmospheric carbon dioxide and its stable carbon isotopic composition from the penultimate glacial maximum to the last glacial inception, Climate of the Past, 9, 2507—2523, doi: 10.5194/cp-9-2507-2013, 2013.

Interactive comment on Clim. Past Discuss., https://doi.org/10.5194/cp-2019-107, 2019.

Printer-friendly version

Discussion paper