Interactive comment on "How does the terrestrial carbon exchange respond to interannual climatic variations? A quantification based on atmospheric CO$_2$ data" *by* Christian Rödenbeck et al.

Anonymous Referee #2

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The authors present a method to estimate climate relevant parameters from the atmospheric long-term records of CO2. These parameters describe the regression of surface CO2 exchange (NEE) onto temperature anomalies (T), a metric that has previously been assessed from a suite of climate models and from atmospheric observations. The inversion method to derive these metrics is based on a well-documented and exhaustively tested system, which also offers the authors the opportunity to benchmark their new inversion method to the existing one. Their findings show that the sensitivity of NEE to temperature anomalies follows seasonal patterns on the NH which are as one would expect based on limitations of (light) and temperature, while in other areas there is not enough data to constrain the seasonal cycle well. On interannual time

scales, both the standard inversion and the gamma-based inversion give very similar temporal patterns of NEE, giving further confidence to the ability of this new type of inversion to use temperature patterns and the derived climate sensitivity to T (as a proxy for other processes) to constrain NEE variations.

I overall find the paper well written, and interesting, and it opens up a new approach to inverse modeling of CO2 mixing ratios. The paper is perhaps a little bit thin on "new findings" but given the novelty of the method and the actual importance of benchmarking well, this does not diminish the value of the paper for me. I would like to see some further details provided about the method since it takes an important part of the value of the paper. Besides some few additional considerations detailed below, the paper should be ready for publication after some minor revisions. I am sure it will make an interesting paper for the readers of this journal.

Minor comments

What I am surprised to *not* find in this paper is the context of gamma as given by the Cox et al (2013) constraint on climate sensitivity. As a simple step, I wonder if you can post-aggregate your monthly gridbox results to global yearly values. This would have to give a number comparable to the Cox et al., (2013) values(5.1 ± 0.9 GtC yr-1 K-1, but also found in a number of preceding and subsequent papers on gamma)? And would creating an annual number yield more robust tropical results when it comes to the sensitivity runs, or do they remain scattered? Finally, it seems to me you are also one of the first who can make a gamma for the non-tropical regions which was not something that Cox et al could do from the global growth rate analysis (they did not have extra-tropical-only growth rates like the CO2 records you use). Comparing this gamma to the tropical one, and setting it out as a target for TBMs could be a nice addition to this study. Please comment on the feasibility of this, and if you agree it can be done, please add this analysis to the results and discussion.

Point-by-point comments

- Section 2.1: I would like to see a brief summary of the number of spatial and temporal unknowns that is associated with each term in equations (1) and (2)

- page 3, line 33, the meaning of the $\Delta NEE/\Delta T$ term is not quite clear. What do the Δ's refer to in this equation? Why is it presented at this point?

- Page 4, line 8: I do not see these residual terms in the equation? Unless you refer to the Trend and SC components? But these are only long-term (slow) changes and therefore cannot be expected to prevent spurious changes in gamma, unless I misunderstand what you mean to say here?

- Page 4, line 17: "For each degree of freedom (Fourier mode)..." this formulation is not clear to me, as I have not read about a Fourier decomposition and cannot relate it to the degrees of freedom. Hence my request to improve the description of the temporal components of the system in Eq 2.

- Page, line 23: "...stay in the data residual of the inversion." Why are you so sure that they will end up there, and not aliased into one of the parameters?

- Page 4, line 28: "such that any data point influences all years of the calculation period simultaneously." This suggests, like the first discussion of the results, that for each gridbox, 12 gamma parameters are estimated representing the sensitivity in each month. This sensitivity is repeated for each year of the analysis period. Correct? If so, I advise to make this clearer from the descriptions near Eq 2.

Page 5, line 23: Were these regression lines forced to go through (0,0), or was an offset also fit?

Page 6, line 10: Did you mean to write "representation"?

Page 6, line 13: after mentioning in the previous paragraph that you will interpret gamma more broadly as an interannual climate sensitivity, you here immediately fall back on the temperature limitation of spring NEE. But would a light limitation not also be just a good an explanation as per your own reasoning? In that line, spring conditions

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with higher T would also have higher incoming solar radiation which would stimulate photosynthesis. Please consider this hypothesis and see if it can find a place in the text if you feel it has merit.

Page 9, line 5: "The NEE-T regression is an example that derived relationships are able to brigde this scale gap" Typo in "bridge", but also, I suggest a statement that this might not necessarily be true in the tropical regions where gamma might be most relevant, but no EC data was available to confirm the inverse results.

Page 9, line 10: "pan-topical". Typo

Page 9, line 18, "impressively" I am not sure this is the qualification you wanted to insert here. If so, what is so impressive here?

Page 10, line 26: "forcast". Typo, 2x in sentence

Page 11, line 23: "outlieres" typo

Page 11, line 28: "insufficiencies". I suggest "deficiencies" or "inabilities"

Page 11, lines 29 and 30: "anomlies" typo

Figure 3: I find the presentation of these results really very dense, and found it hard to summarize for myself the meaning from all the panels. Could this figure be improved by presenting some statistical summary of the results per PFT? Or a simple temporal correlation coefficient per site perhaps. After all, given the large error bars the temporal patterns are mostly guiding the eye anyway in these panels.