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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.

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Authors' Response to Anonymous Reviewer 1

This paper quantified the sensitivity of the terrestrial carbon exchange to interannual climatic variations using a new formulation of atmospheric CO2 flux inversion. Instead of optimizing terrestrial carbon exchange directly as in classical CO2 flux inversion, this study optimized the sensitivity of terrestrial carbon exchange interannual variability (IAV) to temperature, which itself has been used as an emergent quantity to constrain the predictions of future terrestrial biosphere carbon accumulations. They found that the sensitivity changes with latitudes and seasons. The results over the NH extratropics

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are more robust and agree better with independent sensitivity calculated from eddy covariance observations from flux towers. The paper is well written, and the proposed method is quite interesting. I recommend this paper for publication after minor revision.

We would like to thank the Reviewer for taking the time to review our manuscript and for her/his helpful and supportive comments.

Here are my detailed comments: 1. I would recommend adding more details about the inversion system. In describing the standard inversions in the first paragraph in section 2.1, it would be easier for readers to follow if they can add a cost function equation, and then describe how they define each term in that cost function. Currently, it is hard to understand the sentence: "The cost function additionally brings in a-priori information to regularize the estimation, in particular spatial and temporal smoothness constrains on the flux field". I have to guess from that the authors are talking about the prior error covariance structure.

We agree that the sentence cited by the Reviewer is not clear. Actually, Sect. 2.1 was not intended to give a detailed description of the pre-existing inversion algorithm (because that would be very long), but rather to refer the reader to the specific items in the Appendix or the complete description in the Technical Report Rödenbeck (2005). We feel that it would be better not to overload Sect. 2.1 with technical details. However, we will extend the Appendix and give more information there.

We reformulated the unclear sentence and the previous one into: "...closest match between observed and simulated CO2 mole fractions. In addition, the estimation is regularized by a-priori constraints meant to suppress excessive spatial and high-frequency variability in the flux field."

2. The details of sensitivity experiments described in section 2.3 are lacking, which make it hard to judge whether the uncertainties calculated from these sensitivity experiments are realistic. It would be helpful to describe the first three sensitivity experiments quantitatively. How much longer are the spatial correlations and temporal correlations

in the sensitivity experiments? and how much have the a priori uncertainties been reduced in these sensitivity experiments?

We added the quantitative information for cases (1) to (3).

3. Besides the sensitivity of terrestrial carbon exchange (NEE) IAV, the atmospheric CO2 inversion described in this study also optimized the long-term trend and the seasonality trend of NEE. Since only CO2 observations were assimilated, the sum of these three terms should agree with observed CO2. Therefore, these three quantities mathematically have intrinsic correlations. It would be helpful to discuss the dependency of the estimated IAV sensitivity to the a priori assumptions of the other two terms in equation (2). Also, I would suggest adding a few sentences discussing whether the estimated trends are realistic, though this study focuses on the sensitivity of IAV.

Though long-term, seasonal, and interannual degrees of freedom are indeed linked theoretically, the actual a-posteriori correlations are very small (see, e.g., Fig 16 of the Technical Report Rödenbeck, 2005). In sensitivity tests during the development of the NEE-T inversion, we did not find any strong dependence between these time scales either. For the manuscript, these sensitivity tests were not selected because of their small effect.

In response to this comment, we added another paragraph to Sect. 4.1: "Besides the interannual variations, the NEE-T inversion also reproduces the small negative trend in NEE through its residual term $f^{\mathrm{adj}}_{\mathrm{NEE,Trend}}$ in Eq. (2) (Fig. 2). Likewise, it reproduces the northern extratropical increase in seasonal cycle amplitude through its residual term $f^{\mathrm{adj}}_{\mathrm{NEE,SCTrend}}$ (not shown)."

4. Figure 1 used 40 gC/m2/yr as a threshold for robustness of the calculated sensitivity. Where did this number come from? What is the basis?

Unfortunately, we did not find a truely objective criterion for robustness. We therefore took a threshold that would be some meaningful fraction of the size of the structures

seen in Fig 1, and visualize the qualitative difference between extratropics and tropics. The threshold of 40 (gC/m2/yr)/K corresponds to 1 step of the color scale which seemed to fulfill these intentions.

5. The unit in Figure 1 should be gC/m2/yr.

Fig 1 shows the sensitivity gamma = dNEE/dT, which has units of flux per Kelvin, here (gC/m2/yr)/K.

6. In the first paragraph in the introduction, "the response of NEE on..." should be "the response of NEE to..."

Thank you for spotting this. Corrected

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