Response to Anonymous Referee (through Editor's comments)

We thank the editor for adding these addition valuable reviewer comments. Throughout the document reviewer comments are displayed in standard font while author responses are presented with blue text.

The investigators have conducted a series of OSSEs to assess the impact of prior biospheric fluxes on posterior fluxes in CO_2 flux inversions using OCO-2 data. The lack of robust regional flux estimates is a major issue in the flux inversion community. It is known that the choice of prior fluxes can impact posterior flux estimates, contributing to discrepancies between different inversions. This study has conducted the most detailed and thorough sensitivity analysis to date to quantify the potential impact of the prior fluxes in CO_2 inversions. The manuscript is well written and I recommend it for publication in ACP with minor revisions to address my mostly technical comments below.

Comments

1. Page 4, line 3-4: Change "NEE flux (balanced biosphere)" to just "NEE flux".

We have removed the following text "(balanced biosphere for the 1998-2017 time period)" in the revised manuscript.

2. Page 4, line 28: How different is the diurnal variation between the truth and the prior models? This information could be included in the Supplement.

A similar comment was made by Referee #4. In order to demonstrate the difference between the "true" NEE and prior model data in regards to diurnal variability, monthly-averaged 3-hourly (MsTMIP) and hourly (for the 4 prior biosphere models) NEE values were plotted for July 2015 at the well-known Park Falls flux tower site (45.95°N, 90.27°W). This figure has been added to the revised manuscript in the supplementary section as Fig. S1. We added additional text to Sect. 2.1 of the revised manuscript which reads: "We allow the "true" and prior models to have different diurnal variability in order to represent a realistic scenario, as prior models will differ some from the actual diurnal variability of NEE in nature. In general, the diurnal variability of NEE is similar between the "true" and individual prior models. An example is shown in Fig. S1 where it can be seen that the diurnal NEE from the "true" and prior models for July 2015 at the Park Falls flux tower site (45.95°N, 90.27°W) have near identical temporal diurnal patterns and only differ in NEE magnitude.".

3. Page 6, line 2: Change "CO_2 at August" to "CO_2 on August".

This has been corrected.

4. Page 6, line 13: OCO-2 XCO2 is not actually retrieved using Equation (1). Rather, the retrieval is expressed as Equation (1), after the fact.

The following text "OCO-2 XCO2 is retrieved using the following equation" has been changed to "The retrieval of OCO-2 XCO2 is expressed as Eq. (1)" in the revised manuscript.

5. Page 6, line 16: Please add "column" between "a" and "averaging" kernel.

This has been corrected.

6. Page 6, lines 32, 34, 35, etc...: Please change "model grid" to "model grid box" when discussing the model grid boxes. For example, on lines 34-35 it should read "the j^{th} model grid box" instead of the "j^{th} model grid".

This has been corrected.

7. Page 7, line 5, and page 8, line 31: Same comment as above regarding the "model grid" vs "model grid box".

This has been corrected

8. Page 7, Equation (3): Shouldn't this equation be similar to Equation (1) since the observation operator is transforming the model into the observation space? For example, the "ya" and "Ma" in this equation should be the same as "ca" and "XCO2a" used in Equation (1), respectively. The only quantity that should be different in this expression is "f(x)", which represents the simulated profile.

We thank the reviewer for recognizing this. In the updated manuscript we now use the same symbols for the prior CO_2 profile and column CO_2 values from OCO-2 data in the retrieval (Eq. (1)) and observation operator (Eq. (3)) description.

9. Page 7, line 37: Something is missing between "Similar" and "to prior error statistics". Should this say "Similar to our treatment of the prior error statistics:"

This text in the revised manuscript has been corrected to "Similar to the treatment of prior error statistics".

10. Page 8, lines 20: Figure S2 is useful for the reader who is unfamiliar with the TransCom domains. Furthermore, it has the numerical ordering of the regions that is useful for interpreting Table 3. I would suggest moving this into the main manuscript.

We thank the reviewer for this suggestion and we have moved this figure from the supplementary material to be Fig. 1 in the main manuscript.

11. Page 10: Figures S5 and S7 show the spatial distribution of the results and complements the information shown in Figures 3-5. I would suggest moving Figures S5 and S7 in the main section of the manuscript, which currently has only five figures.

We thank the reviewer for this suggestion and we have moved Fig. S5 and S7 from the supplementary material to the main manuscript and are now Fig. 3 and 5, respectively.

12. Page 11, lines 31-33: I don't understand the statement here that the NEE estimates are more sensitive to the prior error when there are sufficient observations available and large differences between the truth and prior. Is this due to the inversion approach used here? Is it because the prior error is a relative error so when the flux is larger, the error is also larger, which gives the inversion more flexibility in adjusting the fluxes?

We refer the reviewer to the end of Sect. 2.4.5 where the discussion of the prior error calculations is presented. In this study, we calculate prior error values from the standard deviation (SD) of the four prior models (as a NEE magnitude) which is then divided by the magnitude of the NEE flux from each individual model (fractional error). We did this in order for our relative error values (fractional error) to be representative of absolute error magnitudes as defined by the SD calculation. This is done so large prior error can be applied to small fluxes and vice versa.

The reason that posterior NEE estimates are more sensitivity to prior error values in regions with sufficient observational coverage/density and large differences in "true" and prior fluxes is as follows. When the model has sufficient observations to constrain NEE fluxes, and the "truth" and prior are noticeably different, the model must optimize the prior flux significantly to match the truth. When the prior error is too small (e.g., 10% in all grid boxes as we apply in our sensitivity study), the model will not have enough freedom to deviate from the prior estimate to match the truth. For cases when large prior error is assigned (e.g., 100% in all grid

boxes), the model is able to diverge greatly from the prior in all regions in order to match observations. As demonstrated in Sect. 3.3 of the manuscript, when applying different prior NEE estimates, the model will optimize CO_2 fluxes in variable ways to match atmospheric observations. The larger the prior error applied to each prior flux will add additional flexibility in each simulation allowing the model to match the atmospheric observations in increasingly different ways when using variable prior fluxes.