Response to reviews of egusphere-2024-1735 by Botía et al.

Reviews from Referee 3 - Received on Feb 1, 2025

The format in which the response is addressed is the following:

1. Black text shows comment of referee. Comments are numerated as RC3.1, for the first comment. The line in the submitted draft referred to by the referee is also shown.
2. *Text in italics show the author's response and it has the same logic for numeration (e.g. AR3.1). If not stated otherwise, here the reference to figures and line numbers are based on the submitted manuscript.*
3. Red text indicates changes to the manuscript. Here the reference to Figures are based on the revised manuscript.

General Comment

[RC3.1]-Review Synopsis 1: Botia et al. quantified the carbon budget over tropical South America by assimilating comprehensive surface, tower, and aircraft observations from 2010 to 2018 using a regional top-down flux inversion system. With ensemble prior fluxes spanning a wide range of annual carbon fluxes, their study revealed a regional carbon sink-source contrast between the Amazon forest and the savanna region over the Cerrado. Additionally, they examined the dependence of their results on prior fluxes and the water vapor correction applied to aircraft observations. Overall, this is a comprehensive study on regional carbon budget estimates for tropical South America. However, I believe the paper would greatly benefit from reorganizing of the results and a more distilled take-home message, as also recommended by the second reviewer. Please see my main comments below:

*[**AR3.1**]: We thank the third reviewer for the comments and constructive feedback. Before answering the specific comments, here we want to highlight that the Results were reorganized and shortened, giving more importance to the water vapor correction and its effect on the carbon budget of tropical South America.*

Specific Comments:

[**RC3.2**]: I would recommend using the flux inversion results that account for the water vapor correction in the main results (section 3) rather than in the discussion section, as the water vapor contamination is a well-recognized limitation of the original data. The impact of the water vapor correction can still be addressed in the discussion section, particularly when comparing this study's results to those of Gatti et al.. While the water vapor correction has minimal impact on the interannual variability, it significantly affects the absolute flux estimation, which is the focus of this study.

*[**AR3.2**]: In the submitted manuscript the water vapor Section is part of the main results, see Section 3.3, so it is not shown in the Discussion. However, following this comment we have rearranged the Results section in the revised manuscript. Sections 3.2 and 3.3 have been merged and condensed into a single section, now labeled 3.2. The first thing we report on Section 3.2 is the water vapor effect and in Figure 5 we contrast the* $F_{NetLand}$ for the Amazon and 'Cerrado & Caatinga' both with and without the water vapor correction.

[RC3.3]: While the paper qualitatively discusses the comparison with OCO-2 MIP results, as suggested by previous reviewers, I recommend including a more quantitative analysis. The latest OCO-2 V10 MIP results are publicly available and were documented in Byrne et al., 2023. Byrne et al., National CO2 budgets (2015–2020) inferred from atmospheric CO2 observations in support of the global stocktake, Earth Syst. Sci. Data, 15, 963–1004, https://doi.org/10.5194/essd-15-963-2023, 2023.

*[**AR3.3**]: We understand the request of the reviewer, which follows what Reviewer 2 suggested earlier and we agree that such a comparison is an interesting way forward. However, we think that this effort is of limited use here given the scope of our study, which is: 1. understanding the constraint given by in-situ and flask data in CarboScope and 2. Correcting the systematic bias in aircraft data and evaluating the effect of that in posterior fluxes and thus in the carbon budget of tropical South America. Now, we did look at the OCO2-v10 MIP fluxes based on the data suggested by the reviewer (i.e. Byrne et al. [2023]) (see Figure 1 below) and during this exercise we were even more convinced that the comparison is out of the scope of this paper and there are several reasons for this. The first one is that those data span from 2015 to 2020 (inclusive), so there are only 4 years in which the MIP and our results overlap: 2015 to 2018, where 2/4 years were anomalous. Secondly, the differences between our inversions and the OCO2-MIP inversions are many (satellite data, regional vs global inversions, the use data inside the Amazon, transport resolution, inversion method, correlation length scales, amongst others). Thus, to make justice to the work done by the MIP modelers and the work we have done here, such a comparison will require an entire new paper discussing all these differences. That said, the comparison shown in Figure 1 is done for Net Biome Exchange (NBE), which is defined as the sum of Net Ecosystem Exchange (NEE) and carbon emissions from fires, basically NBE = NEE +* F_{Fires}*. This is different from what is presented in the manuscript (*$F_{NetLand}$*), which includes fossil fuel emissions (*$F_{NetLand} = NBE + F_{ff}$*), a relatively small flux component in these two regions (based on the EDGAR 4.3 inventory, we get 0.02 PgC/year and 0.04 PgC/year in the Amazon and the 'Cerrado and Caatinga' respectively). The regional flux contrast in the OCO2-MIP (IS and LNLGIS) for 2015 to 2018, differs from our results, with the 'Cerrado and Caatinga' region as a small sink (−NBE) and the Amazon as a source of carbon (+NBE). Disentangling the reasons of discrepancy between our results and the inverse estimates of OCO2-MIP is out of the scope of this paper, but here we can highlight some hypotheses. There could be structural differences when assimilating in-situ data and satellite data only. The studies of Crowell et al. [2019] and Peiro et al. [2022] reported large differences in flux estimates at continental scales between in-situ- and the OCO2-driven inversions. The reason for these differences was attributed to sparse in-situ network coverage and likely to residual biases in the OCO2 retrievals [Crowell et al., 2019]. Furthermore, [Peiro et al., 2022] argues that the difference in seasonal cycle amplitude between the in-situ and the OCO2 inversions in tropical South America, could probably be due to the seasonal bias induced by clouds in the OCO2 retrievals. The seasonal effect due to clouds could also vary spatially, as cloud cover tends to be more prominent in the northwest of the Amazon. In our system, we do not constrain this area either, therefore we do not discard a dipole effect as a result of network coverage. Nevertheless, as we assimilate data sources that are not subject to very strong seasonal cloud biases and actually have calibrated data over the continent, we believe that in the regions with a large uncertainty reduction our results should fundamentally be more trustworthy.*

[RC3.4]: Since there are large data gaps in the aircraft observations in 2015-2016, I would suggest caution when comparing the top-down flux inversion results from this study to previous studies during this period.

*[**AR3.4**]: Thanks for the comment. We agree with this caveat and we have added a note of caution in the revised manuscript where we compare the 2015/2016 response to other systems. It is likely that what we obtain in the Inversion during 2015 from August to October, is dominated by the effect of ATTO, as it is the only station available during those months. In light of this, we added a sentence in Section 3.2 warning the reader about the response to the 2015/2016 drought: Therefore, the findings*

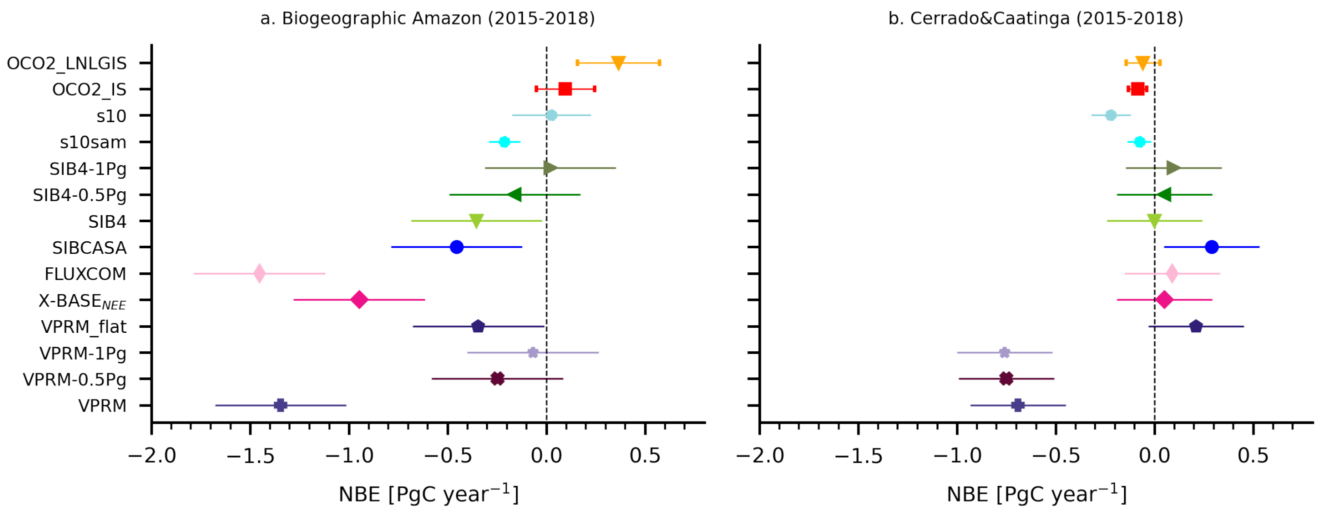

Figure 1: Carbon budget (NBE) for the biogeographic Amazon (a) and the Cerrado & Caatinga (b) regions.

of our sensitivity tests support the hypothesis in Gatti et al. (2023) that the water vapor bias mainly affects the absolute annual flux magnitudes. In both cases, with and without correction, our estimates of the total carbon loss to the atmosphere in the Amazon during 2015 and 2016, are lower (from 0.15 to 0.3 PgC) than other studies (Liu et al., 2017; Gloor et al., 2018). However, it should be noted that the response to the 2015-2016 drought in our system must be interpreted with caution, as there are large gaps in the observational record during 2015 and 2016. Having this in mind, our total net flux is closer to the 0.5 ± 0.3 PgC of Gloor et al., (2018), but note that they used a time period from September 2015 to June 2016 and the area they refer to as Amazonia is not clearly defined. Compared to 1.6 ± 0.29 PgC in Liu et al., (2017), our estimates are much lower, but the difference in area is large, as they refer to tropical South America, including parts of the 'Cerrado & Caatinga' biomes and central America. Additionally, in the Discussion we have added: Yet, a direct comparison of the magnitude in those studies to our results is challenging for the following reasons. First, the response in our system could be biased to ATTO as there was a large gap in the aircraft data in 2015 and 2016.
[**RC3.5**]: The dependence of the posterior fluxes on the prior fluxes is striking (Figure 4). Therefore, for the regional flux contrast shown in Figure 5, I recommend including a plot of the regional flux contrast in the prior fluxes, which could be added in the supplementary material. Additionally, it would be valuable to discuss the extent to which the posterior regional flux contrast is influenced by the prior fluxes.

*[**AR3.5**]: We thank the reviewer for this comment. The suggested figure has been added to the Supplementary material (Figure A15) and also here, see Figure 2, below. If we compare the posterior flux contrast for the whole ensemble (Figure 5, on the submitted manuscript) with the prior ensemble flux contrast (Figure 2 in this document and Figure A15 in the revised manuscript), we conclude that the change from prior to posterior on an ensemble level, results in a solid convergence of a sink of carbon ($F_{NetLand}$) for the Amazon and a source of carbon for the 'Cerrado & Caatinga'. Now, when looking at particular ensemble members, the dependence on the prior is more evident. For example, this is evident for VPRM, FLUXCOM and X-BASE$_{NEE}$, but here is where the "flat" experiment with VPRM becomes relevant, as the mean in the prior is zero for both regions and the direction*

of the adjustment coincides with the pattern for the whole ensemble (Amazon − >sink, 'Cerrado & Caatinga' − > source). In Section 3.2 of the revised manuscript we have added the following text: Despite variations in magnitude, the inversion consistently shifts priors toward a smaller Amazonian source (e.g., SIB4-1Pg) or even a sink (e.g., VPRM-1Pg, VPRM-0.5Pg, and SIB4-0.5Pg). The prior vs. posterior flux contrast (Figures **??**, **??***) confirms a robust sink-source gradient, embedded in the atmospheric measurements, despite limitations in adjusting individual priors.*

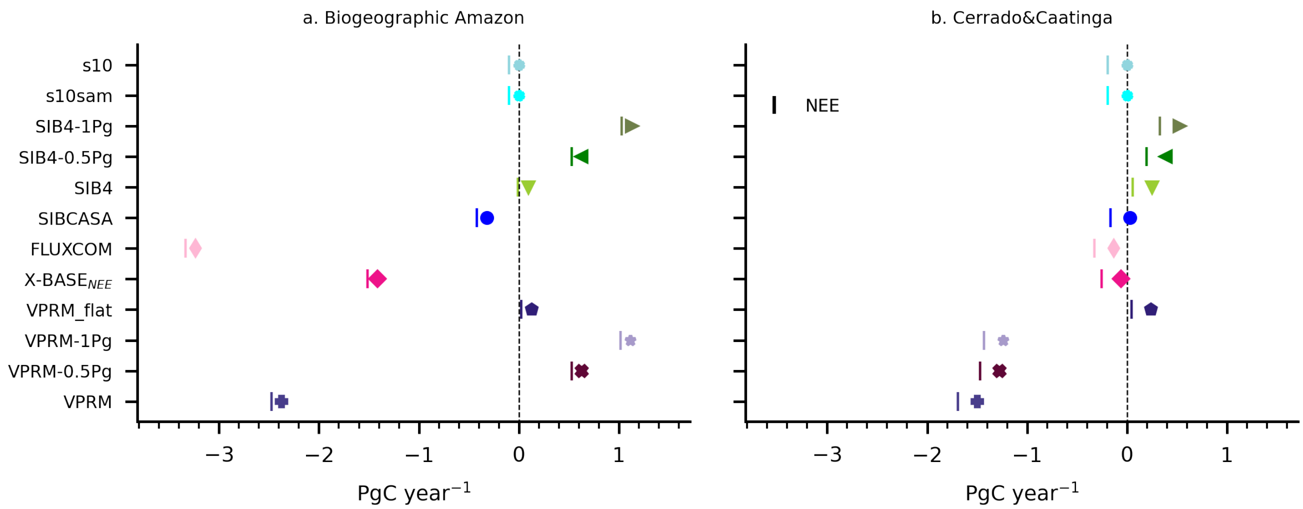

Figure 2: Prior carbon budget for the biogeographic Amazon (a) and the Cerrado & Caatinga (b) regions. The prior flux component shown with a vertical bar (NEE), result from subtracting the F_{fire} and F_{ff} from the prior $F_{NetLand}$ (shown with the markers).

[**RC3.6**]: Figure A9 and A10 plot annual mean prior and posterior fluxes from some of the models. I would recommend the authors to include all the prior fluxes (except the flat one) and posterior fluxes. The fact that the posterior fluxes all show this consistent east-west contrast pattern (A10) is very promising.

*[**AR3.6**]: In Figure A9 we did not add the prior of s10 and s10sam because in these inversions the prior is zero; in the original submitted manuscript this was mentioned in Section 2.1.6. In the newly revised manuscript, we added the additional non-zero priors and all posteriors, as the reviewer recommended. The two plots are shown here for practicality as well (Figures 3 and 4).*

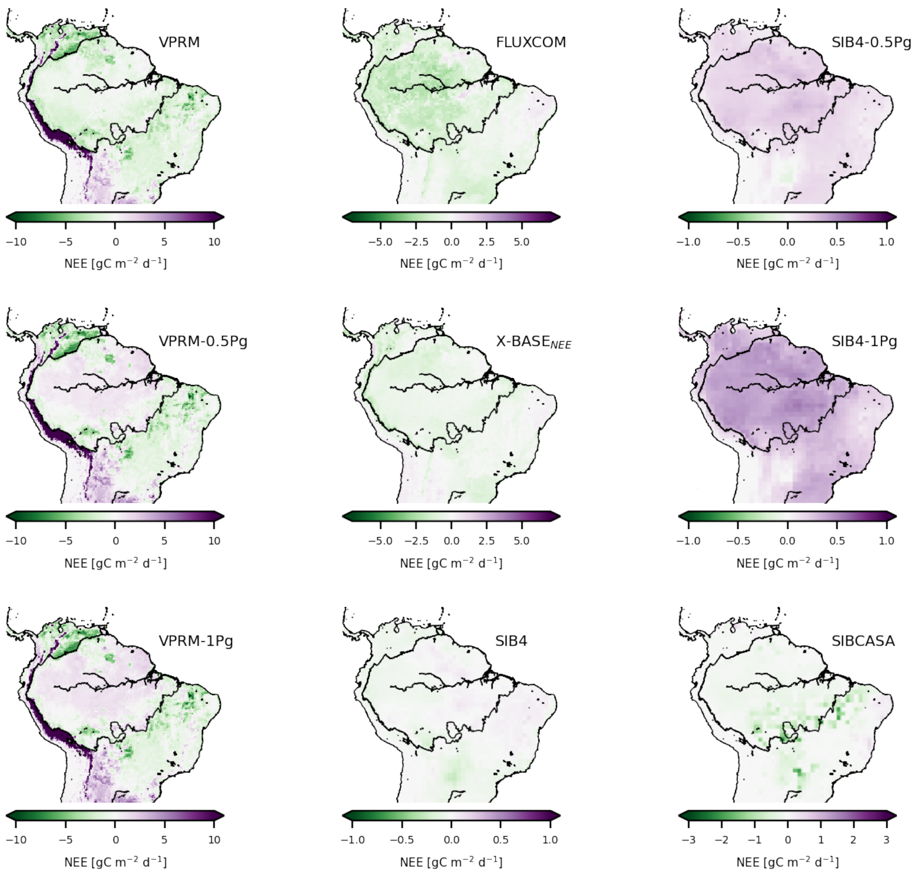

Figure 3: Prior mean NEE over 2010-2018 for several of the models used. Note the different range in the colorbar.

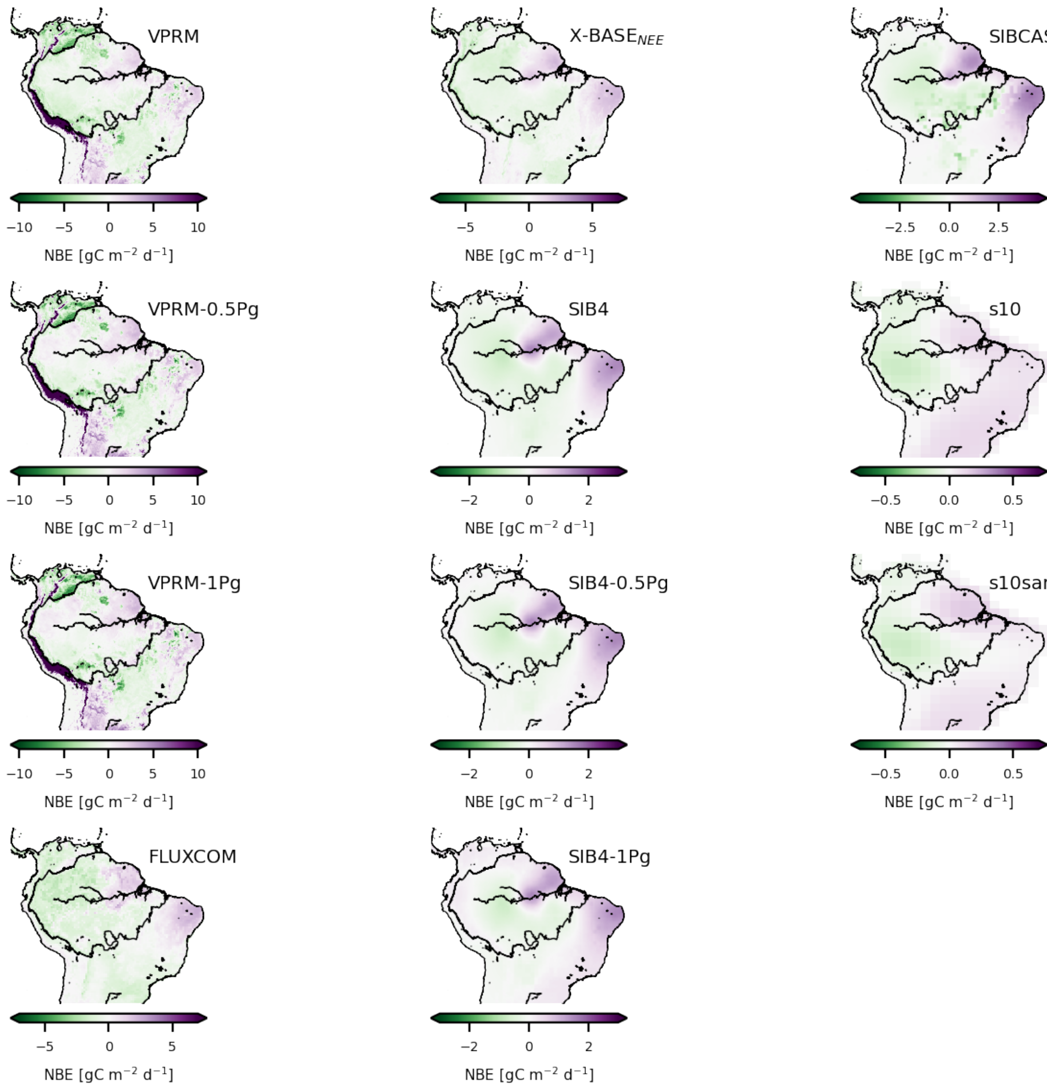

Figure 4: Posterior mean NBE over 2010-2018 for several of the models used. Note the different range in the colorbar.

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