Response to RC1

Review of the manuscript titled "Constraining 2010-2020 Amazonian carbon flux estimates with satellite solar-induced fluorescence (SIF)" by Dayalu et al.

I find the manuscript quite long, but given the data and methods used, the length is justified. The manuscript is well-written, with extensive and intensive data usage (Flux sites, Aircraft profiles, SIF data, XCO2 data from satellites and different NEE simulations). The analysis performed is robust with clear results. The discussion is quite thorough as well, but more detailed discussion on the limitations of the calibration process, especially given the spatial and temporal variability in the Amazon would be desirable.
I recommend minor revisions and have following questions/clarifications?
We thank Reviewer 1 for the comments. The recommended changes have been made and have strengthened the paper. We have also provided clarifications as requested with some being included in the text as additional text or Figures as necessary. Where changes in the paper have been made, comments have been included as "RC1.#".

RC1.1. Is there a reason why the authors did not extend the analysis from 2001-2020 (instead of 2010-2020)? I see that the CSIF is available since 2001, and the EC flux datasets are also available during the 2001-2010 period.

We initially kept the analysis to the 2010-2020 period to reflect the availability of OCO-2 data for the top-down constraint (OCO-2 data availability began only in 2014). The overall goal was to constrain with OCO-2 back to 2014, and extrapolate the model-obs mismatch derived from inversion results by a few more years back to 2010. However, in-progress follow-on work is using additional data sets not previously available and indeed extending the VPRM back to the 2000s. The purpose of this initial work is to justify future transition to VPRM-SIF for the region.

RC1.2. Equation 8: Although the authors clarify why they stick with the bold terms of the eq. 8 for the analysis, it would be great if there is some information about how the other terms of the equation affects the final NEE estimations.

As found in Gourdji et al. (2021) – Figure 5 in that paper – the impact of the higher order terms is to increase the correlation coefficient R^2 with respect to night-time NEE (ie., night-time NEE is a proxy for respiration) measured at a given eddy flux site. It is expected that, for the Amazon eddy flux calibration sites, increasing the number of fitting terms will increase the R^2 but potentially by overweighting conditions specific to a given calibration site. Given the already sparse eddy flux representation for the vast and heterogeneous Amazon, calibrating multiple respiration parameters using a single site would be inappropriate. We had noted this in the text: namely, that absent a large network of eddy flux sites a quadratic formulation : "*However, given both the spatial and temporal limitations of our Amazon region calibration sites (see Sect. 2.1.2), applying the Gourdji et* *al. (2022) respiration parameterization risks overfitting Amazonian respiration to a small number of specific sites."*

RC1.3. Figures 1 & 6. Please get rid of the rainbow color palette (the rainbow colour map is not perceptually uniform) and consider replacing it with the color palette of Figure 9.

Done. We have changed Figure 1b to Viridis; Figure 6bc to Inferno; and Figure 6d to a red/blue uniform palette suitable for displaying difference plots. Figures are reproduced below.

Figure 1b:

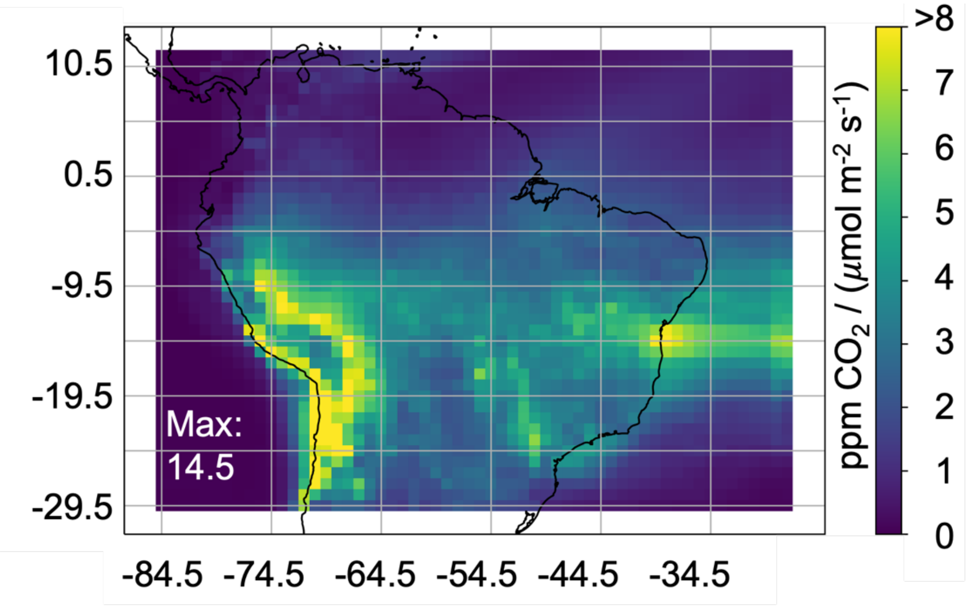
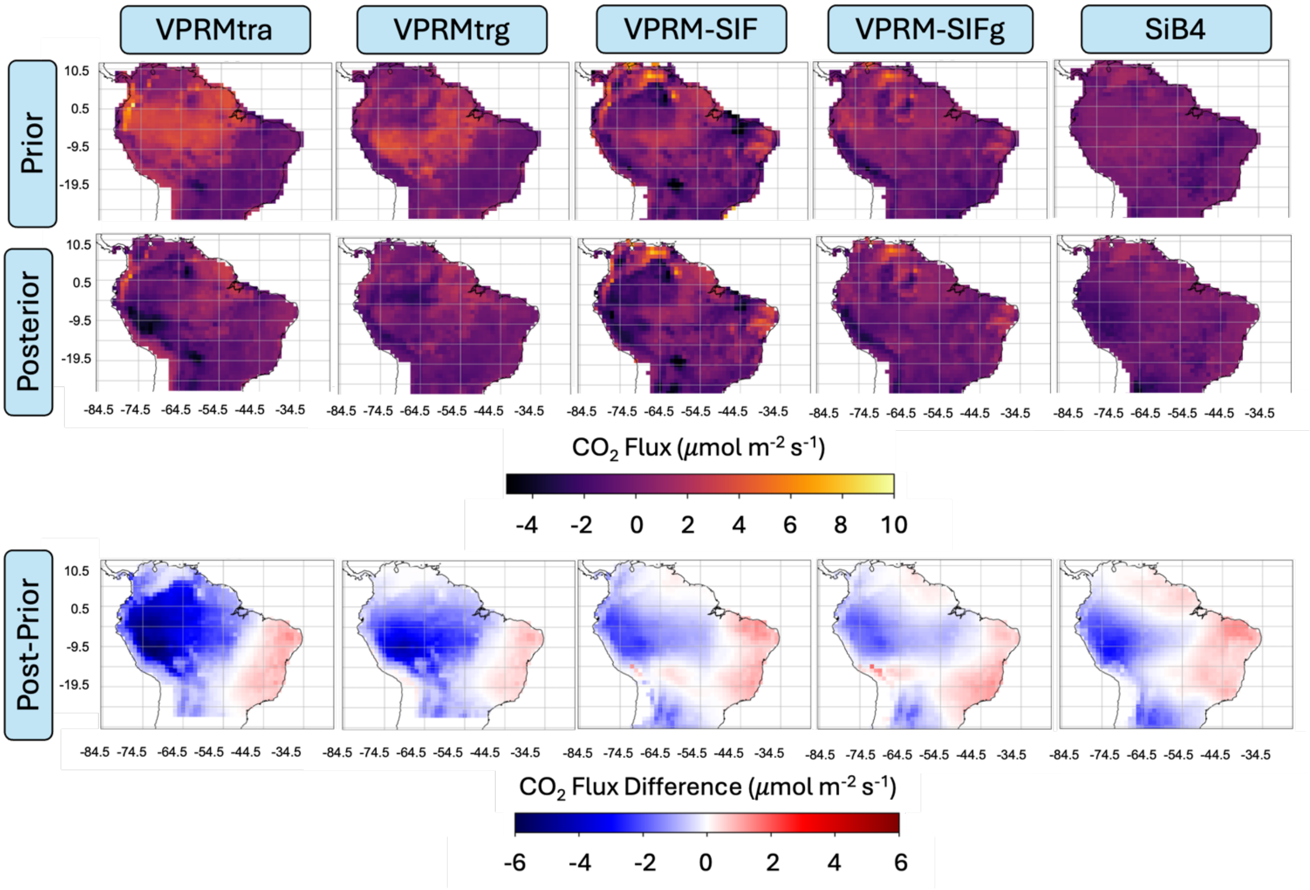


Figure 6bcd:



RC1.4. When comparing the fluxes with SiB4 (section 3.3.2), it would be great if authors clarify whether these differences are due to the different model structures or input data, or whether they reflect genuine differences in carbon dynamics that should be explored further.

We have now explicitly noted this at the end of Section 3.3.2: *"Determining the extent to which the differences between the two models reflect real carbon dynamics requires a multi-year optimization, including separately optimizing GPP and R_{eco}."*

RC1.5. It would be good to also discuss the results shown by VPRM-SIFg in different season with respect to with previous (conflicting) results in the literature by Gatti et al., (2014), Saleska et al. 2005, Huete et al (2006) (cited in the manuscript) and Brando et al., 2010 (https://www.pnas.org/doi/abs/10.1073/pnas.0908741107).

We have included additional analysis – namely, we have created a new Figure 10 and compared with the most relevant and recent work by Gatti et al. (2021) (Amazon basin as a whole) and the Cerrado and Caatinga region (also incorporating eddy flux site results from Mendes et al. 2020 and Alves et al. 2021). We have included a summary of these new results in an additional Section 3.3.3. Comparison with interannual observations. The section and figure are reproduced below. Note that we display the 95% CI in Figure 10b as displaying the larger IQR drowns out the median signal on the plot. Also note that Gatti et al. (2021) report fluxes as Total Flux – Fires ≈ NEE (but not exactly, as the total flux would also include river efflux). However, it's a fair quantity for comparison as NEE dominates that signal.

3.3.3 Comparison with interannual observations

We assessed the performance of VPRM_SIFg and SiB4 from 2010 to 2019 for the Amazon basin (Amazon mask; Fig. 10ab) and separately for the region containing the Cerrado and Caatinga biomes (Cerrado+Caatinga mask; Fig. 10ac) and compared against available observations.

For the Amazon mask, the VPRM-SIFg prior tends to estimate interannual net release while the SiB4 model tends to remain closer to neutral (Figure 10b). In addition, the VPRM-SIFg describes greater ecosystem heterogeneity relative to SiB4: the interquartile range (IQR) over the Amazon for the VPRM-SIFg is -0.47 to 0.83 g C m^{-2} d^{-1}*. In contrast the SiB4 IQR is 0.06 to 0.07 g C* m^{-2} d^{-1}*. Meanwhile, the Gatti et al. (2021) mass balance approach using aircraft vertical profiles tends to estimate net fluxes closer to neutral that generally track SiB4 interannual estimates with a few notable exceptions: in 2016, corresponding to the tail of the severe 2015-2016 El Niño; aircraft profiles suggest a regional net release of 0.1 g C* m^{-2} d^{-1} *in agreement with VPRM_SIFg, while the following year shows a net regional uptake of -0.2 g C* m^{-2} d^{-1}*. We note that the VPRM_SIFg model agrees with the trajectory of the Gatti et al (2021) post-El Niño fluxes in that there is more net uptake implied between 2016 and 2018. Furthermore, we note that the 2010-2011 El Niño corresponds to a VPRM_SIFg estimate of net release, while Gatti et al. (2021) and SiB4 estimate carbon fluxes that are net neutral to uptake. Given the severity of the associated 2010 drought across the Amazon, particularly as it was only five years after the previous severe drought, it is worth exploring whether the VPRM_SIFg is better able to capture the regional carbon effects and impacts of antecedent environmental stressors.*

The performance in the Cerrado and Caatinga region suggests that the ecosystem heterogeneity exhibited in the VPRM_SIFg model is realistic. The IQR for the VPRM_SIFg in the Cerrado and Caatinga region captures the site diversity exhibited by the Mendes et al. (2020) northern Caatinga eddy flux site and the Alves et al. (2021) southern Cerrado/converted pasture site. In contrast, the IQR of SiB4 remains closer to neutral. Note that the Gatti et al. (2021) analysis did not include an assessment of the Cerrado and Caatinga regions.

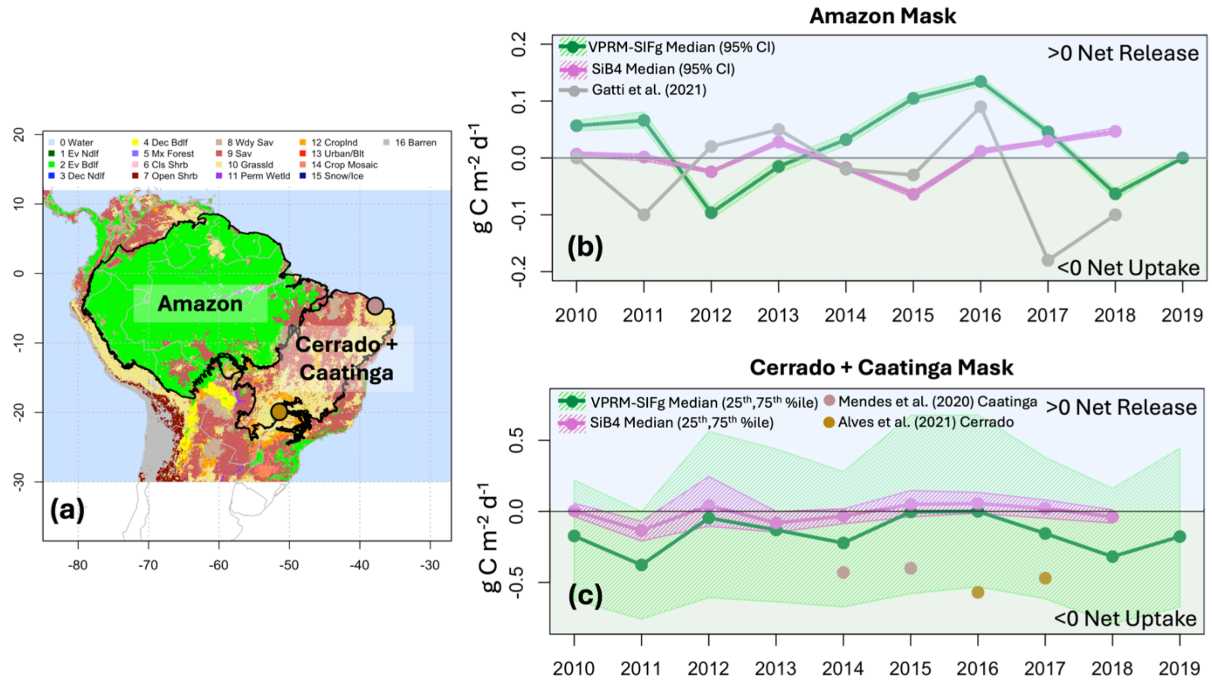


Figure 10. Interannual performance of VPRM_SIFg and SiB4 NEE (g C m^{-2} d^{-1}) relative to available observations for the decade beginning in 2010. (a) IGBP land use map overlaid with the Amazon mask, Cerrado + Caatinga mask, and two Cerrado and Caatinga eddy flux sites used for comparison; (b) VPRM_SIFg and SiB4 median annual NEE (95% CI of the median) for the Amazon mask along with estimates from Gatti et al. (2021); (c) VPRM_SIFg and SiB4 median annual NEE (25th, 75th percentiles) for the Cerrado + Caatinga mask along with annual estimates from two eddy flux sites.

We also expanded Sec 3.2.2:

At ALF the February-March 2016 upwind air masses are potentially significantly influenced by fire activity at all altitudes. In addition, with the upwind air masses bypassing a majority of the Amazon Basin and instead primarily influenced by the Cerrado/Caatinga biome where the models generally agree (Fig. 6d), all prior and posterior flux models perform similarly with a typical model-observation residual of -3 to 3 ppm throughout the vertical column (Fig. 8a–e).