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

Reviews from Referee 1 - Received on September 19, 2024

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

1. Black text shows comment of referee. Comments are numerated as RC1.1, 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. AR1.1). 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

[RC1.1] This comprehensive study uses dry air CO2 mole fractions measured at the Amazon Tall Tower Observatory (ATTO) and airborne vertical CO2 profiles in the CarboScope Regional atmospheric inversion system to estimate the net carbon exchange in tropical South America. They find that the biogeographic Amazon is a net carbon sink after accounting for vegetation fluxes, river efflux, and fire emissions. They note that treatment of Cerrado and Caatinga biomes in previous analyses have been historically lacking and include these biomes specifically, They further note that Cerrado and Caatinga biomes roughly offset the net uptake making the entirety of tropical South America close to neutral. The paper also addresses the role of measurement uncertainties on their results , namely water vapor corrections to aircraft profiles and low representation of measurements in the Amazon-Andes foothills. Overall, this is an important study spotlighting a key region (from both climate and ecological angles) that is underrepresented in existing carbon cycle model/measurement studies. I recommend the following minor revisions.

*[**AR1.1**] We thank the reviewer for the comments and proceed to answer the specific comments.*

Specific Comments

[RC1.2] **Title**: Combined CO2 measurement record indicates decreased Amazon forest carbon uptake, offset by Savannah carbon release". I find the title confusing – consider rewording. Decreasing Amazon forest uptake implies that the Savanna carbon release is doing the opposite of offsetting. That is, a weaker uptake signal in the Amazon forest combined with an increasing Savanna release means an *amplified* overall release rather than a counterbalance/offset. Perhaps you mean to say the Amazon Forest C uptake signal is diminishing in its capacity to offset the Savanna C release?

Minor suggestion – Savanna is far more common as spelling; I recommend changing from Savannah to Savanna; fix throughout (including title).

*[**AR1.2**]: Yes, indeed, the confusion stems from the use of "decreased" to describe the Amazon forest carbon uptake. We have modified the title to: Combined CO_2 measurement record indicates Amazon forest carbon uptake is offset by Savanna carbon release. We have also replaced Savannah with Savanna throughout the manuscript.*

[RC1.3] Abstract: Specify the study period (2010-2018) in the abstract for clarity also.

*[**AR1.3**]: The study period has been added to the abstract.*

[RC1.4] Abstract: uncertainties – specify whether SD, or 95%CI, or other.

*[**AR1.4**]: The uncertainties reported correspond to the posterior uncertainty. The abstract was modified accordingly.*

[RC1.5] L30: a little weak, fails to highlight main points of paper expand on this. Bring more attention to the results summarized in L423-427 re: impact of water vapor correction and L533-537. In addition, there is an information mismatch with the title– the overall results suggest a biogeographic amazon sink (abstract L7), so if you also mean to say there is a diminished sink trend from 2010-2018, make that clear in the abstract. However, this "diminished sink trend" requires further analysis – and meanwhile Figure 6a and Figure A15 don't seem to suggest a strong trend from 2010-2018 for the Amazon as a whole or by region.

*[**AR1.5**]: We have updated the abstract to include the suggestions from the referee. However, note that we do not report a trend, the diminished sink we refer to, corresponds to the effect of the water vapor correction on the magnitude of the posterior fluxes, but not to a trend. Throughout the manuscript, the word "trend" is only used in the Introduction in another context.*

[RC1.6] L30: Assis et al. (2020) has parentheses in the wrong place, also throughout, check the formatting of citations and incorrect placement of parentheses as this happens in multiple locations (e.g., L112, L152, L153...).

*[**AR1.6**]: Thanks for the suggestion, we have fixed the citation format throughout the manuscript where applicable.*

[RC1.7] L34: Inconsistency with L21 (230 PgC). Use a consistent estimate; perhaps in both places indicate 150-230 rather than 150-200.

*[**AR1.7**]: The reference to 230 PgC is for tropical ecosystems, not only the Amazon. But, we acknowledge that this confusion can arise and thus have removed the reference to 230 PgC. The modification reads as follows:* Furthermore, tropical ecosystems store substantial carbon reserves in aboveground ground living biomass (Brando et al., 2019), that can be released rapidly further amplifying the CO_2 growth rate.

[RC1.8] L63: vegetation-related source

*[**AR1.8**]: Corrected.*

[RC1.9] L83 Do you mean 'With this we [conclude]'?

*[**AR1.9**]: With the use of "With this" we were referring to the previous sentences, where we*

describe the main contributions of the manuscript. The last paragraph of the Introduction now reads as: In this study, we use the CarboScope Global and Regional inversion system to assimilate the 2010-2018 airborne CO_2 profile record and the continuous and long-term CO_2 record at the Amazon Tall Tower Observatory (ATTO). We build on previous studies using the CarboScope Regional system in Europe [Kountouris et al., 2018b,a, Munassar et al., 2021], to explore its ability to constrain the $F_{NetLand}$ at the continental scale over a larger domain, but with a sparser observational network. The study is structured as follows. First, we aim to quantify where the atmospheric inversion using this set of atmospheric data can provide a constraint based on uncertainty reduction. Second, a sub-continental analysis of the carbon budget, with a strong focus on the biogeographic Amazon, but not limited to it, is performed to shed light on spatial gradients. Last, we present a detailed quantification of how systematic uncertainties in measured mole fractions in the aircraft network affect the estimated fluxes in an atmospheric inversion. With this study, we provide a broad perspective on carbon exchange in tropical South America, going beyond the Amazon biome and highlighting where do we need to expand our observational efforts to reduce the uncertainty in carbon exchange estimates in the region.

[RC1.10] L84: Sentence fragment; join to previous sentence.

*[**AR1.10**]: We have removed the sentence starting with "An aspect that..". We decided to finish the introduction without referring to RECCAP2, as at the moment the RECCAP2 synthesis for South America has not been released yet.*

[RC1.11] L86: You bring up RECCAP2, but only once in the introduction. Consider expanding more on contributions in the conclusions.

*[**AR1.11**]: We removed the reference to RECCAP2, see AR1.10 and AR1.9.*

[RC1.12] L100: "for all sites are obtained" – you mean all the aircraft sites + MAN from Figure 1b?

*[**AR1.12**]: Here we refer to all the global sites that are used in Step 1 of the two step scheme. This will include aircraft sites, but not MAN, as this site was left out of the inversion for evaluation. We have made this clearer by adding:* Using that optimized NBE flux field and the same atmospheric transport set-up, simulated mole fractions increments for all sites are obtained, except the site left for validation (i.e. the s10 station set plus the South American stations, see Sect 2.1.4).

[RC1.13] Methodology Sec 2.1.6: What eddy flux sites are you using to calibrate VPRM? Provide in appendix, and include in acknowledgments.

*[**AR1.13**]: We have added a list with all the eddy flux sites that were used for calibrating VPRM. See Table A2 (also here for easy access), the reference to it and a citation of the data in Sect 2.1.6.*

[RC1.14] L153: This is confusing. If you are using the ATTO+NAT+Aircraft for the global inversion whose posterior is then the prior for the regional inversion (L99) you are using the ATTO+NAT+Aircraft data twice. So it doesn't seem like this is giving you any new information (ie you're optimizing with the same constraints twice). Wouldn't it be better to, say, use ATTO as an NBE constraint for the step 1 process and then use NAT+Aircraft for step 2? However, I could just be misunderstanding as

Table 1: Eddy flux sites used to calibrate the VPRM parameters.

Site code	Lat	Lon	Site Veg. Description	Veg. Class VPRM
STM-K67	-2.85700	-54.95900	Primary Tropical Moist Forest	Evergreen Forest
STM-K77	-3.02020	-54.88850	Pasture, then Agriculture	Cropland
STM-K83	-3.01700	-54.97070	Primary Tropical Moist Forest,sel. logging Aug/Sept 2001	Evergreen Forest
MAN-k34	-2.50000	-60.20910	Tropical Rainforest	Evergreen Forest
PA-CAX	-1.74830	-51.45360	Tropical Forest, dense lowland tropical forest	Evergreen Forest
RON-FNS	-10.76180	-62.35720	Pasture	Grassland
RON-RJA	-10.07800	-61.93310	Tropical Dry Forest	Evergreen Forest
TOC-BAN	-9.824416667	-50.15911	Seasonally flooded Forest-Savanna Ecotone	Evergreen Forest
SP-PDG	-21.61947222	-47.64989	Savanna	Savannas

Table 1 suggests that all the subsequent prior fluxes for the regional inversion are based off the s10 (rather than s10sam). Can you clarify all this please?

[AR1.14]*: In Step 1 of the 2-step scheme we use the default station (i.e. s10) set from CarboScope global, and to that we add ATTO+NAT+Aircraft. However, the posterior of that global run is* ***not*** *used as the prior of the regional inversion. As stated in Sect 2.1.1, the NBE flux field resulting from the global inversion is used to obtain the mole fraction increments in two sequential runs. The first one is done at the coarse global resolution for all sites globally and the second, only for the regional domain. The difference between these runs corresponds to the far-field contribution, which is then subtracted from the measurements and used as data constraint in the high-resolution regional inversion. The priors used in each of the regional inversions are then independent from the global inversion. We have added a flow diagram in Section 2.1 to complement the explanation of the CarboScope Regional system. We refer the reviewer to our response to Reviewer 2 (AR2.11), where we answered a similar question and the diagram is shown.*

[RC1.15] L174: Expand – Provide citation/justification for assumption.

[AR1.15]*: The assumption of weekly error correlations in model-data mismatch can be justified by the following. Continuous data have always been treated that way in CarboScope, originally this was referred to as "data density weighting" introduced in Rödenbeck [2005]. For the regional inversions with CarboScope-Regional, the justification of model-data mismatch error correlation has been introduced in Kountouris et al. [2018a]. So even though the motivation for the data density weighting is not the same Europe as in South America, we nevertheless need to use it to allow for a combined use of flask and continuous data in the inversion. We have modified Section 2.1.4 as follows: The model-data mismatch uncertainty (including the representation error of the measurements within the transport model) for the three types of sites (in-situ tower, aircraft, and weekly flasks) is chosen to be 1.5 ppm for weekly time scales, following common practice in CarboScope global [Rödenbeck, 2005, Rödenbeck et al., 2018] which assimilates a large set of weekly flask samples. To assimilate multiple data streams, we apply a data density weighting Rödenbeck [2005]: For the hourly ATTO data, the error will be inflated by* $\sqrt{N_{hours/week}}$ *(details see Kountouris et al. [2018a]), while for aircraft profiles (composed of several* *flasks) the error is scaled with $\sqrt{N_{flasks/profile}}$. The data-density weighting practically ensures that one week of hourly ATTO observations, one aircraft profile, or one weekly flask sample have the same weight in the inversion, reflecting the assumption that they provide the same amount of information due to roughly weekly error correlations.*

[RC1.16] L250-L251: What is the physical basis for selecting a 0.5x scaling factor for VPRM and SiB4? Related, Figure A8 – the 0.5VPRM Prior shows a change in sign as well in large portions of the Amazon indicating you applied a scaling factor of >1 to the respiration which had a net result of 0.5xVPRMNEE correct? What was the exact respiration scaling factor? Did you apply that SF because you expected respiration to have been underestimated by VPRM and SiB4 (rather than GPP to be overestimated)? If so, why?

*[**AR1.16**]: The authors thank the reviewer for pointing this out. The reason that motivates the 1x and 0.5x scaling of NEE in VPRM and SiB4 is the following. The total land flux of the Amazon region is highly uncertain, in Table 3 of the manuscript we present estimates from recent studies, where the net land flux spans from -0.34 to 0.29 PgC year^{-1} [Gatti et al., 2021, Rosan et al., 2024]. This range of 0.62 PgC becomes larger than 1 PgC when considering on each end the uncertainties associated with each estimate. Therefore, given such a large range for the total land flux in the Amazon, we decided to keep the eddy-flux based prior NEE products (VPRM and FLUXCOM), as they can be considered as a plausible first guess in an inversion. To account for the positive part of the uncertainty range we then decided to make an experiment scaling VPRM and SiB4 such that NEE = 0.5 and 1 PgC. The way in which we did the scaling was via the Respiration, which is the source component in NEE and for VPRM it is more uncertain due to the very simple parameterization as a linear function of temperature. The scaling factor for SiB4, where NEE = TER-GPP, was calculated as: SF = (NEE_{target} + GPP)/TER. Where, NEE_{target} can be 0.5 or 1 PgC for the long-term mean over the entire period of interest. With that SF factor TER was scaled for each year individually such that the long-term mean of the scaled NEE = NEE_{target}. For VPRM a similar procedure was applied but considering NEE = -GEE + TER. The exact scaling factors for SiB4 and VPRM are: 0.5xVPRM = 1.197, 1xVPRM = 1.229, 0.5xSiB4 = 1.031, 1xSiB4 = 1.059. We have added part of this description and justification to the revised manuscript and it reads as follows: Originally the eddy-covariance-based products, like the two FLUXCOM versions and VPRM, have a large sink magnitude for the Amazon. Note that the total land flux in the Amazon is highly uncertain, spanning from -0.34 to 0.29 PgC year^{-1} [Gatti et al., 2021, Rosan et al., 2024], but this range gets larger than 1 PgC considering the uncertainties associated with each estimate, thus we decided to keep the eddy-flux based prior NEE products (VPRM and FLUXCOM), as they can be considered as a plausible first guess in an inversion. Furthermore and regardless of how they compare to current independent estimates we proceeded to make an experiment scaling two of our priors (i.e. VPRM and SiB4) such that NEE = 0.5 and 1 PgC, and thus we can test an opposing (in sign) prior scenario. To achieve this, we scaled ecosystem respiration in VPRM and SiB4 such that the total NEE integral for the biogeographic Amazon equals 0.5 PgC year^{-1} and 1 PgC year^{-1} (namely VPRM-0.5Pg, VPRM-1Pg, SIB4-0.5Pg,*

and SIB4-1Pg). An example for VPRM-0.5Pg is shown in Figure A9. Two additional sensitivity tests were performed using the original VPRM. In one, we removed the long-term mean, seasonality, and interannual variability (IAV) from VPRM (called $VPRM_{flat}$) and run the inversion only with a diurnal cycle in the prior. In the second one, we used VPRM as prior but left the ATTO data out from the assimilated station set (called VPRMnoATT).

[RC1.17] L268: Expand on this methodology and discuss drawbacks/limitations. You are assuming the same scaling factor for COprior/COpost as for CO2? As CO/CO2 relates to combustion efficiency, it's possible that the GFAS CO prior relates to the CO posterior in a way that is not necessarily mirrored in a CO2prior/CO2post relationship. What if instead you do a biome-specific COprior/COpost factor (with uncertainties) – that way you get a sense of combustion efficiency across a specific biome that integrates dominant plant functional types and accounts for the average expectation of CO / CO2 combustion efficiencies?

***[AR1.17]**: We thank the reviewer for this suggestion. However, we believe that doing a biome-specific inversion is out of the scope of this study. For the CO-MOPITT inversion we refer the reviewer to Naus et al., 2022, where it was shown that GFAS is biased low for CO. Assuming that the CO/CO_2-ratios in GFAS are accurate, we increase the CO_2 fire emission estimates. We do acknowledge that this is an assumption, and state this more clearly in the manuscript now: Thus, our approach assumes that the adjustment of the MOPITT-Inversion in CO is also applicable to CO_2. We acknowledge that this is an approximation, as the emission ratio between CO and CO_2 could also be off in GFAS. However, here we assume they are constant and interpret the underestimation in CO as an underestimation in fire emissions. This is in line with recent studies of undetected African fire emissions [Ramo et al., 2021].*

[RC1.18] L300: "consistent with predominant air transport…" Can you re-phrase and/or clarify this statement? You seem to be correlating observational density and air transport which is confusing.

***[AR1.18]**: We meant to say that the observational constraint and thus where the uncertainty reduction is the largest, is where the predominant air is coming from. We realized that this can be confusing and removed that first part of the sentence.*

[RC1.19] L319: Clarify – is the mean impact 2% or >5%? Do you mean to say that the maximum UR can be >5 %?

***[AR1.19]**: The mean impact over 2010-2018 is 2% for all the biogeographic Amazon. But for individual years it can be larger than 5%. We have modified the sentence to:* At the biogeographic Amazon scale, the mean impact on the UR is small (2%), but in individual years it can increase to more than 5%.

[RC1.20] L250-251; L338: The VPRM (and SiB4) scaling nomenclature is confusing. 1xVPRM seems like it should be just VPRM (mathematically) but I think what you are trying to say is that 1xVPRM is VPRM constrained by respiration to have a total NEE of 1PgCy-1. If this is the case, then can you change the nomenclature? Something like VPRM, VPRM-0.5Pg, VPRM-1.0Pg.

***[AR1.20]**: Thanks for the suggestion. We have modified the nomenclature throughout the manuscript* *and Figures to avoid this confusion.*

[RC1.21] L335, Fig 3: I don't quite follow what your main message is with these results. Are you just trying to show the spread and/or convergence among flux model ensemble members, and break that down regionally? i.e., with the Cerrado & Caatinga region, you are showing that there are two families of ensemble members, namely the VPRM family that suggests the cerrado & caatinga region have net uptake in prior and post (-0.4gCm-2d-1), and all other models showing neutral to net release at least in their posteriors. Can you clarify your main message here? Related, in the next paragraph you are stating the superior constraint by atmospheric data for Figs 3c-f – is this statement based on the change in the posterior distributions (ie approaching normal/biggest reduction in uncertainty) on the y axes? If so, the same can be said for Cerrado and Caatinga region but the issue there is that the VPRM family seems to be driving the bimodality in Fig 3b y and x axis. Again, clarify main message as it seems to be getting a little lost. (Your main message seems to be L350-352.)

***[AR1.21]**: We thank the reviewer for pointing this out. The main message here is to show in which region there is more influence of the prior on the posterior. First, we focus on the large regions, the Amazon and the Cerrado & Caatinga. Then we focus on the smaller regions inside the Amazon. To clarify the main message of this analysis, we have modified the text from line 335 to 352 in the submitted manuscript. The revised manuscript is now more concrete, reading as follows: For the biogeographic Amazon and the 'Cerrado & Caatinga' we find a strong linear dependence of the posterior estimates on the prior (Figure 4a,b). Even though the spread in the marginal distribution is reduced largely from prior to posterior, the models with a large uptake in the prior (e.g. VPRM, FLUXCOM, X-BASE*$_{NEE}$*) do not converge with the main cluster of posterior estimates. We further evaluated such dependence with the VPRMflat experiment, confirming that after removing the long-term mean, the VPRMflat posterior F*$_{NetLand}$* falls closer to the main group of estimates in both regions. Interestingly, the regions in the eastern part of the Amazon ('Amazon River Flat Plains', 'Brazilian Shield Moist Forests', and the 'Guianan Shield Moist Forests') exhibit superior constraint by atmospheric data, as illustrated in Figure 4c-f. The spread in the posterior marginal distribution and the slopes of the linear regression in these four regions are inversely proportional to their respective reduction in uncertainty (Figure 3). This inverse relationship indicates that the posterior estimates are more effectively adjusted, irrespective of the prior magnitude, in regions with a higher reduction in uncertainty. Therefore, the 'Amazon and Andes Piedmont' in the west stands out as an area where a bias in the prior fluxes would exert a more substantial impact on posterior estimates.*

[RC1.22] L353: How significant are these results? South American stations are ATTO+NAT+Aircraft? Somewhere early on state that ATTO+NAT+Aircraft will continue to be referred to as South American Stations and keep that terminology consistent throughout. How does adding more stations (and having no impact on Andes Amazon Piedmont) reinforce lack of observational constraint in that region? Are you trying to say that the stations added are irrelevant to that region, and you need more stations *within* that region?

***[AR1.22]**: The South American (SAM) stations are indeed ATTO+NAT+Aircraft. The effect of* *adding stations in South America was assessed with the global inversion. We found that when adding the SAM stations the Amazon becomes a stronger sink and the Cerrado & Caatinga becomes a stronger source. At these scales, the results are significant for the Cerrado & Caatinga as the mean $F_{NetLand}$ with the posterior uncertainty in s10 does not overlap with that of s10sam. Furthermore, there is a reduction in posterior uncertainty from s10 to s10sam (see Figure 4 on submitted manuscript). When looking into the regional partitioning of this effect inside the Amazon, we found the smallest difference is in the 'Amazon and Andes Piedmont', where the observational constraint or coverage of the SAM station is the lowest. In other words, the station network used in SAM, has very little information content to constrain the fluxes in the 'Amazon and Andes Piedmont' as the difference between posterior fluxes with and without SAM stations is the lowest of all regions. So, the reviewer is right when stating that the SAM stations are "irrelevant" for that region. The lines 353 to 361 in the submitted manuscript were removed from the revised manuscript and a small section referring to the effect of adding SAM stations was added in Section 3.2: The atmospheric inversion allocates a net carbon source ($F_{NetLand}$) to the 'Cerrado & Caatinga' region (except for VPRM, VPRM-0.5Pg and VPRM-1Pg) and consistently identifies a net carbon sink in the biogeographic Amazon (Figure 5 and see Figures A9 and A10 for the spatial patterns). Interestingly, the addition of South American stations amplify this pattern and reduce the posterior uncertainty (compare s10 with s10sam). Despite the considerable variability in magnitude for the biogeographic Amazon, the atmospheric constraint tends to adjust priors with a positive sign, shifting them towards a smaller source (e.g., SIB4-1Pg) or even turning them into a sink with a negative $F_{NetLand}$ (e.g., VPRM-1Pg, VPRM-0.5Pg, and SIB4-0.5Pg). Furthermore, in the global inversion when adding South American data, the resulting fluxes closely follow the sign and magnitude of those obtained in the regional inversion. Therefore, we contend that information suggesting a sink-source gradient between the Amazon and the 'Cerrado & Caatinga' is embedded in the atmospheric measurement record, even with the inherent limitations in adjusting certain individual priors.*

[RC1.23] L356: For Brazilian Shield Moist Forests, did you mean to say movement from neutral to net release of 0.03? That is clearer than "there is a shift in sign".

***[AR1.23]**: The "shift in sign" was referring not only to the 'Brazilian Shield Moist Forests' (from neutral to positive) but also to the 'Guianan Shield Moist Forests'. However, given that we shortened the manuscript, this was one of the paragraphs that we decided to leave out. The main message of this paragraph (the effect of adding SAM station) was added to Section 3.2 in the revised manuscript. The new text added is shown in AR1.22.*

[RC1.24] Table 2: In title, add "averaged over 2010-2018".

***[AR1.24]**: We have added the reference period in the caption of Table 2.*

[RC1.25] L383: "... between these two regions"— change to ""... between the biogeographic amazon and the cerrado&caatinga"

***[AR1.25]**: We have added your suggestion and now it reads as follows:* Therefore, we contend that information suggesting a sink-source gradient between the Amazon and the 'Cerrado & Caatinga' is embedded in the atmospheric measurement record, even with the inherent limitations in adjusting certain individual priors.

[RC1.26] L407: Typo – change to Figure 5b

*[**AR1.26**]: Thanks, we corrected the typo.*

[RC1.27] Figure 6b: This is on average across 2010-2018? Specify in caption.

*[**AR1.27**]: We have added this in the caption. Thanks for the suggestion.*

[RC1.28] Discussion/Conclusions: With all the satellite data now available, it would be worthwhile to have a brief discussion on the value those data could add in tropical NLF constraints.

*[**AR1.28**]: We agree with the reviewer and thus have added a reference to the OCO2 Inversions in the Discussion, it reads now as: To further reduce the uncertainty in this domain, top-down estimates could combine in-situ data with satellite retrievals. The inversions assimilating data from the Orbiting Carbon Observatory 2 (OCO2) [Liu et al., 2017, Crowell et al., 2019, Peiro et al., 2022, Wang et al., 2023] have shown that remotely-sensed CO_2 columns can provide a valuable constraint of net carbon exchange in tropical regions. However, the OCO2-inversions are still limited by cloud coverage during the wet season [Massie et al., 2017, Peiro et al., 2022] and the adjustment of the prior can be biased to dry season retrievals [Crowell et al., 2019]. Nevertheless, our results for the response to the El Niño 2015/2016 coincide with the OCO2 inversions [Liu et al., 2017, Crowell et al., 2019, Peiro et al., 2022] in a carbon source in 2015 and 2016. Yet, a direct comparison of the magnitude in those studies to our results is difficult, as the area for South America in Liu et al. [2017] includes parts of the 'Cerrado & Caatinga' regions and in Crowell et al. [2019], Peiro et al. [2022] they divide South America in three parts: 1. Northern South America: including only the north (north of the equator) of the Amazon basin, the Orinoco basin, a part of central America and the Caribbean islands. 2. Southern Tropical South America, which includes a large part of the Cerrado and the southern part of the Amazon and 3. South America Temperate, which includes the Cerrado and Caatinga, extending until the southernmost point on the continent. None of these regions coincide with our regional distribution, therefore, using our domain definition on the OCO2-MIP results should be part of a next study, as it is out of the scope of this one.*

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