Reviews #1

We thanks the reviewer for the helpful comments. The feedback has helped us improve the paper. We addressed all comments below. The reviewer comments are in grey, our responses in black, sentences from the manuscript are *italic*, and sentences in the revised manuscript are in blue.

Specific comments:

- Line 6: You can leave out "(FIREMo)". It is already introduced in the previous sentence.

We removed it.

- Line 16: "match the fires and observations". I don't think you match fires. You only match CO2 observations from OCO-2 and IS. NEE is the buffer, compensating for any missing or abundant fires.

The matching mentioned in this sentence was mainly referring to the modification applied in the net flux in balance with each fire emission estimates. The difference among the NEE prior emissions are a consequence of the balance between the respiration and the fires emissions (see equation 3).
For better clarity, we replace the following sentence:
"*However, at regional scale, we can observe differences in fire emissions among the priors, resulting in large adjustments in the NEE to match the fires and observations.*"
by:
"However, at regional scale, we can observe differences in fire emissions among the priors, resulting in differences among the NEE prior emissions. The derived NEE prior emissions are re-balanced in concert with the fires. Consequently, the differences observed in the NEE posterior emissions are a result of the balanced with fires and the match of CO_2 observations."

- Line 22: "One major conclusion from this work is the strong constrain at global scale of the data assimilated compared to the fire prior used." This is vague and unclear. Please rewrite.

We re-write the sentence by :
"A major result of this work, that we can observe at global scale, is the strong constraint and influence of the CO_2 assimilated data among the inversions, on the net fluxes. Inversions using OCO-2 (or IS) data have closer emissions each other and so are more influenced by observations, compared to the fire prior used which has minor constraint."

- Line 25: FIREMO => FIREMo Done

- Line 26: “it is not the case for the majority of TCCON sites” Done

- Line 37: “The first uses, since 2017...” You need to write this differently. It implies that all fire models based on burned area use the modification that only GFED4s uses. First explain there are two methods of emission estimation, i.e. burned area approach and FRP approach, and then make a remark that GFED4s works since 2017 somewhat differently because MODIS burned area algorithm has been updated from Collection 5 to Collection 6. That means GFED4s fluxes are not based anymore from the burned area product directly but on the relationships between climatological GFED4s emissions between 2003–2016 and MODIS active fire detections and its FRP. This explanation should actually be included in the Appendix.

Thank you for this comment, we write line 37 with “The first approach uses burned area products.”
and we have added line 740, the sentence “The GFED4.1s version have encountered some changes since 2017 because MODIS burned area algorithm has been updated from Collection 5 to Collection 6. Consequently, GFED4s fluxes are not based anymore from the burned area product directly but on the relationship between climatological GFED4s emissions between 2003-2016 and active fire detection and its FRP product.”

- Line 44: “Two emission inventories use this approach...” Are you sure these are the only ones available? I would write “Two examples of emission inventories that use this approach are...”

We took this comment in consideration, and we replace the sentence with the reviewer’s suggestion.

- Line 46: “emissions inventories” => “emission inventories” Done

- Line 51: “trace gases emissions” => “trace gas emissions” Done

- Line 53: “...complicates the inference a great deal ” Not sure what you are trying to say here.

We changed this sentence with “Moving from global annual fluxes to finer scales in space and time greatly complicates the emission estimation”.

- Line 69: were examined Done

- Line 72: "Rather, it is assumed that fire emissions have much lower uncertainty (generally believed to be less than 10%)" But at line 51 you claim the errors are orders of magnitude for the emissions. Is the 10% uncertainty referring to fossil fuel emissions perhaps? Please check and correct.

This sentence refers to the previous one line 72 " Most inversion models do not explicitly constrain fire emissions with CO_2 observations". Most inversion models do not constrain fire emissions with CO2 observations as they assumed low uncertainty of fire emissions. Which is why we precised line 77 "This inference is problematic, not least due to the aforementioned fire emissions uncertainties in time and space, which could alias into inferred biospheric fluxes at continental or regional scales." It is believed that fire uncertainty are less than 10% however uncertainties can still lead to errors up to an order of magnitude for the total trace gases emissions. This sentence is correct but should be place in the context of other sentences that follow or precede the sentence.

- Line 76: "This inference is problematic" => "This assumption is problematic" Done

- Line 76: "emissions inventories" => "emission inventories" Done

- Line 92: "was caused not by rising of biomass burning emissions " Please rewrite

We rewrite this by "was not caused by increased biomass burning emissions".

- Line 96: "emissions inventories" => "emission inventories" Done

- Line 104: 2016, 2017 and 2018.

It is in fact not correct to say the 2015 El Nino event. The 2015 El Niño started in 2015 and ended in 2016. We changed the sentence with "the 2015-2016 El Niño event", as already mentioned line 186.

- Line 108: "Finally, these updated fire emissions are imposed in an atmospheric CO2 inversion that constrains CO2 fluxes, using either OCO-2 XCO2 retrievals or in situ data, with different assumed fire emissions and appropriately rebalanced prior biogenic fluxes."
  I suggest to write this differently.
  A suggestion:
  "Finally, these updated fire emissions and appropriately rebalanced prior biogenic fluxes are imposed in an atmospheric CO2 inversion to constrain the net land and ocean CO2 fluxes using

either OCO-2 XCO2 retrievals or in situ data. To evaluate these new emissions, an alternative set of fire emissions and rebalanced prior biogenic fluxes have also been used in this CO2 inversion framework."

We thanks the reviewer for this suggestion that we took in consideration.

- Line 113: You can mention the Appendix as well here.

We added the sentence "Description of the different GFED versions are presented in Appendix A."

- Line 229: Are MOPITT CO and OCO-2 CO2 observations also aggregated to 3x2 and 6x2 resolution in the inversions (e.g. in the observation operator)? This needs to be explained clearly in the paper how you treated the observations in regard to the simulation resolutions.

The observations are not aggregated at the model resolution. Fluxes and measured concentrations are linked through the transport and the observation operator. The observation operator samples the model fields at the location and time of the observations. We added in our manuscript line 246 "Fluxes and measured concentrations are linked through the transport and the observation operator. The observations are not aggregated at the model resolution." and line 249 "Due to some information gaps in the observational coverage, there is not enough information for the state vector. Therefore, the prior fluxes are used as the foundation to which we make corrections with information from the observations. These corrections are determined by the relative strengths of the prior uncertainty and the model-data mismatch statistics.".

- Because fire emissions are often very local (say within ~10km) and you use very detailed CO observations at 22km, how can you justify using such a coarse resolution of 3x2 (~300x200km) for transport simulation? You need to elaborate in the methodology or discussion how this can affect your inversion results on CO emissions.

Even if fires are very local, the column observations have a large footprint in space and time. It is hence not possible to work at the fire's local resolution. There is an increasing demand for inversion at higher spatial resolution. However, it calls for new development in the inverse models to reduce the calculation cost and ask a shift from global to regional inversions. The development of regional inversions allows in theory an efficient usage of high-resolution data while preserving a reasonable computational cost. Additionally, in comparison to numerical weather prediction model, global tracer transport models have generally used lower resolution due to the inclusion of chemistry and long window data assimilation which cannot afford such a computational expense at higher resolution. The length scale of emissions is much shorter than the length scale of its atmospheric signature, especially in the column. Consequently, this large length scale needs to be considered for the inversion. Additionally, the observation operator must be stored as a large Jacobian matrix before the computation necessary for the inversion. For the inversion, the computation of the observation operator is consequently problematic at higher resolution when assimilating large time series of satellite observations. In order to produce our CO or CO2 fluxes in atmospheric inversion systems, the observations are used in the 4D-Var (data assimilation system) based on the tracer transport model TM5. It is important also to consider that the transport error grows significantly as we refine our model resolution. We added this paragraph in the manuscript line 246 "If TM5 cannot represent the synoptic variability accurately, then the resulting errors when comparing the model with observations will prevent these observations from being used effectively in the 4D-Var. The mismatch between the model and the observation due to the differences in the resolution of the tracer transport model (including both the resolution of the meteorological ERA-Int fields and the resolution of the fluxes on the model grid) and the resolution of the observation footprint is also known as representativeness error (observational error). If the observational error in data assimilation is not correctly accounted, there will be errors in the optimized parameters (surface fluxes). For more information on the calculation of observational error in TM5, see Bergamaschi et al., (2010). However, it has been shown in previous studies that going from coarse resolution of the global tracer transport models to higher resolution does not provide improvement with respect to observations (Lin et al., 2018, Remaud et al., 2018)."

- I can imagine that the simulation of pyroconvective plumes and the transport of CO high in the troposphere and stratosphere might be very challenging at very coarse resolutions. Is captured adequately, and if not how would it affect your optimized fire emissions?

Since CTMs have at global scale coarse resolution, they could not capture the vertical transport induced by the heat released from landscapes scale fires or the pyronconvective plumes. Therefore, the plume dynamics and its associated vertical transport are based on parameterizations called "Injection Height" (Colarco et al., 2004). This "Injection Height" represents the height and vertical layer of the CTM where smoke emissions are no longer influenced by the plume dynamics but simply released in the atmosphere. As already mentioned in our paper line 252 "*Injection heights, in the CO inversion, are computed using IS4FIRES (Integrated System for Wild-Land Fires, http://is4fires.fmi.fi/, Sofiev et al. (2013)). This emission database is driven by re-analysis FRP obtained from MODIS (Giglio et al.,* *2006)) instrument on board Aqua and Terra satellites.*". The injection height already used in our optimized fire emissions and mentioned in our manuscript, we did not write additional information in the manuscript.

- I assume IS data is sampled inside TM5 at the correct elevation and location, but please explain on how you obtain a representative sample of CO2 when you simulate at a very coarse resolution of 6x4 (~600x400km). This needs to be discussed in the manuscript as well.

For the IS inversion, TM5 is sampled at grid cells containing in situ observation, at the hours corresponding to the observations, and at appropriate vertical level and horizontal location. The model profile is interpolated to a level corresponding, on average, to the altitude above sea level of the observation site. Information on the observational error has been previously provided.

- Line 225: "CO inversion :" remove space before :

We modified that line 255.

- Lines 270-278: I think is more appropriate here to explain how GFED4s has been modified from 2017 onward.

Since this information is already available in the Appendix A, we mentioned "Further description in GFED versions can be found in Appendix A" and we added in the appendix

"The active fire data comes from Tropical Rainfall Measuring Mission (TRMM), the Visible and Infrared Scanner (VIS), and the Along-Track Scanning Radiometer (ATSR), three other instruments on board with MODIS. MODIS has a 500 m horizontal resolution. ".

- Line 279-285. Is a length scale of 1000km not too long for local fire events? Please explain. Would a smaller length scale affected your emission results? The Meirink reference is not about fire emissions but about methane emissions. So why is this a valid choice?

We have used a horizontal length scale of 1000km which has been determined based on previous data assimilation and comparison of emission inventories. This choice is made in order to represent the best realistic spread from errors in emissions. We used Meirink et al., (2008) as reference for choosing a length scale of 1000km because the TM5 CO is based on the methane development described in Meirink et al., (2008). The CO inversions described in Hooghiemstra et al., 2012 or Krol et al., (2013) were based on the 4DVAR version of the TM5 model developed and described by Krol et al., (2005, 2008); and Meirink et al., (2008). More recently, the CO inversions developed in Nechita-Banda et al., (2018) were also based on the TM5 model of Krol et al., (2015, 2008) and Meirink et al., (2008). All these previous studies used a horizontal correlation length scale of 1000km for the global prior emissions, length justified in Meirink et al., (2008).

Additionally, a length scale of 1000km is not the largest horizontal scale used for CO inversions. Larger spatial correlation lengths were previously used. For instance, Barre et al., (2015) used 2000km with the CESM model. All CO inversions with TM5 used a length of 1000km while for LMDz they used 500km (Zheng et al., 2019, Chevalier et al., 2009).

- Line 284: "The errors are assumed ..." This sentence needs to start differently because you switch topic from matrix B to matrix R.
  suggestion:
  In the observation covariance matrix R we only assume uncorrelated errors, meaning we only have errors along the diagonal.
  Also good to explain why or why not this is a realistic assumption.

Thank you for this suggestion that we took in consideration. The errors are assumed uncorrelated allowing the use of a diagonal matrix for the observational error covariance matrix R. This can be assumed since the observation error can be in general easily quantifiable by careful calibration of the instruments.

We added line 284: "In the observation covariance matrix R, we only assume uncorrelated errors, meaning we only have errors along the diagonal. This can be assumed since observation error is in general easily quantifiable by careful calibration of instruments."

- Line 289: "For each pixel..." The pixel size is 3x2 right? Good to add that here. "For each pixel (3x2 degree resolution)" Done

- Figure 1: Because biofuel was added to all CO2 FIRE estimates, should biofuel burning not be included somewhere in the schematic overview?

Indeed, biofuel emissions was added to all CO2 FIRE estimates, including FIREMo. We hence added Biofuel in the schematic overview of Fig. 1.

- Line 297: g.mol−1 I don't think you need to type the dot between g and mol. Same applies for other units elsewhere in the text. Done

- Line 307: Add here that you also included biofuel emissions to obtain FIREMo.

We changed the sentence with "Finally, we sum up these emissions across all surface types and also include CO_2 biofuel emissions (see table 3) in order to get monthly total optimized prior CO_2 biomass burning emissions that we called "FIREMo" (see Fig. 1). ".

- Line 322: The Ott reference links to the dataset of GEOS-Carb CASA-GFED3, but it does not clarify the methodology of respiration modification. Is there another reference available?

There is no other reference available for the GEOS-Carb CASA-GFED3 product than the one we already provided. For more details on the product, it is advised to contact the PI, in this case Lesley Ott. We specified in our manuscript that we took a similar approach than the one use in GEOS-Carb CASA-GFED3, meaning "resembling without being identical". In GEOS-Carb CASA-GFED3 they use monthly fire emission in their estimation of the net CO_2 fluxes, while most of other inversions have chosen to only report net land fluxes by holding fire emissions fixed. This is already mentioned in the manuscript both in the introduction and in the methodology (line 335).

To avoid confusion, we decided to rewrite the following sentence "*Terrestrial biosphere fluxes and fire emissions are difficult to disentangle from CO_2 data alone, and some inverse modeling studies (e.g. Crowell et al. (2019)) choose instead to report the net land fluxes. Likewise, some global land flux estimates such as GEOS-Carb CASA-GFED3 project (Ott, 2020) use fire estimates to revise the terrestrial biosphere flux estimates through modification of ecosystem respiration. We take a similar approach, starting with the gross primary production and respiration estimates from the CASA-GFED3 3-hourly 0.5◦×0.625◦ (Ott, 2020).* " by "Terrestrial biosphere fluxes and fire emissions are difficult to disentangle from CO_2 data alone, and some inverse modeling studies (e.g. Crowell et al. (2019)) choose instead to report the net land fluxes. Likewise, some global land flux estimates such as GEOS-Carb CASA-GFED3 project (Ott, 2020) use fire estimates with ecosystem respiration to revise the terrestrial biosphere flux estimates. We take a similar (but not identical) approach, using emissions of fire and respiration to estimate the terrestrial biosphere flux. We start with the gross primary production and respiration estimates from the CASA-GFED3 3-hourly 0.5◦×0.625◦ (Ott, 2020). ".

- Line 331: which is in balance with Done

- Table 3. If I take for 2017 GFED4s emissions (as an example), and add up all the other flux components (biofuel, ocean, NEEre4, and fossil), the sum is not equal the AGR_noaa. Is there something I'm missing in this logic? 4.9 = 0.486 + 10.07 + 1.78 - 4.83 - 2.6
  However, AGR_noaa for 2017 is 6.06. Please explain.

We thanks the reviewer for this comment and question. It is an error from our part. The AGR_{NOAA} mentioned in the table are the corresponding values from 2014 through 2017 and not 2015 through 2018. Consequently, the 6.06 PgC/yr is in fact corresponding to 2016. We have corrected that in the table 3. Additionally, we realized that the NEE values were not the prior values and so were not correct. Since this table only include prior information, we corrected the table with only prior values (for verification, we can see that the new values are well corresponding to Fig. 5). For further information in the AGR calculated with the re-balanced respiration, we have added their respective values in the table. As we can observe, the AGR calculated are close to the AGR_{NOAA}. We have added the new values of the following table in Table 3 of our manuscript.

	2015	2016	2017	2018
OCEAN	-2.6	-2.6	-2.6	-2.6
BIOFUEL	0.479	0.476	0.486	0.486
FF	9.89	9.91	10.07	10.28
GFED3	2.03	1.63	1.97	1.97
GFED4	2.09	1.73	1.78	1.69
FIRE3	2.51	2.11	2.46	2.46
FIRE4	2.57	2.21	2.27	2.18
FIREMo	1.82	1.47	1.58	1.56
NEECMS	-1.93	-1.71	-1.58	-1.55
NEEre3	-3.42	-3.41	-5.40	-5.10
NEEre4	-3.40	-3.50	-5.11	-4.73
NEEreMo	-2.43	-2.51	-4.25	-3.90
AGR_{CMS}	7.87	7.71	8.35	8.59
AGR_3	6.38	6.01	4.53	5.04
AGR_4	6.46	6.02	4.63	5.13
AGR_{Mo}	6.68	6.27	4.8	5.34
AGR_{NOAA}	6.3	6.06	4.54	5.05

- Figure 2 and Table 4: Suggestion: It makes more sense I think when you name OCO-2 inversions differently. Instead of CMS-GFED3, GFED3re, GFED4re and MOre, you could name them OCOCMS, OCO3re, OCO4re and OCOMOre. That way they are more akin to the IS inversion names and more easily recognisable as OCO-2 inversions.

Thank you for this suggestion, we changed the manuscript using these names.

- In the final column of boxes with inversion names you could give them the same color as used for the bar graphs (e.g. Fig. 5). So, black for CMS, blue for GFED4re, green GFED3re and red for More.

Thank you for this suggestion which we used.

- Line 367: Typo Coparison Done

- Line 376: “involves” => “produces” or “yields” Done

- Line 387: “south America” => “South America” Done

- Line 390: “are strong” => “are large” Done

- Line 390: “are needed” => “is needed” Done

- Line 397: “seem to observe as mush as the prior GFED4.1s.” I would phrase it differently: “a characteristic that is shared between the MOPITT constrained fire emissions and GFED4s”

We considered this suggestion

- Figure 4:

- Include in the legend the colored fire emission categories Done

- Please provide in the final version of the manuscript a higher resolution of the figure image. The current image is somewhat blurry and hard to read. Done

Place ‘year’ tick markers and labels in the middle of each grouping of bars Done

In caption remove space in front of “ :” Done

- Line 401: “Previous studies have shown that peat area and depth, producing large amount of carbon (0.60 PgC/yr which represents 26% of the total carbon fire emissions, Nechita-Banda et al. (2018)), were found to have significant uncertainties in Indonesia in the emissions inventories”

  Suggestion:

  ”Previous studies have shown that the parameterization of peat (surface area and layer thickness) resulted in significant uncertainties in emission inventories. This is especially true for Indonesia where combustion of peat can produce significant amount of carbon.”

We considered this suggestion to write this new sentences: “Previous studies have shown that the parameterization of peat (surface area and layer thickness) resulted in significant uncertainties in emission inventories. This is especially true for Indonesia (Lohberger et al., 2017; Hooijer and Vernimmen, 2013) where combustion of peat can produce significant amount of carbon (Nechita-Banda et al., (2018)).”.

- Line 403: “emissions inventories” Done

- Line 404: “Our posterior have lower emissions than the prior for...” => “Our posterior fire emissions are lower than the prior fire emissions” Done

- Line 404: “southern tropical Asia” => “Southern Tropical Asia” Done

- Line 405: “However, Nechita-banda et al. (2018) assimilated MOPITT and NOAA observations and used GFAS as fire priors, an inversions set-up different to what we used.”

  “However, Nechita-banda et al. (2018) assimilated MOPITT and NOAA observations and used GFAS as prior for fire emissions. Also, their inversion set-up was different to what we used.”

Done

- Line 406: “Additionally, no evaluation against independent data have been performed in their study to determine if their results are more trustworthy than our results. ”

  “Additionally, no evaluation against independent data have been performed in their study, so there is no reason to believe their results are more trustworthy than ours” Done

- Line 410: “that GFED4.1s have a fire peak earlier than MOPITT” => “that GFED4.1s fire emissions have a fire peak earlier than MOPITT constrained emissions” Done

- Line 422: “for the prior4” => “for prior4” Done

- Line 425: “decreasing from 2015 through 2018.” The net sink is actually increasing.

Indeed, the net sink is increasing from 2015 through 2018. We changed it.

- Figure 5

Place tick markers and labels in the middle of each grouping of bars. Done
“Annual prior CO2 emissions, “ add units => “Annual prior CO2 emissions (PgC/yr)” Done
“are represented” => “are shown” Done
“between GFED4.1s (blue), GFED3 (green), MOPITTopt (red) and CMS (black).”
Shouldn’t these not be called either GFED4re, GFED3re, MOre, and CMS-GFED3 according to Table 4, or prior4, prior3, priorMo and priorCMS? Indeed, we corrected the notations.

- Line 432: “FIRE4 and FIREMo ” labeling is still somewhat confusing. Is it not better to call them prior4 and prior3?

We decided not to follow this decision. The notation prior4 in this case represents the net fluxes and so both FIRE4 and NEEre4.

- Line 437: “consistent with the fact that GFFED4.1s CO was observing higher CO fire emissions than MOPITT ” I don’t see the added value of this part of the sentence. The first part already makes that point.

We removed this part.

- Line 439: “observed by ” => “estimated by” Done

- Line 441: “Northern” Done

- Figure 6: “North” Done

- Line 449 and elsewhere: “GFED” write it in full “GFED4.1s”.

GFED in this paragraph corresponds to both GFED3 and GFED4.1s inventories (or FIRE3 and FIRE4). We corrected this paragraph with:

"*For savanna, agriculture and peat lands, FIREMo observed a peak in fire seasonality after the peaks observed with ~~GFED~~ both FIRE3 and FIRE4 (Fig. ~~S9~~ S8). This is particularly true for the 2015 El Nino fires but less for the fires that occurred in 2017 and 2018. In this period, FIREMo does not observed as much fire emissions as ~~GFED~~ FIRE3 and FIRE4 with a similar seasonality. The difference in seasonality for 2015 could be a result of the large and intense fires during the El Nino event burning larger regions and releasing more smoke which could have impacted the MODIS burned area data used in ~~GFED~~ GFED3 and GFED4.1s inventories but probably also the MOPITT retrievals. Further investigation are then needed to study this region.*"

- Line 451: But how sure are we that the MOPITT constrained emission seasonality is "better" (as you write at line 445) if smoke could also impacted the MOPITT observations? Is there evidence in TCCON data? Please elaborate in the paper.

The paragraph referred here is "*As already observed with the CO emissions (Fig. S6) and discussed in van der Laan-Luijkx et al. (2015) and Nechita-banda et al. (2018), the seasonality of fires over tropical Asia is better captured with MOPITT than with the emission inventories for peat lands. However, this is not only true for peat but also for other vegetation types. For savanna, agriculture and peat lands, FIREMo observed a peak in fire seasonality after the peaks observed with GFED (Fig. S9). This is particularly true for the 2015 El Niño fires but less for the fires that occurred in 2017 and 2018. In this period, FIREMo does not observed as much fire emissions as GFED with a similar seasonality. The difference in seasonality for 2015 could be a result of the large and intense fires during the El Niño event burning larger regions and releasing more smoke which could have impacted the MODIS burned area data used in GFED but probably also the MOPITT retrievals. Further investigation are then needed to study this region.*" This was developed later in the manuscript line 644 "*As discussed in Nechita-Banda et al. (2018) and van der Laan-Luijkx et al. (2015) for Equatorial Asia and tropical south America, GFED4 does not capture fire seasonality due to the use of burned area, compared to GFAS. In both GFED and GFAS method (and similarly for MOPITT), the detection of fires underneath clouds and below the canopy is difficult. But, FIREMo emissions, compared to FIRE3 and FIRE4, has the advantage of combining optimized fire emissions with local observations.*". Assumption of the seasonality difference between GFED and MOPITT observed with previous studies was mentioned line 410 "*van der Laan-Luijkx et al. (2015) and Nechita-banda et al. (2018) hypothesized that GFED4.1s might not capture the timing of emissions over area with peat fires due to the use of burned area, which may be more sensitive to the initial stages of the fire than to the continued burning.*". So the difference of seasonality is more linked to the different phase of burning than the smoke biases. However, it is important to also acknowledge the existence of data gaps in both MODIS and MOPITT due to clouds and smokes. For better clarity between all of these elements, we rewrote paragraph line 445 "As already observed with the CO emissions (Fig. S5) and discussed in van der Laan-Luijkx et al. (2015) and Nechita-banda et al. (2018), the seasonality of fires over Tropical Asia seems to be better captured with MOPITT than with the CO emission inventories for peat lands. However, this is not only true for peat but also for other vegetation types and can also be observed for CO2 emissions. For savanna, agriculture and peat lands, FIREMo has a peak in fire seasonality after the peaks observed with both FIRE3 and FIRE4 (Fig. S9). This is particularly true for the 2015 El Nino fires but less for the fires that occurred in 2017 and 2018. In this period, FIREMo does not observe as much fire emissions as FIRE3 and FIRE4 with a similar seasonality. The large difference in seasonality for 2015 could be particularly marked due to the large and intense fires of the El Nino event burning larger regions and releasing more smoke. However, it is important to acknowledge the existence of data gaps due to clouds and smokes in both MODIS burned area products (used in GFED3 and GFED4.1s inventories) and probably MOPITT retrievals. Further investigations are then needed to study this region.".

- Line 452: "emissions : " again remove space after : Done

- Line 452: For simplicity sake, I suggest to title section 3.2.2 in a similar fashion as 3.2.1: e.g. 3.2.2 Posterior NEE and fire CO2 fluxes

We considered this suggestion and changed the title of 3.2.2.

- Line 462: See previous comment about Figure 2. I think it is much clearer if you name GFED3-CMS as OCOCMS. The distinction between OCO-2 and IS inversions is much easier that way.

We apply this change in all the manuscript and in the figures.

- Line 464 and elsewhere: "different priors " better to refer to "different inversions". Now the use of "prior" labels in this particular section is confusing because we are actually looking at "posterior" fluxes. Please change this throughout the section.

Done for the sentence where priors should have been inversions. However, in some other sentences, priors was correctly used.

- Line 466: "across the priors" => "across the inversions" Done

- Line 470: “across the priors” => “across the inversions” Done

- Line 470: “adjusted downward” meaning larger sink? If so, be clear in the text.

We changed by “However, the 2016 sink is larger for the OCO-2 fluxes (between -0.4 PgC/yr and -0.6 PgC/yr) than the in situ fluxes”.

- Line 473: “than the other regions ” => “than in the other regions ” Done

- Line 475: “but we know that there are a few in situ data present in 475 the SH Ext and so they have a different data constraint ” => “but we know that there are a few in situ sites present in the SH Ext resulting in a limited constrain on emissions as well” Done

- Line 476: “across the priors” => “across the inversions” Done

- Line 478: “sinks with in situ NEE emissions.” => “sinks with in situ observations.” Done

- Line 479: “across the priors” => “across the inversions” Done

- Line 481: “The net fluxes of ISMOre and IS4re look similar for the Tropical regions, while the net fluxes of IS3re and ISCMS look alike, suggesting the sensitivity in these regions to the fire prior, not only for IS but also for OCO-2 data constraint.” This sentence needs to be rewritten because it is hard to follow.

We rewrote this sentence with “For the Tropical regions, ISMOre and IS4re net fluxes look similar. Similarly, the inversions constrained with FIRE3 look alike such as IS3re and ISCMS. This suggests the sensitivity of inversions to the fire prior in these regions.”.

- Line 485: “we can see difference in the carbon balance” => “we can see a number of differences in the inferred carbon balance” Done

- Line 486: I don’t agree with this sentence. If I look at Fig. 7, IS data gives the largest net sink for NH ext.

Indeed, the sentence “*If we first look the Northern Extra-Tropical regions (North America, North Asia and Europe), we can see that the OCO-2 inversions have deeper net sinks than IS (see Fig. 8).*” has been modified to "If we first look the Northern Extra-Tropical regions, we can see that the IS inversions have deeper net sinks than OCO-2 (see Fig. 7).".

- Line 490: "with few data (north Asia regions)." => "where data is sparse (North Asia regions)." Done

- Line 492: "It is interesting also to see balance " => "It is also interesting to see the balance " Done

- Line 493: "sink decreased " => "sink reduction " Done

- Line 496: "uptake of around " => "with an uptake of around " uptake where? In Europe?

We changed the sentence with "Reuter et al., 2014 found, using GOSAT data, a similar mass balance between Europe and Northern Africa with an uptake of around 1 PgC/yr in Europe".

- Line 497: Would CarbonTracker Europe not provide a detailed European estimate?

https://carbontracker.eu

CarbonTracker Europe provides CO2 emissions estimation for the Transcom regions combining measurements (such as the ObsPack products) and modeling system. They used a 1x1 degree zoom of the TM5 transport model and 20 sites over Europe. For the prior biosphere, they used SiBCASA-GFED and for the prior fire they used GFED4. They mentioned also on their website that the biological fluxes have not been verified by observations. The uncertainties associated with these fluxes is not known. While recent estimation is available online, there is no publication providing CO2 emission estimate over Europe with CarbonTracker Europe covering 2015-2018 and associated validation, and so there is a lack of carbon budget information over Europe for our period of interest.

CarbonTracker Europe net flux (calculated by extracting the fossil fuel emissions from total flux in their table https://carbontracker.eu/fluxtimeseries.php#imagetable) gives:

	2015	2016	2017	2018
CarbonTracker Europe net fluxes	-0.1	-0.22	-0.51	-0.15

Except for 2017, the OCO-2 and IS inversions have different net fluxes than with CarbonTracker Europe.

- Line 501: "in 2017, as opposed to 2016 " refer to figure 6.

We added "(see Fig. 6 and 8)".

- Line 503: Again somewhat confusing sentence: "MOre and GFED4re inversions (respectively ISMOre and IS4re) are similar, while GFED3re and CMS-GFED3 (respectively IS3re and ISCMS) are more similar."

  Why not:

  "ISMOre and IS4re inversions providing similar results (both based on either optimized GFED4.1s and default GFED4.1s emissions), while the same is true for IS3re and ISCMS inversions (both based on GFED3 emissions)."

Thank you for this suggestion. We changed the sentence by: "ISMOre and IS4re inversions provide similar results (both based on either optimized GFED4.1s and default GFED4.1s emissions), while the same is true for IS3re and ISCMS inversions (both based on GFED3 emissions). Same is true for OCO-2 inversions as well where OCOMOre and OCO4re have similar results while OCO3re and OCOCMS are similar.".

- Line 508: "for each priors" you mean "for each inversion"?

This has been already changed with a previous comment.

- Line 512: "observation" => "observations" Done

- Line 513: "southern and northern hemispheres " => "Southern and Northern Hemispheres" Done

- Line 516: "than the IS are " => "than the IS posterior emissions are" Done

- Line 519: "then come from different area of observation " I don't understand this.

The sentence " This difference in posterior flux could then come from different area of observation" refers to both lines 516 and 517. The posterior emissions from OCO-2 being closer to the prior is explained by the few amount of OCO-2 measurements above the moist Amazon, a area/region affected by cloud. We are realizing that the sentence line 519 does not bring additional information. We hence decided to remove it.

- Line 522: “OCO-2 net fluxes ” OCO-2 doesn’t measure net fluxes. “net fluxes derived with OCO-2” Thanks for this correction. We changed the sentence.

- Line 522: “high sources ” => “large sources” Done

- Line 523: “FIREMo and FIRE4 sinks decrease” Again, these labels don’t fit well in the sentence. According to the definition of FIREMo and FIRE4 these are fire emission + biofuel burning. They cannot be sinks.
  If you write it like this it is easier to understand:
  Posterior net sinks derived with FIREMo and FIRE4 emissions decrease for 2017, however, the posterior net sinks derived with FIRE3 do not.
  Similar issues also appear elsewhere in your text. Please correct this.

Thank you for this suggestion, we changed the sentence and corrected the rest of the manuscript accordingly.

- Line 525: “dependence ” => “known prior dependency of the IS posterior emissions” Done

- Line 526: Again “southern” => “Southern ” Done

- Line 527: Where do we see this? Respiration is not plotted

We can see indirectly the respiration through the NEE emissions. Respiration has been balanced with fires, and this same respiration has been used to calculate NEE emissions. We changed this sentence “*For southern Tropical Africa, we can see the large balance between the fires and the respiration, which are anti-correlated in their variability.*” by “For Southern Tropical Africa, we can see the large balance between the fires and the NEE emissions (indirectly the balance between the fires and the respiration), which are anti-correlated in their variability.”.

- Line 526-531: This section is in particular hard to follow. Need to be rewritten.

We rewrote the sentence "*For Southern Tropical Africa, we can see the large balance between the fires and the respiration, which are anti-correlated in their variability. GFED4re and MOre have larger sources than GFED3re and CMS-GFED3. With the IS, there is large variation across the inversions where IS4re and ISMOre both constrain a source of carbon for the whole period, while ISCMS and IS3re have smaller source of carbon and even a sink in 2016 and 2017. These differences seem to suggest that both fires and respiration are especially important when observational coverage is limited.*" with "For Southern Tropical Africa, we can see the large balance between the fires and the NEE emissions (indirectly the balance between the fires and the respiration), which are anti-correlated in their variability. Additionally, OCO-2 inversions derived with FIREMo and FIRE4 emissions (OCOMOre and OCOG4re) have larger sources than inversions derived with FIRE3 (OCOCMS and OCOG3re). With the IS inversions, there is large variation across the inversions where IS4re and ISMOre both constrain a source of carbon for the whole period, while ISCMS and IS3re have smaller source of carbon and even a sink in 2016 and 2017. These differences between inversions derived with FIREMo or FIRE4 and FIRE3 seem to suggest that fires (and so NEE re-balanced with fires) are especially important when observational coverage is limited.".

- Line 532: "between the priors " but these are posterior emissions. You mean perhaps "between the inversions"

Indeed, this has been changed

- Line 532-535: Also this part is hard to follow.

We rewrote the sentence "*Northern Tropical Asia (Fig. 8) shows agreements between the priors and OCO-2 data constraints for 2015 and 2016, but shows significant differences between OCO-2 and IS for 2017 and 2018. The sparse coverage of in-situ data over this region could explain the difference with OCO-2, though not specifically for 2017 alone, and hence further investigations are needed for this region.*" with "Northern Tropical Asia (Fig. 8) shows agreements between OCO-2 and IS inversions, but shows significant differences in 2016. The sparse coverage of in-situ data over this region could explain the difference with OCO-2, but not specifically for 2016 alone, and hence further investigations are needed for this region.".

- Line 535: “Finally, for southern Tropical Asia, the inversions adjusted the NEE sinks for MOre and GFED4re to be larger than the two other inversions in order to accommodate the smaller fires observed with FIREMo and FIRE4. ”
  Can be simplified to
  “Finally, for Southern Tropical Asia, a larger sink was derived with OCOMOre and OCO4re than with OCO3re and OCOCMS, to balance the smaller fires derived with FIREMo and FIRE4.”
  Still I don’t understand what you trying to say here. Would you not expect a larger sink when fire emissions are larger?

Indeed, we expect a larger sink when fire emissions are larger, which it is observed and was not correctly mentioned in the sentence. We rewrote the sentence with: “Finally, for Southern Tropical Asia, a smaller sink was derived with OCOMOre and OCO4re than with OCO3re and OCOCMS, to balance the smaller fires derived with FIREMo and FIRE4.”.

- Line 485-546: This results section needs some additional editing as some parts are still hard to follow. The final summary paragraph was very informative. I suggest to use this as the main anchor for 3.2.2b. Each sentence of the summary text (L541-L546) can be used as a beginning for a paragraph in 3.2.2.b.

We changed the following sub-section 3.2.2.b:

“*When we compare the posterior regional fluxes, we can see a number of differences in the inferred carbon balance.*

If we first look the Northern Extra-Tropical regions, we can see that the IS inversions have deeper net sinks than OCO-2 (see Fig. 7). The in situ data are placing almost all of the NH Ext sink over Northern Asia, but are placing sources of carbon over North America for 2015 (Fig. 8). In-situ data do not have an homogenize coverage over the NH Ext band: large number of observations are situated over Temperate North America and Europe but are very sparse over the Boreal regions and Temperate Eurasia (see Fig. S1). The large differences in net sinks occur then over the regions where data is sparse (North Asia regions).

It is also interesting to see the balance between the regions in Northern Hemisphere with Southern Hemisphere. For instance, it seems that the sink reduction for 2018 (starting in 2017) observed with *both IS and OCO-2 over North Asia is balanced by net sinks in tropical Asia (North and South). The deeper sinks observed with OCO-2 in Europe are also anti-correlated with the net sources observed in Northern Tropical Africa (Fig. 8). Reuter et al. (2014) found, using GOSAT data, a similar mass balance between Europe and Northern Africa with an uptake of around 1 PgC/yr in Europe which was 0.5 PgC/yr higher than expected from in situ inversions. However, as mentioned in Reuter et al. (2017), there is a lack of carbon budget information over Europe and there is hence no reliable benchmark for comparison. The balance observed here between IS and OCO-2 inversions was also observed in the study of Peiro et al. (2022). However, for Europe, we can see that the variability in our inversions is different than the ones used in Peiro et al. (2022). A major difference between this study and Peiro et al. (2022) is that the rebalanced priors and posterior fluxes provide the largest sink in 2017, as opposed to 2016 (see Fig. 6 and 8). This is likely a consequence of the larger fires and the subsequent rebalanced respiration that was derived in our study.*

Across the different fire emissions we observe a split: MOre and GFED4re inversions (respectively ISMOre and IS4re) are similar, while GFED3re and CMS-GFED3 (respectively IS3re and ISCMS) are more similar. That means fires have a larger impact on the posterior solution than the rebalancing of prior NEE to match the global AGR. We can observe that for almost all regions, the sinks with NEE4re and NEEMore are deeper than with NEE3re and Geos-Carb CMS but are balanced with larger sources in other regions, mainly over the Tropics (Fig. 7).

Focusing on the Tropical regions, OCO-2 fluxes are consistent for each inversions. For Northern Tropical South America (Fig. 8), OCO-2 fluxes have around 0.5 PgC/yr efflux during the El Niño period (2015-2016) and neutral emissions during the 2017-2018 period. IS fluxes are also strong during the El Niño period, but remain moderately high in 2017. As observed in the Fig. 1 of the paper of Peiro et al. (2022), which used the same set of IS data, the number of IS data does not decrease significantly, meaning that changing observational coverage is not the cause of this behavior. The number of in situ observations is particularly low in the tropics compared to the extra-tropical Southern and Northern Hemispheres (Fig. 2 of Peiro et al. (2022)). One possible explanation is the lag between flux in the Tropics and observation coverage by the in situ network, which could be aliasing flux signals in time, though this hypothesis is difficult to test. Very large differences between the IS and OCO-2 inversions appears for Southern Tropical South America (Fig. 8). The OCO-2 posterior emissions seem to be closer to the priors than the IS posterior emissions are. One explanation for that has been mentioned previously in Peiro et al. (2022). The cloud coverage above the moist Amazon *decreases the amount of OCO-2 retrievals, while IS data are located more inside the moist Amazon. In opposition to the other Southern Tropical regions, the ENSO signal appears in 2016 instead of 2015 for OCO-2. This region follows the inter-seasonal variations of the Northern Tropical regions, which also see highest emissions in 2016.*

For Northern Tropical Africa, net fluxes derived with OCO-2 are strong with large sources of carbon between 0.5 PgC/yr and 1.5 PgC/yr. We can see also some fire-dependent differences: posterior net sinks derived with FIREMo and FIRE4 emissions decrease for 2017, however, the posterior net sinks derived with FIRE3 do not. This difference in 2017 is particularly observed with OCO-2. IS, on the contrary, give strong sinks in this region, the strongest one for all Tropical regions. Examining Fig. 6, we note the known prior dependency of the IS posterior emissions. Northern Tropical Africa is known to have very few IS data compared to the other Tropical regions (Fig. S1). For Southern Tropical Africa, OCO-2 inversions derived with FIREMo and FIRE4 emissions (OCOMOre and OCOG4re) have larger sources than inversions derived with FIRE3 (OCOCMS and OCOG3re). With the IS inversions, there is large variation across the inversions where IS4re and ISMOre both constrain a source of carbon for the whole period, while ISCMS and IS3re have smaller source of carbon and even a sink in 2016 and 2017. These differences between inversions derived with FIREMo or FIRE4 and FIRE3 seem to suggest that fires (and so NEE re-balanced with fires) are especially important when observational coverage is limited. Northern Tropical Asia (Fig. 8) shows agreements between OCO-2 and IS inversions, but shows significant differences in 2016. The sparse coverage of in-situ data over this region could explain the difference with OCO-2, but not specifically for 2016 alone, and hence further investigations are needed for this region. Finally, for Southern Tropical Asia, a smaller sink was derived with OCOMOre and OCO4re than with OCO3re and OCOCMS, to balance the smaller fires derived with FIREMo and FIRE4. This is not observed however for the IS inversions which just show NEE sources for both ISMOre and IS4re. The impact of the fires over this region seems to have a strong impact with both data constraint. If we compare the posteriors with the priors, we can in fact see that the IS tends to be closer to the priors than the OCO-2 inversions. This suggest that for this region as well, the few amount of IS data might explain this result and the larger amount of OCO-2 seems to better constrain the posterior fluxes.

In summary, we observe consistent differences in posterior NEE between IS and OCO-2 inversions. Some of these differences are caused by differences in data coverage and cloud fraction. For all data constraints, we can observe a smaller sinks in the tropics during El Nino, while larger net sinks are *observed in the NH Ext. Moreover, larger sinks are observed with OCO-2 in north America and Europe, while larger sinks are observed with IS in Asia. Finally, the net fluxes using FIREMO look like those using FIRE4 for the southern tropical regions, while net fluxes using FIRE3 look alike, suggesting the sensitivity in these regions to the fire prior, not only for IS but also for OCO-2 data constraint."*

with:

"When we compare the posterior regional fluxes, we observe consistent differences in posterior NEE between IS and OCO-2 inversions. Some of these differences are caused by differences in data coverage and cloud fraction. If we look the Northern Extra-Tropical regions, we can see that the IS inversions have deeper net sinks than OCO-2 (see Fig. 7). The in situ data are placing almost all of the NH Ext sink over Northern Asia, but are placing sources of carbon over North America for 2015 (Fig. 8). In-situ data do not have an homogenize coverage over the NH Ext band: large number of observations are situated over Temperate North America and Europe but are very sparse over the Boreal regions and Temperate Eurasia (see Fig. S1). The large differences in net sinks occur then over the regions where data is sparse (North Asia regions). Focusing on the Tropical regions, OCO-2 fluxes are consistent for each inversions. For Northern Tropical South America (Fig. 8), OCO-2 fluxes have around 0.5 PgC/yr efflux during the El Niño period (2015-2016) and neutral emissions during the 2017-2018 period. IS fluxes are also strong during the El Niño period, but remain moderately high in 2017. As observed in the Fig. 1 of the paper of Peiro et al. (2022), which used the same set of IS data, the number of IS data does not decrease significantly, meaning that changing observational coverage is not the cause of this behavior. The number of in situ observations is particularly low in the tropics compared to the extra-tropical Southern and Northern Hemispheres (Fig. 2 of Peiro et al. (2022)). One possible explanation is the lag between flux in the Tropics and observation coverage by the in situ network, which could be aliasing flux signals in time, though this hypothesis is difficult to test. Very large differences between the IS and OCO-2 inversions appears for Southern Tropical South America (Fig. 8). The OCO-2 posterior emissions seem to be closer to the priors than the IS posterior emissions are. One explanation for that has been mentioned previously in Peiro et al. (2022). The cloud coverage above the moist Amazon decreases the amount of OCO-2 retrievals, while IS data are located more inside the moist Amazon. For Northern Tropical Africa, net fluxes derived with OCO-2 are strong with large sources of carbon between 0.5 PgC/yr and 1.5 PgC/yr. We can see also some fire-dependent differences: posterior net sinks derived with FIREMo and FIRE4 emissions decrease for 2017, however, the posterior net sinks derived with FIRE3 do not. This difference in 2017 is particularly observed with OCO-2. IS, on the contrary, give strong sinks in this region, the strongest one for all Tropical regions. Examining Fig. 6, we note the known prior dependency of the IS posterior emissions. Northern Tropical Africa is known to have very few IS data compared to the other Tropical regions (Fig. S1). Northern Tropical Asia (Fig. 8) shows agreements between OCO-2 and IS inversions, but shows significant differences in 2016. The sparse coverage of in-situ data over this region could explain the difference with OCO-2, but not specifically for 2016 alone, and hence further investigations are needed for this region.

It is also interesting to see the balance between the regions in Northern Hemisphere with Southern Hemisphere. For instance, it seems that the sink reduction for 2018 (starting in 2017) observed with both IS and OCO-2 over North Asia is balanced by net sinks in tropical Asia (North and South). The deeper sinks observed with OCO-2 in Europe are also anti-correlated with the net sources observed in Northern Tropical Africa (Fig. 8). Reuter et al. (2014) found, using GOSAT data, a similar mass balance between Europe and Northern Africa with an uptake of around 1 PgC/yr in Europe which was 0.5 PgC/yr higher than expected from in situ inversions. However, as mentioned in Reuter et al. (2017), there is a lack of carbon budget information over Europe and there is hence no reliable benchmark for comparison. The balance observed here between IS and OCO-2 inversions was also observed in the study of Peiro et al. (2022). However, for Europe, we can see that the variability in our inversions is different than the ones used in Peiro et al. (2022). A major difference between this study and Peiro et al. (2022) is that the rebalanced priors and posterior fluxes provide the largest sink in 2017, as opposed to 2016 (see Fig. 6 and 8). This is likely a consequence of the larger fires and the subsequent rebalanced respiration that was derived in our study.

For all data constraints, we can observe a smaller sinks in the tropics during El Nino, while larger net sinks are observed in the NH Ext. In opposition to the other Southern Tropical regions, the ENSO signal appears for Southern Tropical South America in 2016 instead of 2015 with OCO-2 inversions. This region follows the inter-seasonal variations of the Northern Tropical regions, which also see highest emissions in 2016. Moreover, larger sinks are observed with OCO-2 in north America and Europe, while larger sinks are observed with IS in Asia.

Finally, the net fluxes using FIREMo look like those using FIRE4 for the southern tropical regions, while net fluxes using FIRE3 look alike, suggesting the sensitivity in these regions to the fire prior, not only for IS but also for OCO-2 data constraint. Across the different fire emissions we observe a split: ISMOre and IS4re inversions provide similar results (both based on either optimized GFED4.1s and default GFED4.1s emissions), while the same is true for IS3re and ISCMS inversions (both based on GFED3 emissions). Same is true for OCO-2 inversions as well where OCOMOre and OCO4re have similar results while OCO3re and OCOCMS are similar. That means fires have a larger impact on the posterior solution than the rebalancing of prior NEE to match the global AGR. We can observe that for almost all regions, the sinks with NEE4re and NEEMore are deeper than with NEE3re and Geos-Carb CMS but are balanced with larger sources in other regions, mainly over the Tropics (Fig. 7).

For Southern Tropical Asia, a smaller sink was derived with OCOMOre and OCO4re than with OCO3re and OCOCMS, to balance the smaller fires derived with FIREMo and FIRE4. This is not observed however for the IS inversions which just show NEE sources for both ISMOre and IS4re. The impact of the fires over this region seems to have a strong impact with both data constraint. If we compare the posteriors with the priors, we can in fact see that the IS tends to be closer to the priors than the OCO-2 inversions. This suggest that for this region as well, the few amount of IS data might explain this result and the larger amount of OCO-2 seems to better constrain the posterior fluxes.

For Southern Tropical Africa, OCO-2 inversions derived with FIREMo and FIRE4 emissions (OCOMOre and OCO4re) have larger sources than inversions derived with FIRE3 (OCOCMS and OCO3re). With the IS inversions, there is large variation across the inversions where IS4re and ISMOre both constrain a source of carbon for the whole period, while ISCMS and IS3re have smaller source of carbon and even a sink in 2016 and 2017. These differences between inversions derived with FIREMo or FIRE4 and FIRE3 seem to suggest that fires (and so NEE re-balanced with fires) are especially important when observational coverage is limited. ”

- Line 549: “shows a latitudinal gradients ” => “show latitudinal gradients ” Done
- Line 550: “northern hemisphere ” => “Northern Hemisphere ” check this throughout the manuscript Done
- Line 550: “High land values ” => “High concentrations over land” Done
- Line 551: “north tropical south America ” => “North Tropical South America ” Done

- Line 554: “the OCO-2 retrievals (IS data) ” => “the OCO-2 retrievals and IS data ”

We changed with “with either the OCO-2 retrievals or IS data”.

- Line 559: “This result suggests that the inversion does not change much from the prior, but this result can be explain due to the small number of observations available in these regions. ” Please rewrite this.

We rewrote this: “For the IS inversions, the differences between priors and posteriors with the IS data are very similar, suggesting that the inversion does not change much from the prior. The small number of observations available in these regions could explain this result.”.

- Line 561: “For the comparison among the simulations, there is no large difference between the different simulations and the data, particularly for the optimized CO2 measurements. ”
  suggestion:
  “Among the different simulations, in particular, the posterior concentrations vary little in comparison to OCO-2 and IS data.” Done

- Line 586: remove “matches” Done

- Line 587: “priorMO bias are slightly lower or smaller than prior4 ” => “priorMO biases are slightly smaller than prior4” Done

- Line 590: “reduced through the inversion ” => “reduced by the inversion ” Done

- Line 593: “ISMOre can be better at some tropical sites than the other simulation ” => “ISMOre provides a better match at some tropical sites than the other simulations” Done

- Line 595: “all standard deviation ” => “all standard deviations ” Done

- Line 597: “across the priors” => “across the inversions” Done

- Line 609: “with each fire prior” => “with each fire emission estimate” Done

- Line 612: “the recovery period which followed it ” => “the recovery period that followed ” Done

- Line 613-616: Sentence is too long and difficult to understand. Rephrase please.

We change the sentence “*Globally, and for most regions, we find that the dependence of the inversion results on prior emissions is of secondary importance when compared with the data constraint, in the sense that variations in posterior flux are much smaller across different prior mean fluxes (and the different uncertainties that come from scaling the prior mean flux) as compared with differences resulting from assimilating OCO-2 versus in situ data.*” by “Globally and for most regions, we find that the inversion results have a greater dependence on data constraint than on prior emissions. The variations in posterior flux are much smaller across different prior fluxes (and the different uncertainties that come from scaling the prior flux) as compared with differences resulting from assimilating OCO-2 versus in situ data.”.

- Line 623: “on a short time basis ” => “short-term” Done

- Line 626: “over peat fires ” => “of peat fires” Done

- Line 636: “have been found higher than with GFED4 ” => “have been found higher in GFED3 than with GFED4.1s” Done

- Line 638: ‘FIREMo emissions are stronger than with FIRE4 emissions but lower than FIRE3 emissions “ => “net emissions derived with FIREMo are stronger than net emissions derived with FIRE4 but lower than net emissions derived with FIRE3 ”

This sentence correctly refers to fire emissions and not net emissions. We did not change line 638 consequently.

- Line 642: “IS4re and ISMOre have higher net sources of carbons ” = > “IS4re and ISMOre provide higher net carbon sources” Done

- Line 649: “and IS observations But” place period at end of sentence. Done

- Line 652: “the full dynamics” = >”the full dynamic” Done

- Line 653: “changing the combustion efficiency and then the gases emitted ” => “changing the combustion efficiency and the ratio CO and CO2 are emitted ”

We changed the sentence by “changing the combustion efficiency (Zheng et al., 2018b) and hence the CO/CO_2 emission ratio.”.

- Line 655: “Further works is ” => “More work is ” Done

- Line 656: “A recent study has shown the underestimation for Africa of MODIS burned area and consequently GFED4s, compared to the new Sentinel-2 burned area product (Ramo et al., 2021). ” =>
  “A recent study has shown that MODIS product most likely underestimate burned area for Africa (Ramo et al., 2021)” Done

- Line 658: “observed with previous studies ” => “The higher fire emissions estimated in previous studies ” Done

- Line 659: “seems to suggest for future work to carefully choose the CO fire prior used in a CO-CO2 study ” Please rephrase

We changed the sentence “*The higher fire posterior emissions observed with previous studies using GFAS as a prior compared to GFED4 (Nechita-banda et al., 2018) and the results of Ramo et al. (2021) seems to suggest for future work to carefully choose the CO fire prior used in a CO-CO2 study.* ” by “The higher fire posterior emissions observed with previous studies using GFAS as a prior compared to GFED4 (Nechita-banda et al., 2018) and the results of Ramo et al. (2021) seems to suggest for future work to carefully choose the CO fire prior for the inversions.”.

- Line 702: “even if with a difference ” Please rephrase.

We decided to remove this part as it does not bring additional information. We changed the sentence “*We found that OCO-2 and in situ net fluxes have, even if with a difference, a better agreement at global scale as observations are dense enough to constrain the fluxes than at latitudinal and regional scale.*” to “We found that OCO-2 and in situ net fluxes have a better agreement at global scale as observations are dense enough to constrain the fluxes than at latitudinal and regional scale.”.

- Line 705: “Discrepancies between in situ and OCO-2 inversions occurred over Northern Tropical Africa where OCO-2 inversions have shown net sources while in situ inversions have shown sinks ”
  => “Discrepancies occurred over Northern Tropical Africa where OCO-2 inversions derived net sources while in situ inversions derived sinks ” Done

- Line 706: “However, over Southern Tropical regions, discrepancies appear between the different set of priors, with higher net sources observed with the inversion using the CO/CO2 emission ratio (MOre inversion) for OCO-2 inversion over Southern Tropical South America and with IS inversion over Southern Tropical Asia, compared to the IS inversions using GFED3 fires. ”
  => “However, over Southern Tropical regions, discrepancies appear between the different priors, with larger net sources derived with the OCO-2 inversion using the optimized fire emissions (MOre) over Southern Tropical South America and with IS inversion over Southern Tropical Asia.” Done

- Line 709: “the constrain of priors seems” => “the priors seem” Done

- Line 710: “seems to be better representative of the” => ““seems to be better represent the”

We changed with “seems to better represent the”.

- Lines 715-718. This section needs to be rephrased.

The following section “*However, biases for the posterior simulated mixing ratio are in the same order. Evaluation mainly showed that biases have been decreased and variability matches better those of TCCON for the re-balanced posterior simulated mixing ratio suggesting the importance of the accuracy in fire priors and the re-balanced of terrestrial emission with fires for* CO_2 *posteriors emissions. The added value of fire emission for NEE optimization is not apparent. Our results seem hence to be very insensitive to optimized fire emissions.*” has been changed to “Evaluation against TCCON shows smaller biases for all the re-balanced posterior simulated mixing ratios in comparison to the CMS posterior simulated mixing ratio. Additionally, variability of all the re-balanced mixing ratio better matches those of TCCON. This suggests the importance of the accuracy in fire priors and the re-balanced of terrestrial emission with fires, for the estimation of CO_2 posteriors emissions. However, the added value of CO fire emissions for NEE optimization is not significant in term of biases reduction on average.”.

- Line 719: “We illustrated the potential of using CO/CO2 emission ratio, and the re-balanced respiration and NEE with fire and growth rate, in CO2 inversion for better constraint and accuracy in the CO2 fire prior emissions and biospheric emission estimates. ” This sentence needs to be rephrased.

We rephrased this sentence as followed: “We illustrated the potential of using CO/CO_2 emission ratio, and the re-balanced respiration with fire, in order to match the atmospheric growth rate, in CO_2 inversions. This was performed for better constraint and accuracy in the CO_2 fire prior emissions and biospheric emission estimates.”.

- Line 725: “from the future ” => “from the upcoming” Done

- Line 742: Use PgC/yr, as you used throughout the paper. Done

- Supplement document: Fig. S5 is missing. Please renumber the Figs from S1 to S9 Done

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Reviewer #2

I thank the authors for largely addressing my comments. I recommend that the manuscript be accepted for publication after addressing a few remaining, generally minor, comments.

We thanks the reviewer for the constructive comments. The feedback has helped us improve the paper. We addressed all comments below. The reviewer comments are in grey, our responses in black, sentences from the manuscript are *italic*, and sentences in the revised manuscript are in blue.

1. I am still confused about what prior uncertainties were applied to NEE for the inversion. Were they a fraction of the mean NEE estimate? Or were they specified to be the same value in flux units (e.g., gC/m^2/s) for each inversion? And what exactly were these values? I could not find this information in the manuscript, and it is important for concluding why the inversions returned different regional posterior mean NBE estimates.

The inversions returned different regional posterior net estimates because for each simulation, we used different prior NEE and FIRE emissions. As a reminder, the NEE for each re-balanced simulation is calculated from re-balancing the respiration with fires and then we match this to the atmospheric NOAA growth rate. Since we are using different fire estimates, we are obtaining different respiration and so prior NEE emissions. Additionally, we are looking at NEE estimation in our study and not NBE.

Regarding the uncertainty, we already have mentioned in the manuscript "*Ocean fluxes are taken from Takahashi et al. (2009). They are assumed to have an uncertainty variance of 50%. Both biospheric and oceanic emissions are optimized in the CO2 inversions. The uncertainties in the prior fluxes are derived from different climatological fluxes with exponential spatio-temporal correlation assumed. For the oceanic component, the horizontal correlation is 1000 km and the timescales is 3 weeks, while for the terrestrial component, length and timescale are 250km and 1 week. These uncertainties are applied similarly to all experiments.*".

2. I still find the manuscript a bit hard to follow in places. I recommend using the terms "BB CO", "BB CO2", "NEE", and "NBE" thoughout the manuscript so the quantities being discussed are explicitly clear. Then removing terms like "flux" that could refer to many different quantities.

We want to remind the reviewer that the difference between NBE and NEE has been already mentioned in our introduction. NBE being the non-fossil land fluxes while NEE being assumed to be the residual between the posterior total net land flux and the assumed fire and fossil fuel emissions. Through the rest of the manuscript, we only employed NEE as this is the estimation used in our study. The acronym BB (for biomass burning) not being used in our manuscript, we preferred not to use it, and we kept the annotations CO fire and CO_2 fire emissions. However, as mentioned by reviewer #1, we make sure the labels FIREMO or FIRE4 were correctly used to define CO_2 fire emissions and not net fluxes, which was not correctly wrote for some sentences. We have already corrected this.

Specific comments (revised manuscript):

L16: "Tropical flux estimates" - Which flux? NEE or NBE? We changed it by "Tropical net flux estimates". As a remind, net fluxes are the sum of fire and NEE (Net Ecosystem Exchange) fluxes.

L20: "TCCON data shows lower biases" - biases against model CO or CO2? Since the rest of the sentence refers to the three re-balanced priors and the one using CASA-GFED3, this evaluation is referring to the CO_2 TCCON data. For clarity, we modified by "[…] CO_2 TCCON data shows lower biases [...]".

L22-23: "One major conclusion from this work is the strong constrain at global scale of the data assimilated compared to the fire prior used" - Unclear. Is this assimlated CO data or assimilated CO2 data? Constraint on what quantity, NBE?

For clarity, we modified by "A major result of this work, that we can observe at global scale, is the strong constraint and influence of the CO_2 assimilated data among the inversions, on the net fluxes.".

L23: "tropical regions suggest sensitivity to the fire prior" - Sensitivity of what to the fire prior? NBE or NEE?

For clarity, we modified by "But results in the tropical regions suggest net flux sensitivity to the fire prior for both the IS and OCO-2 inversions.".