Review of New Constraints on Biogenic Emissions using Satellite-Based Estimates of Carbon Monoxide Fluxes by Worden et al.

Anonymous Referee #2

The paper "New Constraints on Biogenic Emissions using Satellite-Based Estimates of Carbon Monoxide Fluxes" provides an improved estimation of the biogenic emission, comparing model simulation based on Bottom up inventories with a satellite based "Top Down" emission estimation for CO. The CO production from biogenic emissions (BIO), together with Biomas Burning (BB) and Fossil Fuel (FF) consumption is one of the three most important parts of the CO budget and Flux (F). The "Top down" estimate provides an estimate of the Total CO2 Flux (F) without the ability to distinguish the individual sources and sectors, but in this work the information of the total flux is used to improve the estimate of the biogenic emissions, just using the Bayes probabilities approach. The new approach is realized individually for each grid cells of 4°x5° and month. A systematic pattern and spatial distribution is obtained and compared to other measurements. 1) Biogenic emissions of the isoprene retrieved from the OMI instrument shows a very similar distribution. 2) The temporal pattern which shows a significant difference between apriori and posteriori biogenic CO flux for the north African Savanna is studied and compared to the surface temperature.

General comment:
The Work is well written, interesting and matches the scope of ACP, it should be published after minor correction and after including a bit more information about the methodology. At the moment the paper is quite compact with just one example (region), but the supplement provides more examples, which is adequate and a good idea.

We thank the reviewer for their effort and useful comments and questions. We think that addressing these concerns will improve the manuscript. Our responses are embedded below in blue italics with modified or new text.

1) The new of the paper is that it somehow combines a model study and therefore a detailed "Bottom up" estimation, which contain a detailed distribution of different sectors (BIO,BB,FF) together with a satellite based "Top Down" approach which, just report the total flux "F", latter is somehow a measurement, while the prior is the apriori information. Unfortunately the description is very short and the approach cannot be easily be reproduced. I imagine that the implementation of the Baysian approach ends up in a least square fitting equation and looking finally for the minimum of something like the following cost function will help to find the posterior solution: $1/\sigma^2$ (F(BIO,BB,FF)-A)ˆ2 + (([BIO,BB,FF]-xapr)ˆT (S_(BIO,BB,FF))ˆ(-1)([BIO,BB,FF]-xapr) with σ the uncertainty in the "Top down" approach A, F= the total Flux or Forward Modell F= CH4 related part + BIO+BB+FF. S_(BIO,BB,FF) might be the more or less diagonal covariance matrix which describe the uncertainty. If it is some how different, it would be nice

to get an more easily insight in the criteria which equation is used to determine the vector BIO,BB,FF.

We have expanded the discussion in section 3 to include explicit details of the probability distributions and cost function with added equations 3-5, and a priori uncertainties given in the new Table 1. We agree with the reviewer that these additions improve the reproducibility of this study.

Specific comments:

2) 3 Bayesian CO flux attribution approach I think, this a very crucial section for the work and unfortunately not very easy to understand. ðISI(BB,BIO,FF|A) âĽI ðIṠI(BB,BIO,FF) p(F|A)/p(F) Eq. 1.

   I understand that :
   ðISI(BB,BIO,FF|A)áĽIðÍṠI(BB,BIO,FF) p(A|BB,BIO,FF)/P(A) and p(F,A)=p(F|A)p(A)=p(A|F) p(F) and probable it is valid that P(A|F)=P(A|BB,BIO,FF) as P(F| BB,BIO,FF) =1.0. But here it would be helpful to get a bit more info, and define the relation between F and (BIO,BB,FF).

   Where I get a bit problems is with the statement p(F) = 50%, does this mean p(F)=0.5 As F is a continuous quantity p(F) might be a probability density function pdf and it should be something like p(F) dF = 0.5. Or more likely it should say p(F) is a Gaussian distribution with a priori Fapriori as most probable, mean value and sigma as stdv. p(F)= 1/sqrt(2 Pi sigma**2) exp(- ((F-Fapriori)/sigma)**2) and sigma=0.5*Fapriori
   Or is the pdf a more general pdf, which is produced by the (MCMC) algorithm. If latter is the case, it would be nice to get somehow the formula of the a posteriori estimation, finally it should just be an weighted mean between the three a priori informations BIO,BB,FF aprioris and their a priori Stdev and the Top down estimation of their sum. Similar might apply for other uncertainties and pdf as p(F|A). I would assume that it is assumed to be Gaussian and the standard deviation is calculated from the ensemble of three “top down” inversion estimates, but up to now this is not described clearly. Same the different between F and A, is not be explained. Please include the equations how F is calculated as function of BIO,BB,FF and 877 Tg/yr, at least in the supplement.

   The explicit probability distributions and cost function are now added as equations 3-5. Since these apply to each model grid cell, the global 877 Tg/yr of CO from CH4 destruction is not estimated in the MCMC approach. This is a global constraint determined by Jiang et al., (2017).

3) 4 Uncertainty prediction and limitations
   The use of a measured total flux and redistribute the fluxes of the different sectors, might produce a very strong dependence between the errors in BIO,BB,FF. Is there a way to characterize this ? How could the estimate improve, if you could reduce the uncertainty in FF to 0.0.

We have added a new Table 1 in response to Ref. #1 that shows how aposteriori uncertainties are reduced compared to the prior assumptions. While there will be a dependence on the relative errors in BIO, BB, FF in general, for the tropical regions studied here, the FF emissions are small enough (Figure 2) that even reducing the prior uncertainty to 0.0 would not make a significant difference in the BIO term. Sensitivity to the choice of prior uncertainty will be the subject of future work.

4) One of the main results is the very nice correlation between Surface Temperature and BIO-Emission: The CO flux "Top Down" estimation is based on the joint near and also mid infrared MOPIIT retrieval product. The result and sensitivity of mid infrared nadir sensors might depend on the surface temperature. Therefore it would be nice to discuss shortly if such errors could be relevant.

Sensitivity in mid-infrared nadir sensor retrievals depends on thermal contrast between the surface and atmosphere. In the case of vegetated tropical biomes, thermal contrast near the surface is usually close to zero, regardless of surface temperature, due to humidity. For the MOPITT joint thermal and near-IR product, sensitivity to near surface CO in these regions is mostly driven by NIR surface albedo (Worden et al., 2010). Furthermore, variations in the sensitivity of the MOPITT retrievals are characterized by the averaging kernels which were included when the data were assimilated for the original flux estimates in Jiang et al.(2017). Therefore, we don't expect the dependence of MOPITT vertical sensitivity on surface temperature to be relevant to the re-partitioned flux estimates. However, since MOPITT retrievals require cloud free observations, there could be inflated errors in the flux estimates due to fewer MOPITT samples during the rainy season, which corresponds to lower surface temperatures. This effect would need to be included in a future study with more comprehensive flux errors. The new Table 1 in section 4 (in response to referee #1) now includes the variance of tropical grid cell posterior flux errors, and we will add a footnote into the new Table 1:

> "The variance in tropical grid cell flux errors includes both spatial and temporal variability, however, these errors have not been weighted to account for sampling effects, such as inflated errors due to fewer MOPITT observations during rainy seasons".

5) 6 Global budgets of CO and C5H8 from biogenic emissions
Maybe it would be nice to see an correlation plot between OMI based C5H8 and a) the apriori and b) a posteriori estimated biogenic CO flux.

We looked at spatial and temporal correlations of isoprene with apriori (isoprene and CO) and aposteriori CO and could not find conclusive results. This is likely due to the high correlation for low-emission grid cells. Overall, MEGAN is usually too high for both C5H8 and CO, which is what we are trying to convey in the table.

6) 7 Seasonality of biogenic emissions – case study for the North African Savannas

As mentioned earlier, just for the completeness it would be nice just to discuss if the Surface Temperature or other surface properties which might have an impact on the CO MOPIIT retrieval.

Please see above response to comment #4. We think the revisions to section 4 now give a more comprehensive description of uncertainties that would not benefit from further discussion in section 7.

7) Table1: Maybe could you include "F" or "A" in this table. Suggestion: the "MEGAN" emission estimate is the apriori and might be included in the same box just in brackets together with the apriori uncertainty.

Thank you for this suggestion. This simplified the table and also allowed us to include more information, i.e., the apriori values for the BB and FF sectors. We also found that the posterior uncertainties in the tropical sub-regions needed to be corrected by sqrt(8) to account for the 8-year average. This was already reported correctly in the other regions.

REFERENCES:

Worden, H. M., M. N. Deeter, D. P. Edwards, J. C. Gille, J. R. Drummond, and P. Nédélec (2010), Observations of near-surface carbon monoxide from space using MOPITT multispectral retrievals, *Journal of Geophysical Research (Atmospheres)*, *115*(d14), 18314, doi:10.1029/2010JD014242.