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Title: Sensitivity of biomass burning emissions estimates to land surface information

Authors' response to anonymous referee #1

We truly appreciate all the constructive comments and suggestions from the reviewer. The comments are very helpful to improve our manuscript, and we will adopt all the suggestions in our revised manuscript.

The authors calculate four sets of global biomass burning (BB) emission estimates with bottomup approach, through combining two different aboveground biomass (AGB) with two different land cover classification (LCC) datasets. Modeled atmospheric CO concentrations from four simulations that use these four sets of BB emission estimates are then compared with observations. This study is a useful reference for the large uncertainties introduced to BB emission estimates (and hence model simulations) from AGB and LCC. The following comments need to be addressed.

1. I found the abstract a little hard to understand without reading through the main text. Please consider revising it.

- For example, "We estimated four types of global BB emissions" is misleading and I suggest change it to "We developed four sets of global biomass burning emission estimates".

We appreciate the suggestion; we corrected the text.

- "We found a substantial spatial difference in CO emissions for both the AGB and LCC data ..." This sentence can be changed to "We found a substantial spatial difference in CO emissions result from the use of the AGB and/or LCC data".

We appreciate the suggestion; we corrected the text.

- "At ground-based observation sites during fire seasons, statistical comparisons indicated that the impact of differences in the BB emissions estimates on atmospheric CO variability was poorly defined in our simulations." This sentence is very hard to understand without reading through the main text.

We appreciate the comment; we will revise the manuscript.

- Consider adding some numbers in the abstract. For example "The mean annual BB emissions with their standard deviation are 526 ± 53 , 219 ± 35 ,

624±57, and 293 μm^4 Tg CO yr¹, for GlcGlob, GlcGeoc, McdGlob, and McdGeoc, respectively."

We agree with the suggestion and will revise the abstract to describe the differences in emissions estimate using some numbers.

2. In the introduction, please acknowledge previous studies that attempted to address or quantify the uncertainties in BB emission estimates caused by land surface information (including but not limited to AGB, LCC, burned area etc) if there's any.

We agree with this point and will write acknowledgement to previous studies in the introduction.

3. Line 81: "If a 1-km resolution grid point showed a fire flag on a particular day, then the 4 surrounding sub-grids with a 500 m resolution, located within the original MOD14A1 grid, were assumed to have burned; that is, $BA_{i,k} = 250,000 \text{ m}^2$." I'm a little confused here. Shouldn't it be $BA_{i,k} = (500+500) \times (500+500) \text{ m}^2 = 1\text{e}6 \text{ m}^2$?

MOD14A1 provides fire mask data at a 1-km resolution, while our study estimates biomass burning emissions with a spatial resolution of 500 m. We regridded the MOD14A1 data to a 500-m resolution without interpolation, then the regridded fire mask data were used as $BA_{i,k}$. We approve that the sentence in Line 81 confuses the readers and will revise it.

4. Section 2.3: I'm wondering why the authors only pick three sites. And what are the reason(s) for choosing these three specific sites?

The MNM site is located in an isolated island and we think that the site is an appropriate location for representing background variations of atmospheric CO concentrations. We investigated all available observation sites on the WDCGG website, then the BKT and ETL sites were chosen as representative observation sites clearly showing the influence of fire events in the variability of atmospheric CO concentrations. We will clarify this point in the revised manuscript.

5. Line 125: Need more information on the description of MOPITT. For example, which MOPITT version are you using. And "mean XCO distribution products (L3V95.6.3; Deeter et al., 2014) retrieved from both thermal infrared and near infrared observations", do you mean you used both TIR and NIR products separately, or used the joint product (JIR)? The model results need to be smoothed with MOPITT averaging kernel and prior profile before comparing to MOPITT, if you have done so please state it here for clarification.

We really appreciate this important comment. In this study, multispectral TIR/NIR retrievals were used, but MOPITT averaging kernels were not taken into account for model simulations by assuming that the total

column averaging kernels of MOPITT are near unity over the altitude. However, as mentioned by the reviewer, MOPITT user's guide shows sensitivity of the averaging kernels to the altitude, so that we will reconfigure the model simulation to include the MOPITT averaging kernels and the prior information.

6. Results: Please consider separate the results section to two sub-sections "comparisons of emission estimates" and "comparisons of model results".

We agree with the reviewer on separating the results section to two sub-sections.

7. Line 145: Figure 1 is for the year of 2009. While this info is included in the figure caption, it needs to be also included here in the main text.

We agree with the reviewer and will add an explanation on Fig. 1 in the revised manuscript.

8. Adding figures of global maps for the four datasets you use would be more intuitive for readers (2 LCC and 2 AGB).

We agree with this suggestion and will add the figures.

9. Figure 2: This figure provides mean and standard deviation of the four BB emissions estimates. While this is useful, please also provide maps for the 4 estimates so that it's more intuitive and straightforward.

Thanks for this suggestion; we will show maps for the 4 emissions estimates in the revised manuscript.

10. The authors compared their global total CO emission estimates with that from Andreae (2019), which is very useful. It would be nice if the authors can also provide comparisons of regional total CO emission estimates to other emission inventories. The main goal of this paper is to demonstrate the large differences in the emission estimates caused by AGB and LCC. For this purpose, Figures 2 & 3 are not enough. It would be helpful to show more detailed comparisons of the four estimates. For example, results for more regions such as those in which the three ground sites locate, or the six regions highlighted in Figure 6, or the 14 GFED regions.

We agree with that it is necessary to compare our emissions estimates with other emissions inventories over regional scale for clarifying the differences between our estimates and other inventories. We will add new analyses regarding this point and revise Figs. 2 and 3 in accordance with the reviewer's suggestion.

11. Line 190: Change "we compared each BB estimate in the atmospheric CO field" to "we compared modeled CO fields using each BB emission estimate."

We appreciate the suggestion; we corrected the text.

12. Section 3: If I understand correctly, the four emission estimates are monthly. Comparing model results driven by monthly fire emissions to daily observations is not informative as fire events are episodic. Model will not capture fire-induced daily variability from observational data. As shown in Figure 5, the model-observation agreement is poor. The author also noted this issue in the Discussion section. I suggest either (1) downscale the emission estimates to daily resolution with active fire detection satellite products and re-run the model, or (2) average the daily observations to monthly before doing the comparisons.

As suggested by the reviewer, the atmospheric tracer transport model NICAM-TM was operated with a time resolution of 20 minutes, whereas input BB emission estimates have a monthly resolution. We admit that the monthly resolution of BB emissions estimates is insufficient to simulate daily variations of atmospheric CO concentrations at ground-based observation sites. Considering the amount of work, we would like to attempt (2) in the revision.

13. Line 221: Please change "Monthly mean XCO variations and the root mean square error (RMSE, ppb)" to "Monthly mean XCO and the root mean square error (RMSE, ppb)". It was confusing.

We appreciate the suggestion; we corrected the text.

14. Line 222: I'm wondering if there is a specific reason for choosing southeast North America instead of Pacific Northwest?

We chose simply the southeast North America as a higher BB emissions area, but it is certainly true that the Pacific Northwest has been affected by severe wildfires. We will analyze the Pacific Northwest and revise the manuscript.