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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Six Global Biomass Burning Emission Datasets: Inter-comparison and Application in one Global Aerosol Model" *by* Xiaohua Pan et al.

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Response to Referee #2

We really appreciate the constructive comments from Dr. Parrington. Following each comment/suggestion from Dr. Parrington <Referee>, we have provided our responses below <Response>.

<Referee> The manuscript presents a comparison of biomass burning emissions estimated using satellite observations of active fires including burnt area and fire radiative power. Evaluation of the different emissions datasets is performed by application in a

global aerosol model and comparing the relative changes in the organic matter aerosol fields over MODIS satellite and AERONET ground-based observations of aerosol optical depth (AOD). The authors acknowledge the limitations of the nature of a model-specific study like this but the inter-comparison is very thorough and provides valuable, and timely, insights into variability of estimating biomass burning emissions for application in models. The manuscript is well written and in the scope of Atmospheric Chemistry and Physics, and I recommend it for publication subject to the authors addressing the comments below.

<Response>Thank for your encouraging comment on the merit of this manuscript. We hope that this study will contribute toward advanced understanding of the differences between BB emission datasets, and will eventually facilitate the improvement of the estimation of BB aerosol emissions in models.

General comments:

<Referee> Discussion of uncertainties in emission factors – would the known underestimate of PM emission factors, especially for peat fires in South East Asia, impact on the model AOD? https://www.mdpi.com/2072-4292/10/4/495/htm or https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2017JD027827

<Response>Yes, it is true that the emission factors estimated from those two studies are far larger than those by Andreae and Merlet (2001) and Akagi (2011). With the higher PM emission factor and thus PM emission, AOD will be enhanced accordingly in the model. In equatorial Asia (EQAS), the experiments based on all six BB emission datasets underestimated AOD during September (the peak of the burn season) to the same degree ($\sim$50%) as the run without any biomass burning emission input, compared to MODIS-Aqua (See Figure 5 and Table S1 in the ACPD version), regardless of whether these BB aerosol emissions are based on the burned-area or FRP approach. This may be largely attributed to missing fire detection from satellite, for example, due to low signal from peat fires, which are predominantly smoldering. In addition, the EF

values for aerosols emitted from peat fires may be underestimated as well (Table 2 in Kiely et al., 2019). Several studies based on in-situ measurements of EF reported that the EFs of PM2.5 for peat fires provided by Andreae and Merlet (2001) and Akagi et al. (2011) as 9.05 and 9.10 g PM2.5 per kg dry matter (see Table 2), respectively, are much lower than their measurements. For example, the studies by Wooster et al. (2018), Stockwell et al. (2016), and Roulston et al. (2018) reported EF values of 21 $\pm$ 4.6, 17.8 to 22.3, and 24 g PM2.5 per kg dry matter, respectively, for peat fires in EQAS. Unfortunately, the underestimation of AOD is not shown in the revised version against the MISR AOD, because MISR observation is missing in this region during September 2008. We are asked by the referee #1 to use MISR AOD to evaluate model simulation in the revised version (Figure 5-7), considering QFED and FEER derived their BB emission datasets with historical MODIS AOD.

Specific comments/questions:

<Referee> Page 4, line 107: specify the multi-model study (is it "The AeroCom multi-model study"?).

<Response>Yes, we have clarified it in the revised version as "The AeroCom multi-model study".

<Referee> Page 9, lines 365-367: could it be the case that the two day persistence in FINN1.5 is more representative of peat fires which may be more prevalent in EQAS?

<Response>The two-day persistence approach used by FINN1.5 in the tropical regions may have been more representative of peat fires that are quite prevalent in EQAS. This may be because peat fires typically burn less vigorously and potentially last longer than other fire regimes. We pointed out this in the Section 4.1.2.

<Referee> Page 9, section 3.1.2: it may be useful to describe briefly why 2008 was chosen to investigate the seasonal variation. Does each emissions dataset capture inter-annual variability in the same way?

<Response>The reason we chose 2008 is because it is the year assigned as a benchmark year by AeroCom community with which this study is associated; it is also because the AeroCom Multi-model study of biomass burning lead by Petrenko (mentioned in the introduction part of our manuscript) also chose 2008 as a focus year. As such, the results from these two studies can be intercompared if needed and some synthesized conclusions drawn. In addition, 2008 was chosen because it is a neutral ENSO year, which represents normal burning conditions.

Figure_a shows the comparison of the interannual variation of OC biomass burning emissions in three biomass burning (BB) datasets during the period of 1997-2018 over the Amazon. The three BB emission datasets are FEER, GFED4s, and QFED, which are analyzed in our study. The interannual variability are pronounced across the three BB datasets although with different magnitudes. Apparently, 2007 is the highest burn year, 2009 is the least burn year, while 2008 is a normal burn year. Overall, QFED has the highest OC BB emission, FEER has the second highest, and GFED4s has the least ($\sim$1/3 of QFED) from year to year, which are consistent with our result for 2008. A similar result can be drawn from the region of Africa (Figure_b), where the interannual variability is less pronounced though. In summary, these BB datasets capture similar interannual variability although they have different magnitudes, with QFED having the highest OC BB emission, FEER the second highest, and GFED4s the least.

<Referee> Page 10, line 409: "with each BB emission dataset instead" is repeating the earlier part of the sentence.

<Response>We have changed this sentence to "Therefore, in this study we have implemented all six global BB emission datasets separately in the GEOS model, and evaluated their respective simulated aerosol loadings."

<Referee> Page 11, line 433: change "peaking" to "peak".

<Response>Changed.

<Referee> Page 11, section 3.2.1: it may be useful to a reader to give the names of each region as well as the acronym.

<Response>The full names of the regions have been added in the revised version, such as southern hemisphere South America (SHSA), and southern hemisphere Africa (SHAF).

<Referee> Page 12, section 3.2.2: it may be useful to give the country of the named AERONET sites, which is more intuitive to understanding the geography than giving just the regions.

<Response>The country names of the AERONET sites have been added in Figure 7 as below.

<Referee> Page 12, lines 487-488: “in each respective region”.

<Response>We changed to “in each region”.

<Referee> Page 12, line 488: change “At most other AERONET” to “At most of the other AERONET”.

<Response>Thank you. We have changed “most” to “most of the”.

<Referee> Page 13, line 534: “resembled with” should be “resembled”.

<Response>We have deleted “with”.

<Referee> Page 13, lines 537-538: “All of these evidences” should be “All of this evidence”.

<Response> We have changed to “All of this evidence”.

<Referee> Page 13, line 539: should “respond” be “correspond”.

<Response>The meanings of “respond” and “correspond” are very similar in some sense. Here we prefer to use “respond” to mean doing something in reply.

<Referee> Page 13, line 543 (and other locations): would using “active fire detections” rather than “fire hotspots” be a more scientific way of describing this?

<Response> Changed.

<Referee> Page 13, line 553: “over entire” should be “over the entire”.

<Response> Changed.

<Referee> Page 14, line 566: should “emitted from smoke aerosols” be “emitted as smoke aerosols”?

<Response> Changed to “the dominance of the fine-mode aerosol particles in smoke aerosols”.

<Referee> Page 14, line 567: change “These evidences” to “This”.

<Response> We changed to “This evidence”.

<Referee> Page 14, line 574: change “On broader: : :” to “Over broader: : :”?

<Response> Changed to “in regional emission”, which is relative to the local scale.

<Referee> Page 14, line 577: “largest month” should be “largest monthly”.

<Response>Changed.

<Referee> Page 15, line 624: should GFAS1.2 also be included as an FRP-based estimation?

<Response> Right, we have added GFAS1.2.

<Referee> Page 16, line 662: change “on inclusion” to “in including”.

<Response> Changed “on inclusion of” to “in including”.

<Referee> Page 16, line 675: change “exceeds” to “is greater”.

<Response> Changed.

<Referee> Page 16, line 677: change “emissions is 10%” to “emissions are 10%”.

<Response> Changed.

<Referee> Page 17, lines 713-715: please clarify this last sentence as it isn’t clear what is meant “by active fire product”. I thought that FINN1.5 and GFED4s are based on the burnt area product available from MODIS.

<Response> FINN1.5 actually uses active fire product to estimate the burned area by assuming each active fire pixel represents a burned area of 1 km2 for most biome types (see details in Sect. 2.1.3). GFED4s uses the official burned area product for large fires, but estimates burned area for small fires using active fire detections. We have rewritten the sentences in the revised version as:

“This issue also affects FINN1.5 (Wiedinmyer et al., 2011), which derives the burned area by assuming each active fire pixel to correspond to a burned area of 1 km2 for most biome types (see details in Sect. 2.1.3), and GFED4s, which uses burned area product for large fires but derives burned areas for small fires using the MODIS active fire product.”

<Referee> Page 17, line 721: “scares” should be “scars”.

<Response> Changed. Printer-friendly pper

<Referee> Page 18, line 758: a citation for other model assumptions may be helpful to the reader.

<Response> We have removed this vague expression, i.e., other model assumptions, from the revised version.

<Referee> Page 19, final paragraph: while the focus of the evaluation has been based on AOD observations from MODIS and AERONET, it would be useful if some comments could be made on the potential use of in situ, especially aircraft, observations could be used in this context – for example, measurements made during the WE-CAN

or FIREXAQ campaigns in recent years. Also some comment on potential improvements to fire emissions estimates based on FRP products from geostationary satellite observations, especially in combination with low Earth orbit observations such as MODIS (and VIIRS).

<Response> Thank you for your suggestions. We have added your suggestions in the last paragraph as

“The investigated global BB emission datasets driven by fire remote sensing and retrievals of FRP and burned-area products, which have hitherto depended heavily on MODIS, can be augmented with products from higher resolution sensors such as Visible Infrared Imaging Radiometer Suite (VIIRS), and the global suite of geostationary meteorological satellites such as Meteosat (covering Europe, Africa and the Indian Ocean), Geostationary Operational Environmental Satellite (GOES, covering North, Central, and South America) and Himawari (covering east Asia, southeast Asia, and Australia). Also, measurements from the recent field campaigns such as WE-CAN (https://www.eol.ucar.edu/field_projects/we-can) and FIREX-AQ (https://www.esrl.noaa.gov/csd/projects/firex-aq/science/motivation.html) are expected to contribute toward advancing our knowledge of biomass burning emissions in North America. The evaluation in this study has been solely based on remote sensing AOD data, including retrievals from both satellite and ground-based (AERONET) sensors. Continuous mass concentration measurements are needed to validate the fire-generated aerosol loading in specific contexts, such as in analyzing collocated surface and vertical aerosol concentrations and composition, at least in the major BB regions.”

<Referee> Page 30: specify “annual total organic carbon biomass burning emissions”? I also think that removing the sites from the maps could be useful as they aren’t that clear to discriminate from the colours on the map, and is a bit distracting from the values in the data.

<Response> We have specified “The spatial distribution of annual total organic carbon

biomass burning emissions" in the caption of Figure 2. The AERONET sites have been removed from Figure 2 as below.

<Referee> Page 35, line 1290-1291: clarify that the climatology of AERONET AOD is AERONETclim in the legend. <Response> We have added it in the caption of Figure 7, "The climatology of AERONET AOD (i.e., AERONET-clim)".

References: Kiely, L., Spracklen, D. V., Wiedinmyer, C., Conibear, L., Reddington, C. L., Archer-Nicholls, S., Lowe, D., Arnold, S. R., Knote, C., Khan, M. F., Latif, M. T., Kuwata, M., Budisulistiorini, S. H., and Syaufina, L.: New estimate of particulate emissions from Indonesian peat fires in 2015, Atmos. Chem. Phys., 19, 11105–11121, https://doi.org/10.5194/acp-19-11105-2019, 2019.

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Stockwell, C.E., Jayarathne, T., Cochrane, M.A., Ryan, K.C., Putra, E.I., Saharjo, B.H., Nurhayati, A.D., Albar, I., Blake, D.R., Simpson, I.J., et al.: Field measurements of trace gases and aerosols emitted by peat fires in Central Kalimantan, Indonesia during the 2015 El Niño. Atmos. Chem. Phys., 16, 11711–11732, 2016.

Wooster, M., Gaveau, D., Salim, M., Zhang, T., Xu, W., Green, D., Huijnen, V., Murdiyarso, D., Gunawan, D., Borchard, N., Schirrmann, M., Main, B. and Sepriando, A.:New Tropical Peatland Gas and Particulate Emissions Factors Indicate 2015 Indonesian Fires Released Far More Particulate Matter (but Less Methane) than Current Inventories Imply. Remote Sensing. 10 (4), p.495, https://doi.org/10.3390/rs10040495, 2018.

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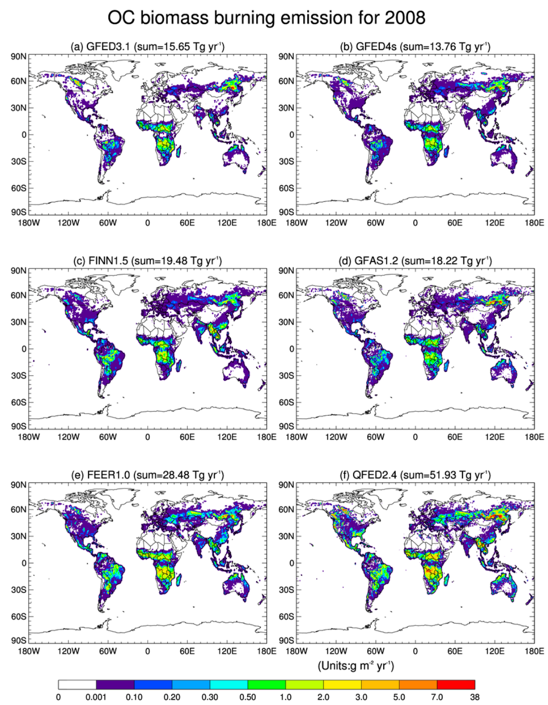

Fig. 1. Figure 2. The spatial distribution of annual total organic carbon biomass burning emissions for 2008 estimated by six biomass burning emission datasets (units: g m-2 yr-1).

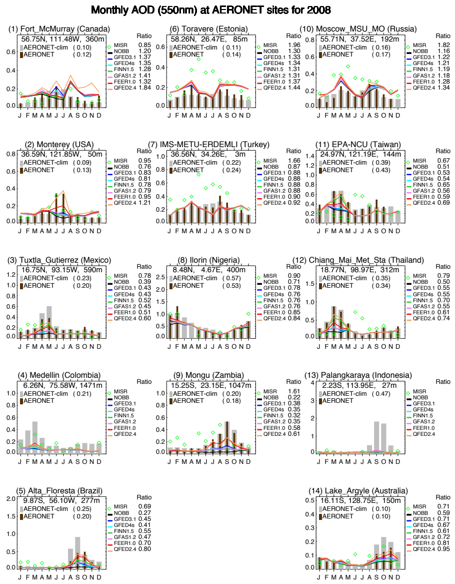

Fig. 2. Figure 7. Monthly variation of AOD (at 550nm wavelength) for 2008 over 14 AERONET sites selected from their respective regions (with its country indicated in parentheses).

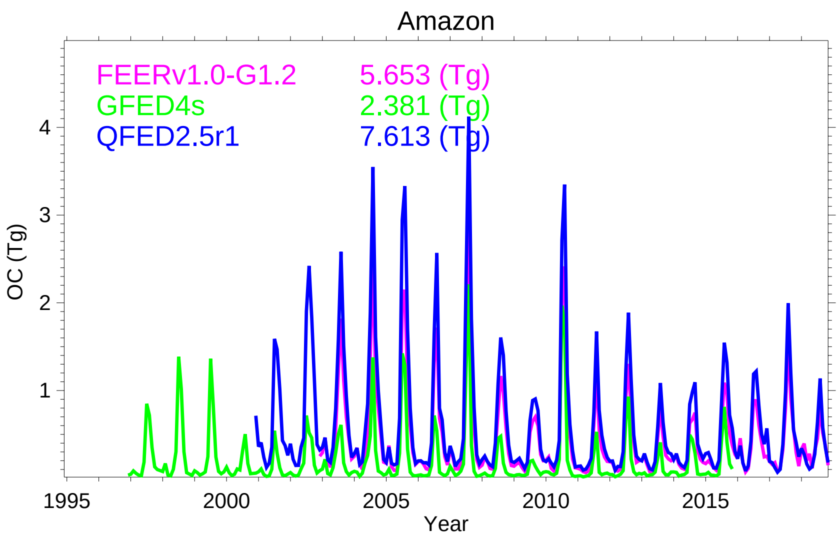

Fig. 3. Figure_a. The comparison of the interannual variation of OC biomass burning emissions in three biomass burning datasets during the period of 1997-2018 over Amazon (80W-30W, 60S-15N).

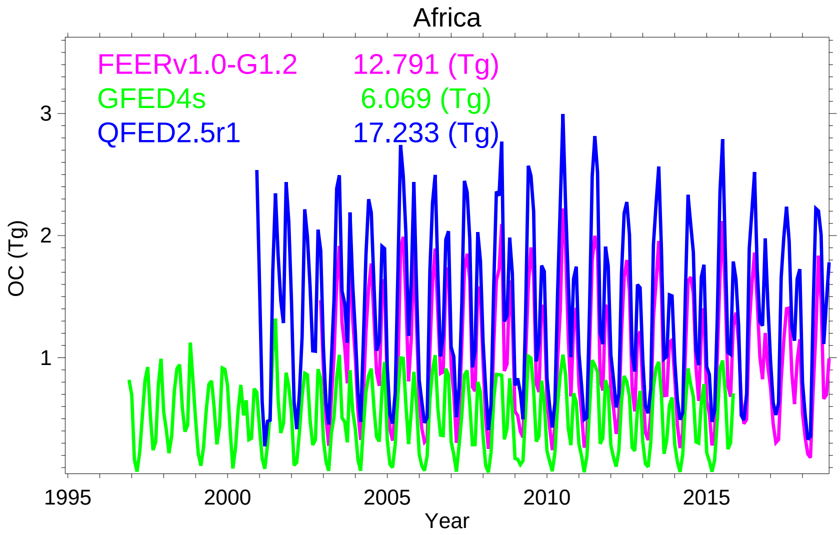

Fig. 4. Figure_b. The comparison of the interannual variation of OC biomass burning emissions in three biomass burning datasets during the period of 1997-2018 over Africa (24W-50E, 40S-20N).