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Interactive comment

Interactive comment on "How emissions uncertainty influences the distribution and radiative impacts of smoke from fires in North America" *by* Therese S. Carter et al.

Anonymous Referee #3

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The study by Carter et al. uses a chemical transport model to compare four widely used fire emission inventories and assess the diversity in emitted and simulated quantities of biomass burning aerosol (BBA). To examine the performance of the model driven by the different fire emission inventories, model simulations are evaluated against in-situ and remote sensing observations. Implications of the diversity in fire emission estimates on air quality and aerosol radiative effects are also quantified and discussed. The paper is well written and structured, and the figures are well presented and clear. The concept of the study is certainly within the scope of ACP and I believe it will be very useful to both developers and users of these fire emissions datasets. I have a few minor general and specific comments (listed below) and I strongly recommend publication in ACP

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Discussion paper

once they have been addressed.

General comment

This study does a good job of exploring some uncertainties associated with quantifying fire emissions and the diversity between the different fire emissions datasets; and the subsequent impacts of these on simulated BBA. However, I would argue that without a full sensitivity analysis the study cannot fully quantify the magnitude and causes of uncertainty in simulated BBA. In reality, the sensitivity of simulated BBA to uncertainties in fire emissions is likely to be much larger than estimated in the paper because (as acknowledged by the authors e.g. in Section 3 paragraph 3) additional factors that are not considered may increase the estimated uncertainty range in fire emissions of BBA and secondly, because the sensitivity of simulated BBA to uncertain parameters is assessed one-at-a-time and interactions are not considered. There is some discussion in the paper in relation to the former e.g. L115-116 and L370, however it could be made clearer that the quantified "uncertainty" range is really the diversity range between emission datasets and that the full uncertainty range in fire emissions is yet to be quantified.

Specific comments

1. Abstract (P1, L20): "We aim to quantify the uncertainties associated with fire emissions…" related to the general comment above, I would say the study aims to explore the uncertainties rather than quantify them.

2. Abstract (P2, L37-39): "…sizeable range in BBA population-weighted exposure…" Could you state the time period you quantify the population-weighted exposure for (year and averaging period) and stress that it's exposure to BBA PM2.5.

3. Introduction (P2, L48-49): "Because of their small size…" Here it would be better to identify that it's aerosol in the size fraction below 2.5 μm that can penetrate deep into the lungs.

4. Introduction (paragraph 1): can you include some more references from the epidemiological literature for specific health impacts of BBA?

5. Introduction (P2-3, L56-68): Nice summary of papers on in-plume SOA production. Could be worth adding that several studies (some already cited) have suggested that the limited net changes in SOA mass could be explained by a balance between SOA formation and dilution and evaporation of POA mass (e.g. Jolleys et al., 2015; May et al., 2015; Zhou et al., 2017; Morgan et al., 2019. . . etc.).

6. Introduction (P3, L79-80): "The uncertainty in fire radiative impacts has not been assessed." This sentence could be written in a clearer way as there has been some previous assessments of the influence of biomass burning emission uncertainty on aerosol radiative forcing (e.g. Carslaw et al., 2016; Hamilton et al., 2018. . .). Perhaps just add "in detail" to the end of the sentence or something similar to: "The uncertainty in fire radiative impacts due to uncertainty in fire emissions has not been assessed in detail."

7. Section 2.1 (P6, L168-169): Can you specify whether fire emissions are averaged evenly across the PBL or if there is a gradient applied? What is the typical (or peak) model height of the daytime PBL over North America? What is the average model (vertical) resolution in the PBL over North America?

8. Sections 2.3 & 2.4 (general): Really nice descriptions of the observations and their uncertainties. However, these uncertainties are not referred to or taken into account in the results section (when the model is evaluated against these observations). I'm guessing that this is because the variability in observations and the model structural and emission uncertainties likely far outweigh measurement uncertainties, but this should be mentioned.

9. Section 3 (P10, L312): "variable in this inventory (i.e., more variability from 2004-2016 as evidenced by the taller boxplots)". I'm not sure the term "taller boxplots" is clear here. Do you refer to the larger range between 25th and 75th percentiles for

QFED? Can you give the range?

10. Section 3 (P10, L314-315): Are you referring to the global mean total annual emissions here?

11. Section 3 (paragraph 2): Can you add a line or two about any differences/similarities in the spatial pattern of emissions between the datasets (just for CONUS)?

12. Section 4 (general): Can you give some numbers to quantify the model skill in the text so that the different simulations can be quantitatively compared? Perhaps give temporal correlation values and/or model bias where appropriate.

13. Section 6 (general): To calculate fire PM2.5 are the BC and OC mass fractions summed for aerosol smaller or equal to 2.5 ïĄ■m? Is there any contribution to PM2.5 from "primary" sulphate?

14. Section 6 (general): Do you see a range in exposure due to the differences in spatial patterns of the fire emissions? Are there any years that stick out?

15. Figure 8: It is very difficult to distinguish the colours of the overlapping circles (the black outlines obscure the colour inside the circle), particularly in the west. I suggest either showing an average in crowded regions or perhaps overlay the circles instead and just show the top colours.

16. Figure 11: It is difficult to assess the magnitude of the difference between the model and observations in this figure. I suggest including a figure showing some quantification of the difference e.g. showing the spatial distribution of the absolute difference or model bias? This figure could be put in the supplementary material.

References included in the review above:

Carslaw, K. S. et al. Large contribution of natural aerosols to uncertainty in indirect forcing. Nature 503, 67–71, 2013.

Hamilton, D.S., Hantson, S., Scott, C.E. et al. Reassessment of pre-industrial fire emissions strongly affects anthropogenic aerosol forcing. Nat Commun 9, 3182, doi:10.1038/s41467-018-05592-9, 2018.

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