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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Interannual Variability and Trends of Combustion Aerosol and Dust in Major Continental Outflows Revealed by MODIS Retrievals and CAM5 Simulations During 2003–2017" *by* Hongbin Yu et al.

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Referee #2 General comments: In the paper, "Interannual Variability and Trends of Combustion Aerosol and Dust in Major Continental Outflows Revealed by MODIS Retrievals and CAM5 Simulations During 2003-2017", the authors analyze both satellite-based and model-based datasets of various aerosol types in continental outflow regions over a fifteen-year period. A great deal of research has been completed and the narrative is generally well-written. I find no significant issues with this study; however, I believe it can be improved in a few areas. Several technical errors were found, and

while I outline many of them in my review, the paper should be given a thorough round of proofreading edits. Overall, I recommend a minor revision for this manuscript. The authors should address the specific comments and technical corrections discussed below.

We appreciate the reviewer's detailed comments and suggested technical corrections. Below is our point to point response to the comments. The paper will be revised accordingly. Co-author LAR has offered to proofread the paper thoroughly once all comments are addressed.

Specific comments: 1. Page 4, Line 12: Are you using the most recent MODIS data available (i.e., Collection 6.1)?

In this study we used Collection 6, not Collection 6.1. But our major findings will not change if Collection 6.1 is used. Major updates from Collection 6 to 6.1 include (a) the improved calibration (affecting MODIS/Terra more than MODIS/Aqua), (b) updated aerosol models over land, and (c) land/ocean masks. We tested C6 and C6.1 difference by comparing over ocean AOD and FMF from first 15 days of each month in a year. Statistical analysis of C6 versus C6.1 for MODIS/Aqua yields a mean bias of -0.001, RMSE of 0.006, and linear regression of C6 = 0.995 x C6.1 -0.001for AOD. Correspondingly, MODIS/Aqua FMF has a mean bias of 0.005, RMSE of 0.043, and linear regression of C6 = 1.002 x C6.1 + 0.001. Because of the improvement (a), the spurious trend in the MODIS/Terra could have been reduced to some extent in C6.1, but not been removed totally. In this paper we have been using MODIS/Aqua to study the trend and interannual variability. As we emphasize in this and previous studies, it is more important to use data in a self-consistent manner (e.g., characteristic fine-mode fractions for individual components need to be derived from the same data collection). Once the MODIS data are used self consistently, the derived aerosol components agree among different data collections (Yu et al., 2009).

2. Page 5, Line 155: Why is SOA not included in the tagging?

We excluded SOA tagging in the simulation due to the limitation of computational resources and relatively large biases in source attribution from simplified treatments of SOA formation and gas precursor emissions in climate models, including CAM5. The latter makes SOA tagging less useful.

3. Page 5, Lines 162-163: It does not look like an increase to me. Please double check.

The SO2 emissions from South Asia did increase steadily from 4.35 Tg S yr-1 in 2003 to 7.82 Tg S yr-1 in 2015. Because it only contributes a small fraction to the global total, this increase is not clearly seen from the stacked emissions.

4. Page 7, Lines 220-222: What is the uncertainty associated with this?

Although this parameterization of marine aerosol optical depth could introduce significant errors on the basis of regional and short time scales, the derived global mean marine aerosol agrees well with the AERONET-based measurement.

5. Page 8, Line 231: Do you have sources/citations for the claim that the derived dust AOD is likely overestimated?

Although dust plumes originated from the Namibia sources have been observed (Vickery et al., 2013; Formenti et al., 2019), there are no DOD records that can be used to evaluate the MODIS derived DOD in this region. Given that the region has high cloud cover, MODIS retrievals of AOD in particular coarse-mode AOD are prone to cloud contamination. In Yu et al. (2019), we found that MODIS-derived DOD is higher than MISR and IASI DOD south to the equator.

References: Formenti, P., et al., The aerosols, radiation and clouds in southern Africa field campaign in Namibia, Bull. Am. Meteorol. Soc., 100, 1277-1298, 2019.

Vickery, K. J., F. D. Eckardt, and R. G. Bryant, A sub-basin scale dust plume source frequency inventory for southern Africa, 2005–2008, Geophys. Res. Lett., 40, 5274–5279, doi:10.1002/grl.50968, 2013.

Yu, H. et al., Estimates of African dust deposition along the trans-Atlantic transit using the decade-long record of aerosol measurements from CALIOP, MODIS, MISR, and IASI, J. Geophys. Res. -Atmos., 124, 7975-7996, 2019. https://doi.org/10.1029/2019JD030574.

6. Page 8, Line 244: In addition to AERONET, you can also compare against Maritime Aerosol Network (MAN) observations (since here much of the discussion is focused on over ocean)?

Yes, MAN observations with extensive coverage should be useful. For the purpose of evaluate marine aerosol (NOT maritime aerosol), it is necessary to rigorously screen out continental influences from the MAN observations, which is beyond the scope of this study. The MAN observations have been compared with AERONET in-island observations (Smirnov et al., 2009) and used to evaluate MODIS retrievals (e.g., Levy et al., 2013; Remer et al., 2013).

Levy, R. C., et al., The Collection 6 MODIS aerosol products over land and ocean, Atmos. Meas. Tech., 6, 2989–3034, 2013.

Remer, L.A., et al., MODIS 3km aerosol product: algorithm and global perspective, Atmos. Meas. Tech., 6, 1829-1844, 2013.

Smirnov, A., et al., Marine Aerosol Network as a component of Aerosol Robotic Network, J. Geophys. Res., 14, D06204, doi:10.1029/2008JD011257, 2009.

7. Page 8, Line 249: Please make sure this is mentioned somewhere later in the paper.

Yes, we discuss it later in the paper.

8. Page 8, Line 255: Be clearer here with your definition of fractional AOD. Also, in Figures 5 (b) and (d), I would not show AOD fraction this way, as it can be confusing. For example, dust always appears to be at 100%. I suggest editing these plots.

The fraction AOD is defined as fractional contributions of combustion, marine, and dust

aerosol to the total AOD. The sum of three fractions is 1. Figures 5 (b) and (d) show the stacked contributions of the three components distinguished by different colors. We clarify it both in main text and in the figure caption.

9. Page 10, Lines 301-304: Include the values of each trend.

We will consider in revision.

10. Figure 1: I thought SOA was not included in the tagging? Also, is the y-axis supposed to be in percentages? Please add the correct units.

SOA and VOL are not tagged in terms of source regions. But they are accounted for as the combustion aerosol in this study to be consistent with the aerosol component definition for the satellite observations. We change the y-axis to "Stacked fraction of combustion AOD".

11. Figure 2: Shouldn't the units here for the y axes be just Tg?

The units must be specified with sulfur (S) or carbon (C).

12. Figure 6: Add the trend lines and trends for each plot.

The trends apparently depend on time period of the data record. Adding the trend lines makes the plots too heavy.

13. Figure 8: Why no CAM5 for 2016-2017? Is the MODIS trend only up to 2015, or does it include 2016-2017? It is of concern if the trends are computed for different time periods. This same comment can be applied to some of the later figures as well (see below).

Our CAM5 simulations stopped in 2015 because 2016-2017 emissions are not available. Data points for individual years are clearly shown in figures so that readers can see how 2016 and 2017 data are trending compared to previous years. Although the MODIS trend statistics include 2016 and 2017, this inclusion would not significantly affect our conclusions. Note also that significance tests of trend were performed by using

actual number of samplings (e.g., 15 and 13 for MODIS and CAM5, respectively).

14. Figures 9, 10, and 11: same concerns/questions/comments as Figure 8.

See response to #13.

15. Figure 11: How come no climatological seasonal cycle plots are shown, as in Figs. 8-10?

In this revision, we have added the climatological seasonal cycle plots for these regions affected by biomass burning smoke. Because of this addition, we have split the figure into Figure 11 (GOG and SAT) and Figure 12 (SEA). Appropriate discussion about seasonal cycles has been added.

16. Figure 12: Are you comparing trends from different time periods?

MODIS data include two extra years (2016 and 2017). Given that the individual data points are shown in figures, agreement and disagreement between the two datasets are evident.

Technical corrections: 1. Page 4, Line 120: "sea-spay" should be "sea-spray". Fixed.

2. Page 9, Line 268: The "0.025" here should be "0.015", correct? It should be 0.025.

3. Page 11, Line 340: I would switch "well captures" to "captures well". Fixed.

4. Page 11, Line 343: "the peak occurs" : : : the peak what? Be specific. Change to "the peak of combustion AOD occurs . . ."

5. Page 11, Line 343: Remove "the" before "MODIS" and "CAM5". Fixed.

6. Page 11, Line 345: Add "the" before "NAT", "MED", and "NAT and MED regions". Fixed.

7. Page 11, Line 356: "season" should be "seasons". Fixed.

8. Page 12, Line 369: Remove "the" before "CALIOP". Fixed.

9. Page 12, Line 370: Remove “the” before “SeaWiFS”. Fixed.

10. Page 13, Line 405: Remove “the” before “CALIOP”. Fixed.

11. Page 13, Lines 406-407: Define PM2.5, SO2, and CO. Fixed.

12. Page 13, Line 407: “decline” should be “declining”. Fixed.

13. Page 13, Line 408: “decline” should be “declining”. Fixed.

14. Page 13, Line 409: I would reword this sentence by changing “How” to “The manner in which”. Fixed.

15. Page 13, Line 410: Why is “Figure 10” in bold print? Fixed.

16. Page 13, Line 417: “possibly” should be “possible”. Fixed.

17. Page 13, Line 422: Remove “the” before “MODIS”. Fixed.

18. Page 13, Line 426: Define ATSR. “Along-Track Scanning Radiometer”. Defined.

19. Page 14, Line 459: Remove “the” before “northern”. Fixed.

20. Page 14, Line 460: Remove “the” before “northern”. Fixed.

21. Page 15, Line 461: Remove “the” before “southern”. Fixed.

22. Page 15, Line 462: Remove “the” before “northern”. Fixed.

23. Page 15, Line 468: In this context, I think “driving up” should be “drove up”, although I suggest finding another phrase. Fixed.

24. Page 15, Line 490: Add “the” before “literature”. Fixed.

25. Page 16, Line 496: Remove “the” before “CALIOP”. Fixed.

26. Page 16, Line 500: Add “of” after “factor”. Fixed.

27. Page 16, Line 506: Collection 6.1, correct? We used Collection 6, not 6.1. As we

discussed earlier, it will not affect major conclusions of this study.

28. Page 16, Line 507: Replace “the” after “over” with “a”. Fixed.

29. Page 17, Line 528: Remove “only”. Fixed.

30. Page 18, Line 566: Add commas after “Asia” and “China”. Fixed.

31. Page 18, Line 570: Add “the” after “of”. Fixed.

32. Page 18, Line 585: Replace “the” after “such” with “a”. Fixed.

33. Page 26, Table 3 caption: Add “an” before “asterisk”. Fixed.

34. Page 26, Table 4 caption: In the first line, “trend” should be “trends”. Add a comma before “respectively”. Also, add “an” before “asterisk”. Fixed.

35. Page 27, Figure 1: (a) Add a label to the color bar. (b) Add latitudes and longitudes to the map. Added.

36. Page 28, Figure 2: Add labels (a)-(c) to the plots and the figure caption. The figure is labeled with (a), (b), and (c).

37. Page 29, Figure 3: I suggest using (a)-(c) for labels. Please also edit the caption accordingly. Also, add the difference between the marine cases to the caption. The figure is labeled and the caption is modified accordingly. The marine case is categorized into marine1 and marine2, representing different season.

38. Page 30, Figure 4: Add labels (a)-(h) to the plots and the figure caption. The figure is labeled and the caption is changed accordingly.

39. Page 32, Figure 6: Add labels (a)-(d) to the plots and the figure caption. The figure is labeled and the caption is changed accordingly.

40. Page 34, Figure 8: Add labels (a)-(f) to the plots and the figure caption. Also, add labels to the y axes of the middle plots. Add “by” after “simulated” in the last line of the figure caption. The figure is replotted with y-axis labels and the caption is revised

accordingly.

41. Page 35, Figure 9: Add labels (a)-(f) to the plots and the figure caption. Also, add labels to the y axes of the middle plots. The figure is replotted with y-axis labels and the caption is revised accordingly.

42. Page 36, Figure 10: Add labels (a)-(f) to the plots and the figure caption. Also, add labels to the y axes of the middle plots. The figure is replotted with y-axis labels and the caption is revised accordingly.

43. Page 37, Figure 11: Add labels (a)-(f) to the plots and the figure caption. Also, add labels to y axes of the plots on the left-hand-side of the figure. The figure is replotted with y-axis labels and the caption is revised accordingly.

44. Page 38, Figure 12: Label the x and y axes for each plot. Also, add labels (a)-(f) to the plots and the figure caption. In the figure caption, remove “and” before “the tropical Indian Ocean”. The figure is replotted with y-axis labels and the caption is revised accordingly. The “and” before “the tropical Indian Ocean” is removed.

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