Atmos. Meas. Tech. Discuss.,
doi:10.5194/amt-2019-437-AC3, 2020

Atmospheric Measurement Techniques Discussions

Interactive comment on "Solar radiometer sensing of multi-year aerosol features over a tropical urban station: Direct Sun and inversion products" *by* Katta Vijayakumar et al.

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Received and published: 21 May 2020

Authors' replies to Referee 2 comments on the manuscript titled "Solar radiometer sensing of multi-year aerosol features over a tropical urban station: Direct Sun and inversion products by Katta Vijayakumar et al."

The authors are highly grateful to the Referee for valuable comments/suggestions, which improved the scientific content of the original manuscript. The authors are very grateful to the Referee for valuable comments and suggestions which aided to improve the quality of the original manuscript. The corrections in the revised manuscript have been indicated in BLUE colour.

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Discussion paper

C1: In all the sub-sections of the 'Results and discussion' from 5.1 – 5.9, the first paragraph defines aerosol quantities and talk about its importance in the climate system. This is just REDUNDANT information. How about just discussing the results?

R1: Revised as suggested. First paragraph of the sub-sections from 5.1 to 5.9 has been condensed in the light of the comments.

C2: All the figures showing seasonal variations in aerosol quantities could be merged as single figure with sub-panels. This would greatly help the reader to relate each quantity and get a holistic view of the regional aerosol characteristics.

R2: Thanks for the valuable suggestion. All the relevant plots have been merged as single figure as suggested. The text has been edited accordingly.

C3: Similarly, for the figures showing long-term trends of all quantities. One could choose a wavelength (say 440 nm) and provide trends of all quantities as sub-panels in a single figure. I think, at least all derived quantities could be merged. Further a tabular form can be presented with all information (fitting line, R, SD, trends, etc.) corresponding to all wavelengths and quantities.

R3: Revised as suggested. All the relevant plots have been merged into single figure, and the trend line information relating to different parameters corresponding to different wavelengths are tabulated.

C4: Even before presenting any results, can you mention what additional quality checks were used in calculating monthly, seasonal means and annual data trends? For example, minimum data points required in counting it as a valid day and the minimum number of days required to calculate monthly mean, etc?

R4: A minimum of about 35 data points (at each wavelength) in a day have been considered for a valid daily mean while a minimum of 20 monthly data (at each wavelength) has been considered to qualify a monthly mean. All the time, the data for all 12 months have been considered as a valid seasonal and annual mean. This scheme strictly

depends on atmospheric stability and sky condition over the study area.

L 318: Do you mean 'Holi' celebrations in pre-monsoon caused increase in aerosols? Previous studies have also reported increase in aerosol loadings during 'Diwali' (post-monsoon) for several sites in India. However, there is no such evidence in post-monsoon data, how do you explain it?

R: Increase in aerosol loading during the two well-known festivals in India, namely, Holi (pre-monsoon) and Diwali (post-monsoon). The loading enhancement during Diwali which is celebrated in the post-monsoon season depends on the rainfall frequency, intensity as well as on withdrawal of monsoon.

L 323 – 325: Do you mean cloud contamination is reported as aerosol loading in the observations here?

R: This was encountered particularly during the monsoon months due to frequent overcast sky conditions.

L 760: daily variability of AOD is high in monsoon months, could it be possible cloud contamination?

R: Authors agree with the Referee. Normally, it is very difficult to get clear-sky data during monsoon season over the study location, unless there are breaks occur during the monsoon season. Moreover, this increase in aerosol loading can also be attributed to transport of marine aerosols over to the study region. As Referee commented, there is a possibility that the enhancement could be due to cloud contamination nuclei over the study region during the monsoon months although the data used here are cloud screened.

C5: From fig 6 and fig 16, there is an increasing trend in non-absorbing nature and total aerosol amounts over the region. However, the long-range transport of dust or marine events is seasonal, but the data trends do not capture the increase in vehicle emissions (more absorbing aerosols) over the decade. Can you explain this?

R5: Authors agree with the Referee. As explained, contributions from vehicular emissions / road-dust reflected in the pre-monsoon (dry season) aerosol loading, other sources dominate during other seasons. Moreover, the dust over the study region mostly alkaline in nature. Hence, the long-term trends are mainly dictated by non-absorbing aerosols over the study region.

C6: It will be helpful to present an envelope of the data trends accounting for the uncertainties in AERONET products?

R6: As suggested, a table showing the trends observed in different AERONET products and the corresponding uncertainties in the measurement is included in the revised manuscript.

C7: Since the primary contribution of this paper is long-term trends in aerosol quantities. Can you also provide a consistency exercise with version 3 products? Or provide a discussion on how the changes in different versions reflect on the data trends for the derived quantities presented here?

R7: As suggested in a recent paper by Giles et al. (2019), the version 2 products used in the present manuscript will not differ much from the version 3. Long-term monthly averages analysed for the entire V3 and V2 databases produced average differences (V3–V2) of +0.002 with a $\pm$0.02âĂŁSD.

Giles, D. M., Sinyuk, A., Sorokin, M. G., Schafer, J. S., Smirnov, A., Slutsker, I., Eck, T. F., Holben, B. N., Lewis, J. R., Campbell, J. R., Welton, E. J., Korkin, S. V., and Lyapustin, A. I.: Advancements in the Aerosol Robotic Network (AERONET) Version 3 database – automated near-real-time quality control algorithm with improved cloud screening for Sun photometer aerosol optical depth (AOD) measurements, Atmos. Meas. Tech., 12, 169–209, https://doi.org/10.5194/amt-12-169-2019, 2019.

C8: Aerosol radiative forcing: o This section is just incomplete without mentioning the actual methodology on which of the radiative transfer (RT) model is used, what specific

inputs from AERONET observations is provided to the model, etc?

R8: The methodology involved in computing the aerosol radiative forcing is explained and related information including references has been incorporated in the revised manuscript.

In the present study, the aerosol radiative forcing (RF) at BOA, ATM and TOA has been estimated by following the method reported by Yisong et al. (2018). The method involves forcing calculations from broadband fluxes between 0.2 and 4.0 micron from aerosol size distribution, spectral AOD, single scattering albedo and phase function by using the radiative transfer module integrated in the AERONET inversions (Garcia et al., 2008; 2012). In this method, the AERONET-defined RFTOA and RFBOA have been directly used to calculate RFATM = RFTOA -RFBOA. The above references have been incorporated in the revised manuscript.

C9: Comparison with satellite observations:

o What spatial and temporal colocations of satellite observations were used in the comparison? The complete methodology is missing here!

o Not co-located, but synchronous MODIS, TOMS satellite and AERONET ground-based observations have been used in the comparison. References dealing with methodology and data retrieval have been included in the revised version.

o Is it a MODIS Dark Target or Deep Blue product? Similarly, there are two different aerosol products from OMI observations. Please use specific product names in the main text and figures.

Deep Blue Product from MODIS have been utilized in the present study.

o Can you also add trend lines (equation and %-amount per year) in the figure 28 and explain the observed differences?

Revised as suggested. Trend lines are already available in the figure. Now the equation

and % amount per year have been indicated.

o In figure 28-a, the observed differences are significant for the initial five years and later both observations merged. What caused that feature?

The large difference in the trend lines in the initial about 5 years could be due to increase in urbanization vis-à-vis anthropogenic activities.

o In figure 28-b, the differences are quite substantial – the wavelength difference (2 nm) is NOT the right answer!

Apart from a small sensing wavelength difference of 2 nm, higher AOD values by AERONET and relatively lower values by OMI have also been reported by Humera et al. (2015) due to anthropogenic activity and biomass burning.

Humera, B., Khan, A., Farrukh, C., Samina, B., Imran, S., and Thomas, B.: Intercomparison of MODIS, MISR, OMI and CALIPSO aerosol optical depth retrievals for four locations on the Indo-Gangetic plains and validation against AERONET data, Atmos. Environ., 111, 113-126, 2015.

C10: Based on the results of comparison with satellite observations (presented here) and model simulations (in the literature), could you add some discussion on what improvements could be needed by these communities? I am aware this not a complete assessment paper, but some comments or discussion could be helpful.

R10: Some discussion in the direction of comparison between models and observation or in short, model validation is added in the revised version, although it is not the main aim of the present paper.

Few more comments L 98: What are the colors coded regions in fig 1(b)? It is nowhere described or cited in the main text.

The entire map is for the State “Maharashtra”. The regions with different color codes are districts/talukas. The study location is highlighted with an arrow in the map.

L 146: ‘The diffuse sky radiances, called almucantar. . ...’? Please rewrite this sentence.

Revised as suggested. The scenario, ‘Almucantar’ denotes a series of measurements taken at an elevation angle of the Sun for specific azimuth angles relative to the position of the Sun.

L 164 – 165: remove ‘revised’ and brackets. Please cite the appropriate reference for Ver-2 Level 2 AOD products. Revised as suggested.

L 167: ‘which confirm to the standards . . .. . .’. Is it ‘conform’? Thanks, corrected.

L 319: ‘long-range transport values. . ...’. What are those? The sentence has been re-written in the light of comment.

Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2019-437, 2019.