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Interactive comment

Interactive comment on "Analysis of Global Three-Dimensional Aerosol Structure with Spectral Radiance Matching" *by* Dong Liu et al.

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We thank the reviewer again for the comments and suggestions. We apologize for the first version of response being kind of vague on the changes we made. Here we include a more specific list of changes in manuscript.

To address the reviewer's comment on comparisons with ground-based lidars, the following experiment and discussion has been added to Section 4.3, Page 10-11.

"In the three-month period, the Asian dust and aerosol lidar observation network (AD-Net) site at Seoul, Korea (37.5N,127.0E) provided measurements of atmospheric profiles that we were able to compare with RXS-expand. Seoul station has a standard lidar system in AD-Net, which is a two-wavelength (1064 nm, 532 nm) polarization sensitive

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(532 nm) Mie-scattering lidar, plus a 532 nm Raman (Shimizu et al., 2004). Based on the ground track, the A-Train sensors made overpass near the station for a total of 6 days during spring 2015. However, 4 out of these 6 days were heavily cloudy. For the remaining 2 days, March 7th and April 24th, the comparisons among ground-based lidar profiles, CALIPSO profiles at shortest distance and RXS-expand profiles averaged 25 km around the location of Seoul station are shown Fig.6. The CALIPSO measurements used for comparisons are level 1.5 data products of attenuated backscatter profiles, which clouds, overcast, surface, subsurface, and totally attenuated samples have been removed before being averaged to a 20 km horizontal resolution. In this case, RXS-expand profiles are based on the same products. The ground-based measurements used for comparison are the 532 nm attenuated aerosol backscatter coefficient products, averaged within 2 hr before and after the satellite overpass with 15 min time resolution.

For the aerosol layer 0-4 km above the ground, the relative error between CALIPSO profiles and ground station profiles are on average 21.6% on March 7th, and 18.7% on April 24th. The distances between station and ground track are 51.0 km on the first day, and 50.1 km on the second. Between RXS-expand profiles and ground station profiles, the average relative error is 27.9% and 23.4%, respectively. The results from the comparisons agreed in general. Previous studies found that there were considerable disagreement between CALIPSO measurements and ground-based lidar measurements; in most studies, the differences were found to be around 20% (Mamouri et al., 2009;Wu et al., 2011;Kim et al., 2008;Chiang et al., 2011). For example, Mamouri et al. (2009) compared CALIPSO attenuated backscatter coefficient profiles with a ground-based lidar in Athens, Greece, and they found the agreement on the order of $-10\pm12\%$ for cloud-free daytime measurements between 3 and 10 km, while the differences between 1 and 3 km were much larger ($-34\pm34\%$). In addition, the scene construction method in this work is not intended to get a precise quantification of aerosol profile, but to provide an estimate of the column's vertical structure. We did expect, to some extent, the estimation could be improved through calculations with constrains such as the column

AOD measured by passive sensor at the exact location of the recipient pixel, which will need a lot more work in the future."

Please see Figure.6 in the marked-up manuscript. The complete caption is following. Figure 6 Comparisons among ground-based lidar profiles of 532 nm attenuated backscatter coefficient products (units: m-1sr-1, averaged 2 hour within satellite overpass), CALIPSO profiles at shortest distance and RXS-expand profiles averaged 25 km around the location of Seoul station. The two plots on the left are from March 7th, 2015, and the two plots on the right are from April 24th, 2015.

Specific comments:

Page 2, lines 1-23. I'm surprised not to see any mention here of ground-based lidar networks, which are sometimes used in combination with CALIOP data; or of the shorter-lived NASA CATS lidar that was aboard the ISS.

We thank the author for the suggestion and we plan to add the following lines to the content, as a separate paragraph after the first one on page 2, lines 10-16. "The development of Lidar technology helped provide these vital missing piece of information. Ground-based lidar systems have been stationed at various locations and also used in field campaigns to measure the vertical and horizontal distribution of aerosols (Welton et al., 2000;Welton et al., 2002;Badarinath et al., 2010). Ground-based lidars provide measurements on the fixed locations on timescale of minutes to hours, depending on the specific type of lidar used in the experiment. Limited by the stationary setting, ground-based lidars could not achieve true global coverage, nevertheless, network of ground-based lidars (e.g. MPL-NET, EARLINET, AD-NET) provide key insights to atmospheric study and are involved in validation of satellite sensors (Kovacs et al., 2004;Mamouri et al., 2009;Pappalardo et al., 2010)."

Page 6, lines 18-21. These cloud cover rates seem very low. For passive sensors, 70% is a reasonable ballpark estimate for the fraction of the globe covered by clouds at any given time. Most such clouds would occupy only a small part of the vertical column (and as the paper states, almost never at high altitudes) but the numbers still seem difficult to reconcile. Have you calculated the global cloud cover from the column perspective, for comparison?

We thank the author for the question and comment. We made changes to paragraph on page 6-7 to make it more clear that the numbers in Table.2 refers to cloud occurrence as percentage they occupied in the vertical column, and also addressing reviewer's other questions.

"Table.2 summarizes frequencies of occurrences of atmosphere conditions. These numbers refer to the occurrence of atmospheric features as percentage they occupied in the vertical column. We calculated this occurrence rate according to CALIPSO VFM products, which was then scaled for vertical and horizontal resolution of the products (Hunt et al., 2009).The majority of conditions were identified as clear. Above 8.2 km clear arrays occur over 90% of the time. Aerosols and clouds occurred below 8.2 km, in about 7% and 5% of the cells, respectively. Note that arrays identified as 'no signal' represent 16 – 18% of cells in this layer; CALIPSO's signal can be totally attenuated beneath opaque clouds and certain aerosols. This indicates that the numbers in the table likely underestimated the amount of clouds in actual atmosphere. After removing elements identified as 'no signal', surface, and sub-surface, aerosols and clouds occupied 4.43 – 4.52% and 5.35 – 6.15% of the cells; clear-skies account for the remainder. The horizontal cloud coverage between 60°N and 60°S for the tested periods in April and September 2015 are 68.7% and 71.3%, respectively."

Page 6, Figure 2. This is fascinating. It would be interesting to see a more detailed discussion of the contrast between 0-2 km and 2-4 km, which appear to distinguish local aerosol from aerosol undergoing long-range transport.

We thank the author for the suggestion. We add more discussion about the contrast between 0-2 km and 2-4 km into the last paragraph on page 7, lines 10-23. The paragraph is modified as following: "Height-resolved global AOD maps (averaged for a $2^\circ \times 2^\circ$ lat/long grid) based on the two selected periods are shown in Fig.2. In the near-surface layer, 2 km above ground level (AGL), in April, relatively high aerosol loadings are found in the cross-Atlantic African dust transport, Saudi Arabia, and India. In September, dust dynamics are much weaker but much biomass burning is apparent in the Brazilian Amazon and Southern Africa. This seasonal trend of dust and smoke is more obvious in the layer 2-4 km AGL. Aerosol in this layer aloft are expected to be undergoing long-range transport. In April, the thickest dust layers are found slightly inland of the western coast of Africa, around 12.5°N, 5.5°E, and in the center of Saudi Arabia around 24.5°N, 42.5°E. The shift of AOD distribution between surface layer and layer above is logical, and indicates the movement of dust layers as the aerosol loadings are transported towards the oceans. In September, this contrast is harder to observe as the dust dynamic is weaker, but similar trends are found in the biomass burning regions. In addition, persistent high aerosol loadings in both 0-2 km and 2-4 km AGL are found in India and the east coast of China with mixed sources of natural aerosols and pollutants. The results could be affected by the local topography. Marine aerosols are confined largely to the near-surface layer, with some vertical transport in Southeast Asia in September due to the Asian monsoon. The observed pattern is mostly consistent with other studies in terms of global distribution and seasonal variations (Martins et al., 2018;Liu et al., 2012;Chen et al., 2018)."

Page 8, Figure 3. This plot is somewhat difficult to read. A different color scheme may make the drop in the matching rate at the ITCZ easier to spot, but I'm having trouble seeing any other patterns. We agree with the reviewer that Figure.3 is rather vague for the information we tried to convey. In fact, we think Figure.3 does not give enough extra information on its own, other than these results given in Figure.4. Therefore, we make a decision to remove this figure and change the order of figures accordingly.

Page 6, line 14. "Losing".

Page 8, line 19. "CALIOP profiles".

We thank the author for the comment, and these lines will be changed as suggested.

“From 10 - 24 April and 14 - 29 September, CALIPSO functioned normally except during a boresight diagnostic and alignment on 18 September, losing about half of that day’s data.”

“With the complete datasets of CALIOP profiles, MODIS radiances and geolocation fields, construction based on the SRM method can be applied worldwide.”

Please also note the supplement to this comment:
https://www.atmos-meas-tech-discuss.net/amt-2019-182/amt-2019-182-AC3-supplement.pdf

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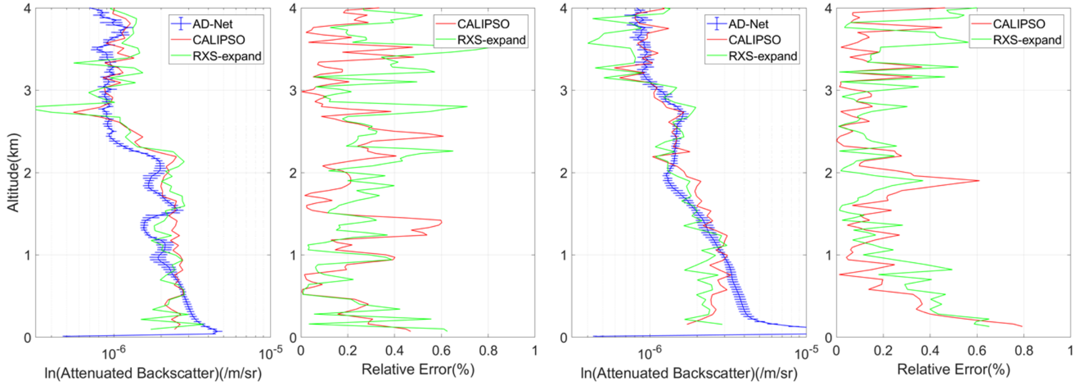

Fig. 1. Comparisons among ground-based lidar profiles, CALIPSO profiles and RXS-expand profiles.

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