Atmos. Meas. Tech. Discuss.,
doi:10.5194/amt-2020-246-AC2, 2020

Atmospheric Measurement Techniques Discussions

Interactive comment on "A new measurement approach for validating satellite-based above cloud aerosol optical depth" *by* Charles K. Gatebe et al.

Charles K. Gatebe et al.

charles.k.gatebe@nasa.gov

Received and published: 15 October 2020

Major Comment: 1. There is little mention of the scattering phase function, asymmetry parameter or otherwise which are used in the retrieval methodology of this study.

Response: The attached figure shows the scattering phase function F11, along with optical properties of carbonaceous aerosol model assumed in the ACAOD and sky AOD inversion.

2. The retrieved above cloud aerosol optical depth presented seem to show distinct dependence on scattering angle, which is likely a large retrieval artifact, which is not at

all discussed in this manuscript.

Response: The RT model (VLIODRT) used to create aerosol look-up table treats the outgoing radiance in a pseudo-spherical geometry. Therefore, it is expected that the aerosol radiance simulation at slant geometry, i.e., viewing zenith angle > 70° may not carry the same accuracy as the case with lower viewing angles. This may result in less accurate retrievals at extreme viewing geometries. Additionally, larger retrieval errors at lower cloud optical depth measurements and heterogeneity in aerosol and cloud fields also add to the apparent dependence on scattering angle. This discussion has now been incorporated into the manuscript (Section 2.2).

3. There seems to be significant non-uniform aerosol optical depth within the hemisphere that seems to be related to scattering angle (at various view zenith angles) and not to the actual aerosol plume shape (Fig. 8). Is this a remnant of an inconsistent assumption in aerosol scattering phase function, or maybe incongruent asymmetry parameter? This calls into question much of the retrieval methodology. Similar considerations are raised with the seemingly always centered high in AOD_cloudtop. Albeit the very good match with AATS, one would suspect that the asymmetry parameter, or the underlying scattering phase function may be erroneous, but on average a good approximation, with its high biases compensating for its low bias. This variation, that could be caused by a bad scattering phase function, may also be a causal link to one of the major findings of the paper, where the cloud optical depth is anti-correlated to the above cloud aerosol optical depth.

Response: First, the hemispheric distribution of sky AOD, i.e., retrieval above the aircraft altitude, looks more uniform throughout the scattering angle range, except around Sun disk where the CAR measurements show saturation. Second, we don't think that inconsistent assumption in aerosol scattering phase function or asymmetry parameter is a cause of remaining minor variability of AOD fields as the aerosol model used here provided a good-level of agreement between the retrieved ACAOD and AATS direct measurements [Jethva et al., 2016]. Furthermore, consistency between the sky

AOD retrievals from CAR measurements and that from AATS sunphotometer shown in Figure 12 of the present study (green and red dots/lines in Figure 12) stands as another supporting evidence that the retrieval methodology and assumptions made in the inversion are suitable for the smoke event investigated in this paper.

The anti-correlation between the retrieved ACAOD and COD observed for several CAR profiles is noted for COD mostly lesser than 10. This has been a known limitation of the color ratio method, in which the uncertainty in the retrieved ACAOD is estimated to be larger at lower COD and ACAOD values. This is because the retrieval domain at lower ACAOD/COD becomes narrower limiting the ability of algorithm, given several assumptions about aerosols and clouds, to accurately derive the aerosols and cloud fields.

Above discussion was added to the revised manuscript (Section 2.2).

General Comments: 1. In the introduction there should be mention, and comparison of a color ratio method for above cloud AOD by Meyer et al., 2015, that is applied to MODIS, and/or similarly from Peers et al., 2015. Additionally, there is little mention of the recent work based on the ORACLES measurements that follows from SAFARI. Potential to reference Redemann et al., 2020, and potentially LeBlanc et al., 2020.

Response: We added the suggested references: Meyer et al. 2015; Pistone et al. 2019; LeBlanc et al. 2020; Redemann et al. 2020.

2. Discussion of the impacts of the absorption properties of aerosol seems missing, particularly when referencing the color ratio technique in Section 2.2. Maybe a reference to the absorption properties from other radiative measurements during SAFARI; Bergstrom et al., 2003, or alternatively on the variations of the absorption as showcased by Pistone et al., 2019.

Response: The aerosol model used here in the ACAOD inversion is identical to the one employed in Jethva et al. [2016] paper, in which the MODIS retrievals of ACAOD were

found to be in very good agreement (RMSE$\sim$0.05 and 99% matchups within predicted uncertainty) against those directly measured from AATS sunphotometer. The results implied that the aerosol microphysical-optical properties assumed in the inversion that are essentially based on the long-term, ground-based AERONET inversion at an inland site Mongu, are suitable for ACAOD retrievals over the adjacent Atlantic Ocean.

Above discussion was added to the revised manuscript (Section 2.2)

3. Presentation of the figure 12, combining the AOD_cloudtop and AOD_sky might be better suited if there is inclusion of the measurement altitude, which might help indicate the partitioning. P.9 line 261: AOD from AATS would be representative either if directly above clouds, or below all significant layer of aerosol in the event of a clear-air-slot between cloud top and the bottom of the aerosol layer. It is suggested to add this caveat. The conclusion mentions this note again, but some care can be taken by careful data selection of sunphotometer data as presented by LeBlanc et al., 2020.

Response: The CAR BRDF measurements were obtained $\sim$600 m above the clouds as pointed out in P.9 line 261 (or line 281 in the revised paper. So including the measurement altitude may not be necessary, plus it will make the plot more complex. The mean aircraft altitude is shown in Table 1 for each case. We would argue that the “clear-air-slot” concept is relative, where the concentration of aerosols in the slot is much lower than the layer above and/or below.

Specific Comments: 1. P.4 lines 121-122, AATS and 4STAR acronyms are not defined, please define and add pertinent citations.

Response: added: NASA Ames Airborne Tracking Sun Photometer (AATS) and Spectrometer for Sky-Scanning, Sun-Tracking Atmospheric Research (4STAR)

2. P.8 line 236: typo: ‘betweent’ should be ‘between’

Response: the typo was corrected.

3. Table 1 shows an error value of 0.00 for much of the AATS AOD, this seems im-

probable and likely missing a significant digit. Additionally, there is no mention of what wavelength these AODs are reported (as compared to the retrieved ACAOD).

Response: We have corrected this anomaly based on actual errors derived from the AATS AOD. AOD are reported at wavelength= 0.500 μm as now indicated in Table 1.

4. Figure 4, There are no units on the colorbars, or the title is misleading – shouldn't it be radiance values in W/mËĘ2/nm/sr, or is it normalized radiances? If normalized radiance, it is normalized to what? The solar disc is apparently saturated, therefore if you normalize to that value, wouldn't that be misleading?

Response: The measured (sky or surface) radiance in any given direction is normalized by the solar irradiance incident on the top of the atmosphere, assuming mean Sun–Earth distance, and then converted to a non-dimensional quantity equivalent to effective BRF (or BRDF times π). This statement was added to Figure 4 caption.

5. Figure 4 a) & c), the solar disc seems to be not centered on the scattered light plot. The 0âŮę line does not seem to be in line with the principal plane.

Response: the appearance of the solar disc is not a reliable measure of asymmetry because of the saturation issue that we have. A plot of sky radiance as a function of azimuthal angle helps in identifying asymmetry due to errors in the geometrical correction. No action was taken.

6. Figure 8, the AOD above clouds retrieval at the solar disc seems drastically different than the surrounding region outside of the non-valid region.

Response: The spurious retrieval of AOD around Sun disk is a result of saturation in the CAR reflectance measurements and partly due to the inability of the RT model in simulating reflectance when directly looking at the Sun. This has been now clarified in the revised manuscript – Figure 8 caption.

7. Figure 12 – the figure caption lacks the identifier 'Figure 12:'

Response: We have added the identifier.

Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2020-246, 2020.

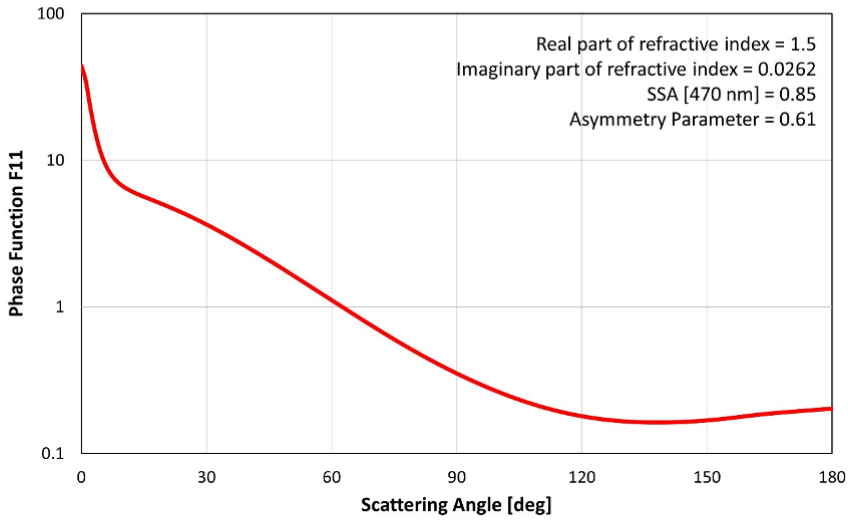

Fig. 1. Scattering phase function F11 of the carbonaceous aerosol model assumed in the aerosol inversion