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Comment on amt-2022-95

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Referee comment on "The new MISR research aerosol retrieval algorithm: a multi-angle, multi-spectral, bounded-variable least squares retrieval of aerosol particle properties over both land and water" by James A. Limbacher et al., Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2022-95-RC3, 2022

The manuscripted by Limbacher et al provide a thorough and interesting study on the impact of surface reflectance on aerosol retrievals using a new MISR research algorithm. Analyses are conducted by using four years of MISR data over both land and water. Details in the aerosol model updates and optimization algorithms are provided, with improvement quantified by comparing quality ensured AROENT data and MISR retrieval results. The MISR algorithm has been well optimized for aerosol retrievals. The new research algorithm further demonstrates the most current capability of aerosol retrievals using multi-angle measurements.

Specifically, the main motivation of this work is the observation of large biases in retrieved aerosol optical depth (AOD) as aerosol loading increases (>1). To resolve this issue, the authors proposed to use the surface reflectance data from the Multi-Angle Implementation of Atmospheric Correction (MAIAC). A combined algorithm is developed with surface properties directly retrieved for low AOD (<1), and a prescribed surface reflectance from MAIAC for large AOD (>2), and a linear combination of the two surface options are used for 1<AOD<2. By comparing with AERONET product and the MISR research algorithm product, the AOD uncertainties are well quantified as: ± (0.225*[MISR AOD] + 0.025) over land, and ±(0.20*[MISR AOD] + 0.01) over water.

This study provides useful experiences and techniques in exploiting aerosol and surface information from multi-angle measurement. Please find my suggestive comments for the authors to consider.

Main comments:

Most of my questions are related to how the surface reflectance are treated and how they impact retrieval results:

- Since there is a larger number of retrieval parameters when using directly retrieval surface properties, it makes sense that there could be large uncertainties. But it is still not clear to me why this leads to a negative bias of AOD as clearly shown in Fig 2(b).
- Page 4, line 25 "The fact that this bias correction was not sufficient to remove the AOD bias seen in the prescribed surface retrieval over-land (especially at AODs < 0.20) indicates that a camera-by-camera correction should probably be used in the future." Since the MAIAC reflectance has been corrected according to MISR retrieval results at low AOD (Page 4, since line 19), do you suggest the angular shape is still different between the MAIAC and retrieved surface reflectance? Is this part of the reason to have the bias in AOD retrievals?
- Since the authors have done retrieval using both retrieved and prescribed surface reflectance, it could be useful to compare the angular/spectral shape of these surface reflectance to understand exactly where the difference are. Specifically:
  - What are the retrieved surface reflectance difference under low and high AOD? How do they compare with the prescribed surface reflectance?
  - How does the surface reflectance (retrieved and prescribed) impact aerosol property retrievals differently? Currently only AOD are discussed which shows clear bias over land, it would be interesting to understand how the surface reflectance impacts other properties, such as SSA, FMF etc.
- Page 25, Fig 6, MISR retrieved surface case seem work good over water comparing with the prescribed ocean surface. Does the prescribed ocean surface derived in the same way from MAIAC as discussed for land? Do you have the same correction coefficients applied for the surface reflectance over water? I am curious why there is less AOD bias over ocean than over land.

Minor comments:

- Page 3, line 29: "SSA spectral slope ("Brown Smoke" AOD fraction)". Are they the same here?
- Page 4, line 5, "applies a spectrally invariant angular-shape-similarity assumption to derive 5 the surface reflectance (over land)". This is probably explained in later discussions, but do you assume that the same land surface reflectance at different angles and wavelengths?
- Page 4, line 7, "whereas the other algorithm prescribes the surface reflectance for both land and water from other sources", specify the sources or add reference?
- Page 4, line 11, "We then correct these TOA reflectances for the following: gas absorption, out-of-band light, stray-light from instrumental artifacts, flat-fielding, and temporal calibration trends". Do you have an estimated accuracy after all those correction in the measurement?
- Page 4, Line 21/22, "surface reflectance", are they defined in the same way in Eq (1) using E^{TOA} (or E^{BOA})?
- Page 5, Line 7, "10m wind-speed". What 10m mean here? The wind speed is retrieved, right?
- Page 5, Line 10, "appropriate solar/viewing geometry", do you consider spherical shell effect of the atmosphere?
- Page 6, Table 1, it would clear to explain BrS and BlS in the caption.
- Page 6, Line 7, how to do you define "non-sphericity" by mixing two coarse modes?
- Page 8, line 16, "(2)" and "(3)" seem not used for referred later on?
- Page 8, Line 20, cost function seems not normalized by the total number of measurements (N)? The current definition seems agree with a Chi square function which will have the most probable value at N. Is this the case here?
- Page 9, Line 15 "and MAIAC retrieved surface reflectance error (which should be much larger for the MISR 70Ë☐-viewing cameras than for the near-nadir cameras). Does this relate to earth spherical shell effect too?
- Page 10, line 15/18, "set the result to 0", so you are finding both A* and Lc to minimize the cost function, right? (I appreciate the authors provide details in the optimization approach (eg. Sec 2.1.2). The optimization are represented by a system of linear equations, which seems work well for this algorithm.)
- Page 11, line 19, "an additional 9 pieces of information", do you mean the total parameters for land surface are 9+4=13?
- Page 11, line 26, what is the 'prescribed surface AOD', are they also provided by MAIAC?
- Page 15, line 12, Do you remove the measurements at particular cameras if the inputs are not 'good'?
- Page 15, Line 14, cost function < 1, check the normalization of the cost function as mentioned previously.
- Page 15, line 30, "A larger 2nd derivative corresponds to a steeper minimum in our cost function with respect to AOD; we use 10 as a lower bound here in quality flag 6 as this tends to mask out some lower quality results (mostly clouds)". How do you determine the threshold? Since the derivatives are available, can the authors compute the uncertainties using error propagation, which can provide a more meaningful criteria?
- Page 17, line 8, a prognostic error is introduced here, but not well explained. Some information seems scattered in the Fig 3 captain and discussion from later sections. It would be useful to explain early how the error is computed. Another question: what dataset bins are used to compute the 68^{th} percentiles? Are these bins with respect to AOD, reflectance, uncertainty?
- Fig 3(b): 2% of reflectance?
- Page 22, Fig 5: It seems the MISR algorithm have the flexibility to deal with different aerosol types (therefore different refractive index). For large AOD at Fig 5 (bottom row), the data are peaked at either small or large FMF, which results in better SSA and non-sphericity agreement with AERONT. But for small AOD, there are many intermediate FMF values. If I recall correctly, AERONET retrieval algorithm assumes the

same refractive indices for both fine and coarse mode. So the AERONET product should have better representation for fine or coarse mode dominated cases. Does this partially explain what we observe in Fig 5 here?