Authors' response to comments are highlighted in **red.**

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.
The authors thank Meng Gao for his thorough comments.

Main comments:

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

1. 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).
The retrieved surface AOD is shown in Figures 2a and 2d. The large negative bias when AERONET AOD is >~1.5 is likely due to the large number of free parameters of the over-land retrieval (19) compared to the over-water retrieval (10), and the algorithm's inability to establish a deep local minimum in cost function when aerosol loading is elevated.
2. 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?
We only compared the MISR retrieved surface albedo to the MAIAC surface albedo for these low AOD cases where the retrieved surface algorithm performed well (as compared to AERONET). We then scaled the surface reflectances for all MISR cameras as described in the manuscript. We never compared camera-to-

camera results, as this could result in a significant digression from the main purpose of the current paper. It is likely that the angular shape is different between MAIAC and MISR and that this likely contributes to the AOD bias.

3. 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:
    a. What are the retrieved surface reflectance difference under low and high AOD? How do they compare with the prescribed surface reflectance?
    b. 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.

These are fantastic suggestions for a future paper on surface reflectance retrieval, but the current paper is already quite long, and the authors want to limit to focus the current manuscript on MISR RA retrieved aerosol loading/aerosol properties. We would also likely need the full set of MISR/AERONET coincidences (with MISR radiances), rather than the ~4 years included in this paper to do this job adequately.

4. 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.

This is likely due to the over-water algorithm having significantly fewer free parameters compared to the over-land retrieval (10 vs 19), combined with the Lambertian water-leaving reflectance assumption possibly holding in this case better than the shape-similarity assumption used over land. The prescribed surface over water is simply a set of static remote-sensing reflectances (ocean color), with the values presented in the paper. It works pretty well at high-AOD because water color tends to be less variable (especially over open-ocean) than the color/brightness of land surfaces. There was no need for correction coefficients for the over-water retrievals, as we don't use MAIAC.

Minor comments:

Page 3, line 29: "SSA spectral slope ("Brown Smoke" AOD fraction)". Are they the same here?
We have changed this to "…SSA, and brown smoke AOD fraction (analogous to SSA spectral slope)…"

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?
This is explained later, but it simply means that the color of the surface is not allowed to change with view angle, only the brightness (the ratios of surface reflectance are essentially fixed). This is a widely used assumption for multi-angle retrievals over land, and has been shown empirically to be valid in many cases.

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?
We have changed this to "…whereas the other algorithm prescribes the surface reflectance for both land (MAIAC) and water (uses a static set of remote-sensing reflectances)."

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?

We assume an uncertainty in TOA reflectance of 0.003 + 2% in the algorithm, which seems reasonable given what is known about atmospheric gases and the MISR validation work of Bruegge et al., but we have no way to further verify this.

Page 4, Line 21/22, “surface reflectance”, are they defined in the same way in Eq (1) using ETOA (or EBOA)?
The surface reflectance as described here would use EBOA, the irradiance at BOA.

Page 5, Line 7, “10m wind-speed”. What 10m mean here? The wind speed is retrieved, right?
No, and we have added that this is prescribed here.

Page 5, Line 10, “appropriate solar/viewing geometry”, do you consider spherical shell effect of the atmosphere?
No, the RT code is run in plane-parallel mode. The plane-parallel approximation is adequate for this application in nearly all cases.

Page 6, Table 1, it would clear to explain BrS and BlS in the caption.
Thanks for catching this.

Page 6, Line 7, how to do you define “non-sphericity” by mixing two coarse modes?
The algorithm selected either spherical or non-spherical models, non-sphericity is the fraction of 550nm AOD that occurs due to non-spherical aerosol. This has been updated.

Page 8, line 16, “(2)” and “(3)” seem not used for referred later on?
They are referred to in Figure S1.

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?
The sum of the weights corresponds to the total number of weighted measurements. Over-land, the sum of w is frequently 36.

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?
There is certainly the possibility of plane-parallel errors at high latitudes, where steep view angles combine with steep sun angles. We have added this as a potential error source, thanks.

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.)
Yes, the algorithm retrieves both. However, because the retrieval of Lc depends on the retrieved value of A, these are not really independent retrievals. This interdependence is also a potential source of our AOD bias.

Page 11, line 19, “an additional 9 pieces of information”, do you mean the total parameters for land surface are 9+4=13?
Correct

Page 11, line 26, what is the ‘prescribed surface AOD’, are they also provided by MAIAC?
This is the AOD from our prescribed surface algorithm in 2.1.1, we have clarified this.

Page 15, line 12, Do you remove the measurements at particular cameras if the inputs are not ‘good’?
Yes, if MISR radiometric QA indicates they are bad, or if reflectance is <0.002.

Page 15, Line 14, cost function < 1, check the normalization of the cost function as mentioned previously.

Because we are summing over weights (which will be 1 for good measurements), our function should be accurate.

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?
This threshold (and others) was determined by looking at MISR/AERONET comparisons themselves. This is truly a cloud screening metric. We could take the aggregate derivative for our “effective” aerosol model to come up with a more analytical approach to uncertainty, but we will probably address that in a future paper.

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 68th percentiles? Are these bins with respect to AOD, reflectance, uncertainty? Fig 3(b): 2% of reflectance?
Thanks for catching this. We have added the following:
“This prognostic error is taken as a line fitted to the 68th percentile absolute AOD errors (with respect to AERONET), binned at every 2% of MISR retrieved AOD (so 50 bins in total). “

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?
We believe this indicates at higher AOD we are more likely to see homogenized aerosol types (mostly dust or mostly smoke, for instance). The authors agree that errors in fine/coarse mode assumptions when the refractive indices for two modes in the atmospheric column are different could lead to errors in AERONET particle properties, especially if the plume was not either fine-or-coarse dominated though.