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Interactive comment on "Development and Assessment of a High Spatial Resolution (4.4 km) MISR Aerosol Product Using AERONET-DRAGON Data" *by* Michael J. Garay et al.

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Response to Anonymous Referee 2

We thank the referee for this careful review of the manuscript and the suggestions to improve the clarity of the work. Below we provide specific responses to the comments. The reviewer's comments are in italics, and the responses are in normal text.

The new MISR 4.4 aerosol product is mentioned for the first time in the same paragraph that describes the work of Kahn et al. 2010, Kalashnikova et al. 2013, etc. identifying specific performance issues with the V22 MISR algorithm. However, it is not stated whether these issues are addressed in the prototype 4.4 km algorithm or

whether the prototype 4.4 km algorithm is different from V22 only in the resolution. In some parts of the manuscript, it seems clear that there are other changes besides just the resolution (for example, the bottom of page 9 where it is mentioned that the cost functions have been changed). However, in the discussion and conclusions, it states that the improvements did not require significant changes to the algorithm itself. It is very important to clarify and explain what algorithm differences there are between V22 and the prototype algorithm, and the mechanisms by which these changes lead to the observed improvements. This should be made clearer throughout the manuscript, in the introduction, methodology section, results, and discussion. The improvement is impressive regardless of whether it was solely due to the resolution change or not, but it's important for readers to understand how the algorithm changes produced the improvement.

There are no significant changes to the algorithm used for the 4.4 km retrievals compared to the 17.6 km retrievals. The relevant changes have to do with the input data, both in terms of resolution when discussing the "local mode" data, and the area of interest (4.4 km vs. 17.6 km). The relaxation of the chi-squared threshold described on page 9 of the manuscript refers to a decision regarding whether or not a specific retrieval was considered "successful." This primarily impacts the coverage obtained by the 4.4 km algorithm and the adjustment was required because the threshold was designed to provide adequate coverage for the original 17.6 km product. The manuscript has been modified to make the equivalence between the 4.4 km and 17.6 km algorithm more apparent throughout per the reviewer's suggestion.

Specific comments: Page 3, lines 7-11. The descriptions of the issues found by Kahn et al. (2010) should probably be expanded and clarified somewhat. What does "a small gap" mean? That description is evocative, but fairly ambiguous; I can think of several possible meanings. Similarly, what does "missing particles in the aerosol look up table" mean? Does this mean particle types? Does it mean that the particle types in the look up table did not adequately represent all observed aerosol types? Perhaps most

importantly for the context of the current manuscript, was there any explanation (or speculation) for the systematic underestimate when AOD was greater than 0.4 (lines 10-11)?

The list on Page 3, lines 7-11 was meant to provide a summary of the issues identified in the V22 MISR aerosol product, with the idea that an interested reader would be able to find more information in the papers themselves. However, in the interest of making our paper more self-contained the section has been modified as follows:

"Kahn et al. (2010) also identified a number of issues in the performance of the V22 MISR aerosol retrieval algorithm, including: lack of extremely low AODs in the MISR data compared to AERONET that causes an apparent "gap" in the comparison plots; the appearance of quantization noise; lack of particle types in the aerosol look up table to adequately represent all observed aerosol types; and a frequent underestimate of AOD relative to AERONET over land when the AOD was greater than about 0.4. The authors speculated that this underestimate was due to insufficiently absorbing particles being selected in cases where absorbing aerosols were present, or AOD variability at the 17.6 km spatial scale of the retrieval being incorrectly treated as surface variability reducing the contribution of aerosols to the top of atmosphere reflectances, resulting in a systematic underestimation of the AOD in these situations."

Section 2: Figures 1 and 2 refer to a version of the 4.4 km prototype that was analyzed using the local mode data, whereas Figures 4-7 refer to a different version of the prototype algorithm that uses different input data, at least. Please add some text early in section 2 mentioning that there are two different prototype algorithms, so it doesn't come as a surprise later in the section. Also, please make some distinction in the figure captions. Are there any other algorithm differences between these two versions besides what data is used for input? If so, make sure to describe them in the methods section.

Again, the key point is that the algorithms are *identical*. The input data are different,

however. The figure captions have been updated per the suggestions of both reviewers to make their content clearer.

Page 6, lines 11-30. There's a fairly ambiguous transition between the observation that the MODIS high resolution retrieval did not improve MODIS performance and the idea that the high resolution AERONET data is a requirement for adequate assessment of high resolution satellite products. The second paragraph makes a very good point about requiring a high resolution assessment data set. This paragraph starts neutrally "A further point", but do you mean to suggest that the assessment technique is part of the explanation for why the MISR high resolution product shows better performance and the MODIS high-res product didn't? After reading the conclusions, it seems that you are making this suggestion, so it should be made more explicit here where it is first brought up. Is the high resolution assessment the primary reason for the difference? If it is, then would a comparison of MISR 4.4 km with the "permanent" AERONET stations that MODIS used would also show little or no improvement? And would a comparison of MODIS 3 km product using the DRAGON sites be expected to show improvement? If this is not the primary explanation for the different results, do you have any explanation or theory what other factors are at play?

The existence of the MODIS 3 km data and the conclusions drawn by Remer et al. (2013) create unexpected difficulties for this work. As the reviewer correctly points out, the Remer et al. (2013) analysis is for a globally distributed set of AERONET sites, which does not include AERONET-DRAGON deployments. Munchak et al. (2013) do compare the 3 km MODIS Dark Target (MODIS-DT) results with AERONET-DRAGON in the Washington, D.C./Baltimore area. They identified other issues with the MODIS-DT algorithm having to do with urban areas violating the Dark Target algorithm assumptions. A comparison of the MISR 4.4 km AOD retrievals with a larger suite of AERONET sites is ongoing. The primary factor in the improvement of the 4.4 km MISR product relative to the 17.6 km product likely has to do with the assumption of aerosol spatial variability on these different scales. As mentioned above, the algorithm attempts to

separate the surface (assumed to be heterogeneous) from the aerosol (assumed to be homogeneous). It seems that 4.4 km is a more appropriate spatial scale for assumed aerosol homogeneity than 17.6 km, at least for the MISR retrieval.

Section 2.3. Does this describe both the V22 algorithm and the prototype 4.4 km algorithm? Differences between them should be described here.

As mentioned above, the algorithms are the same, so this section describes both the 17.6 km and 4.4 km retrieval algorithms. The text has been modified elsewhere as suggested to highlight their equivalence.

Page 9, line 26-27. "The fall-off evident in the V22 17.6 km resolution retrievals is greatly mitigated, if not eliminated entirely". Why? Please explain the mechanism by which going to higher resolution corrects a large bias at high AOD values. Or if there is more required than just the higher resolution, explain that. This is a critically important point of the paper and really needs to be explained well.

As noted in the response to the other reviewer, the reasons for the improvement in the MISR retrievals at 4.4 km compared to 17.6 km are complex. Going to higher resolution requires that the aerosols are spatially homogeneous on a much smaller spatial scale, so it is less likely that true aerosol variability is assigned to the surface, resulting in higher AODs. That said, even though the algorithms are identical, there are other consequences of changing the retrieval resolution that are more difficult to tease out. As the focus of this paper was on demonstrating the improvement in the MISR retrieved AODs relative to AERONET when the algorithm is run at a higher spatial resolution, rather than a complete description of the MISR retrieval algorithm, we felt it was out of scope to go into these details in the present work. It is our intention to further investigate these changes and report the results in a future publication.

Page 9, line 30. "Relaxation of the thresholds on the chi-squared parameters to admit better spatial coverage". Relaxing the cost function seems like potentially a pretty significant change. Doesn't this mean that you are allowing the models to represent

the aerosols a little less well than they do in V22? Would relaxing these thresholds also result in better spatial coverage in the V22 17.6 km resolution retrievals? This point seems like it needs more supporting material to understand its implications.

As previously mentioned, the relaxation of the chi-squared threshold is necessary to maintain the spatial coverage of the 4.4 km product relative to the 17.6 km product for which the threshold was initially developed. While it is true that this effectively allows the 4.4 km retrieval to be successful for an AOD/aerosol model combination that agrees with the observations less well than in the case of the 17.6 km retrieval, the choice of the threshold was made somewhat arbitrarily (i.e., "tuned") to provide good coverage at 17.6 km resolution. Making a similar change to the 17.6 km retrievals has comparatively little effect on the coverage.

Page 10, line 12. When you say "the greatest benefit of the 4.4 km resolution MISR aerosol retrievals", it's not clear whether you mean the benefit of the higher resolution, or the benefit of the new prototype retrieval and all associated changes (of which the higher resolution is just one). Indeed, the better coverage is described as being due to the relaxation of the cost function, and not (or not primarily) due to the higher resolution, although later it is implied that it is due to the higher resolution because it can get in closer to exclusion zones.

The sentence refers to the 4.4 km resolution product including the associated changes in the chi-squared threshold. We are comparing the results of the 17.6 km algorithm (as implement in the operational V22 MISR aerosol product) with the 4.4 km algorithm results in an overall sense.

Figures 2 and 4 are described as regressions both in the captions and the text, but there is no regression line shown, only a one-to-one line and prescribed error bars. It's important to show the regression lines if you describe this as a regression. Also consider including the slope in the statistics describing the regression (in the figure legend as well as the text). Are the RMSE values calculated with respect to the one-

to-one line or the regression?

The reviewer is correct that the term “regression” was used inappropriately for these intercomparisons. The text has been changed to “scatterplots” or “intercomparisons” as appropriate. There are no linear regressions performed for reasons clearly elucidated by Dr. Sayer in his comment on this issue. The RMSE values are calculated with respect to the paired AERONET values.

Page 6, line 9. "Most significant improvements" (missing word)

Changed.

Page 10, lines 27-30. These two sentences are both true but seem to give the opposite impression (high res has better coverage because of getting closer to exclusion zones; low res has better coverage because of fewer exclusion zones). So I suggest tweaking the wording and the transition between the two sentences. "In contrast" might make more sense than "for example".

This is a good suggestion: “for example” has been changed to “in contrast”.

The figures are too small to see the detail we are being directed to notice, without zooming in to 200% or even 400%. The AERONET data circles are not much bigger than a period in the figure caption and the color bar text is much, much smaller than the text in the caption. Please blow up the figures and remake the color bar text to make it easier on the reader.

We have made the colorbars larger in the revised manuscript to hopefully improve the legibility.

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