Paper # amt-2014-252

Improving satellite retrieved aerosol microphysical properties using GOCART data

Response to Comments

Reviewer #2:

The article aims to improve MISR aerosol optical properties by incorporating information from model-simulated (GOCART) aerosol properties. When AOD is below 0.15 or 0.2, the sensitivity of the V22 MISR retrieval algorithm to aerosol component information is low. The authors propose a post-processing technique whereby inclusion of additional constraints from the GOCART CTM is used to constrain MISR's aerosol mixture selections. Specific aerosol mixtures are selected as the final retrieval only when the differences of ANG and AAOD between MISR and GOCART are below a certain threshold. These thresholds are not fixed a priori but dynamically adopted. It is not clear though: (a) how these dynamic thresholds should vary by season and/or region, (b) how much of an improvement does this post-processing technique buy, and (c) how relevant these results are beyond the MISR community. These points are of concern, and the following comments/question revolve around those issues and few other assumptions/choices that have been made.

(1). Section 3.2 and Figure 3 – This is really the crux of the manuscript. Unfortunately, the results that are currently in the manuscript (either in the Table or in the Figures) are not adequate to justify the authors' claim that their work improves the aerosol properties when AOD < 0.2. There are a variety of results that are presented, sometimes with all AOD, AOD > 0.2, or AOD > 0.5. And it is really difficult to distill the main message – whether or not the proposed methodology improves the aerosol optical properties for AOD < 0.15 or AOD < 0.2. A few comments to highlight this issue:

(i) The authors should include a column (d) in Figure 3, which shows visually the validation of the AOD, ANG and AAOD obtained from their work against the AERONET observations. Only the summary statistics are presented in Table 1 but these summary statistics are not presented for MISR and GOCART. Hence it is difficult to assess how much of an improvement in the aerosol properties is obtained.

Response*: We thank the reviewer for comments that have helped us clarify many points in our study. To address the overall notes above, interest in this combined MISR-model product seems likely to be quite high in the wider user community, as we frequently receive questions about what to do when many mixtures pass the MISR retrieval algorithm acceptance criteria. When many mixtures pass, which typically occurs when the AOD is low, the MISR observations do not contain strong constraints on aerosol type [e.g., Kahn et al., JGR 2010]. Under these circumstances, having an external constraint that effectively weights the retrieved aerosol types adds value to the product.*

The improvement this provides comes both in the form of lowered ambiguity about aerosol type, at least to the extent that a leading aerosol transport model offers meaningful aerosol type constraints, and in terms of better ANG and AAOD values in some situations, as illustrated in the

new Table 1 presented below.

Regarding the reviewer's specific suggestions, we have added our results to column (d) of Figure 3 and moved all the statistics to a new table to replace the old Table 1.

(ii) Both rows (1) and (2) in the revised Figure 3 should show a set of red dots indicating AOD <= 0.2. For row (3), that is AAOD, this can be revised to AOD <= 0.5. Currently, row (2) shows a set of red dots for AOD > 0.2 and the expected improvement in the fit of MISR to AERONET observations. But the main point of the proposed algorithm is to improve the estimates when AOD <= 0.2. Indeed if the proposed technique is serving its purpose, the results (Table 1 and 2, Figure 3) should highlight: for AOD and ANG - (a) all AOD, and (b) AOD <= 0.2; and for AAOD – (a) all AOD, and (b) AOD <= 0.5.

Response*: Yes, the reviewer's understanding is correct. Our method shows better performance for ANG when AOD <=0.2 and for AAOD when AOD<=0.5. To highlight this result, we have reorganized Figure 3 and made a new table (Table 1) for different AOD value ranges in the revised manuscript. Overall, our conclusion can be summarized as follows:*

1. *Our AOD is comparable with the MISR product in various AOD value ranges.*
2. *Our ANG agrees better with AERONET when using the entire dataset and for AOD <0.2 only (r: 0.45 or 0.42) compared to MISR alone (r: 0.29 or 0.28). When AOD >0.2, MISR ANG improves as well (r_MISR1: 0.4; r_MISR2: 0.49), but the improvement is not statistically significant (r: 0.5).*
3. *Our AAOD is closer to AERONET when the complete dataset is used or when restricted to AOD <0.5 (γ: 0.74 or 0.73) compared to MISR alone (γ: 0.5 or 0.47). When AOD >0.5, MISR AAOD improves (γ _MISR1:0.61; γ _MISR2:0.65), but again, the improvement is not statistically significant in this AOD regime (γ:0.75).*

We have thoroughly revised multiple sections of the main text to make these points clear.

(iii) Line 25, Page 8960 – The authors claim that "...Better correlation is seen in the East (0.87), summer (0.78) and fall (0.88)". But "better" relative to what? The authors haven't presented the corresponding values for MISR (or GOCART), so it's not clear how much of an improvement takes place.

Response: In the revised manuscript, we have compared MISR with AERONET by seasons and geographical regions in the revision (see Table 2). Correspondingly, we applied our method to different seasons and geographical regions for comparison. Overall, our AOD is comparable with MISR, but our ANG and AAOD are better than the original MISR product.

(iv) In the caption, the authors should add a line clarifying the red dots in rows 2 and 3.

Response*: We have updated the caption of Figure 3 in the revised manuscript accordingly.*

(v) It is highly disappointing that in reporting the parameter estimates, the authors make no

attempt to include a standard error on that estimate or report the statistical significance of that parameter (associated p value, for example). It is hard to interpret the differences, especially the slope and intercept values (for example, Figures 3.3a and 3.3b) without knowing whether the differences are significant or not.

***Response**: In the revised manuscript, we have added the standard deviation (SD) and the errors for slope and intercept in Table 1. In the footnote, we stated that all the regression slopes are statistically significant ($p < 0.0001$).*

(2). Line 26, Page 8954 – What do the authors mean by 'model-satellite discrepancies'? Is it simply differences in resolution or more general differences in how the aerosol-related information is derived in MISR and GOCART?

***Response**: Yes, the absolute AOD and AAOD values between MISR and GOCART may differ due to various uncertainties, such as resolution differences, satellite retrieval errors, and the impact of assumed emissions on the model, etc. To reduce these discrepancies, we used the fractional AOD and AAOD instead of absolute values.*

(3). Even though the authors have broken up their analyses by both season and geographical regions (Tables 1 and 2), the dynamic thresholds (for Equations 4 and 5) are assumed to be constant over the entire contiguous US (Lines 7-10, Page 8961). The authors need to clarify the impact of this assumption. Also in Line 9-10, Page 8961 – what do the authors mean by 'other parameters'? To demonstrate the full value of this methodology, additional sensitivity tests need to be presented by re-generating Figure 4 for different seasons and regions considered in the study.

***Response**: The reviewer's understanding is correct. Selecting the thresholds is an important limitation of our method that is still being refined. The ANG and AAOD thresholds in the original manuscript are generated for the entire contiguous US and across four seasons, to ensure the best agreement between the complete data set and AERONET. In the revised manuscript, we have conducted additional sensitivity tests for different regions and seasons. We have shown in the Supplemental Material (Figure S1) that thresholds can be set to achieve better results for stratified regions and seasons. We also compare our results with the corresponding standard MISR product in Table 2.*

Regarding Line 9-10, Page 8961, in this analysis, we selected the parameters of ANG and AAOD as the criteria to constrain MISR mixtures. MISR and GOCART (or other CTMs) also provide other parameters, such as component-specific AOD and aerosol volume fraction. We meant to say that these parameters might be used to improve satellite retrievals.

(4). What are the assumptions made by GOCART that may affect the final results presented here? In Lines 1-9, Page 8956 the authors highlight a number of factors that may contribute to the poor performance of GOCART relative to AERONET. Are these factors specific to GOCART or any other CTM. How will switching to a different CTM (for e.g. GEOS-Chem as mentioned in Section 4) help? Later in Section 4, the authors state that GEOS-Chem may help

(Line 12-14, Pg 8966) – '...especially when the information is lacking in the MISR radiances themselves, such as at low AOD'. But isn't that the reason for using GOCART in the first place. Why do the authors expect that GEOS-Chem will produce additional benefits relative to GOCART?

***Response**: The factors we mentioned in Line 1-9, Page 8956 generally apply to all CTMs. However, various CTMs have their own characteristics, such as different emission inventories, meteorological fields, chemical solvers, and optical parameters (see for example Textor et al., 2006 and Kinne et al., 2006). GOCART has its merits and specific deficiencies (e.g., as mentioned in Line 9-10, Page 8956, not considering any internal mixing). Other models like GEOS-Chem might have a better representation of aerosol chemistry, as it does include nitrate aerosols that are important in some regions such as California. However, GEOS-Chem currently does not provide ANG estimates, which is an important reason for us to choose GOCART instead. As the models evolve and enhance, other models can potentially be used to improve MIRS's aerosol microphysical properties.*

(5) Table 2 – The values reported in the AAOD section, especially for the row 'our work', do not match the stated values in the text in Section 3.3 (Pages 8963-8964). The differences are almost of an order of magnitude. Kindly check.

Response: We thank the reviewer for pointing this out. We have corrected this typo in Table 2 (Table 3 in the revised manuscript).

(6) Also, the authors present only the mean values in Table 2. Calculating a direct 'mean' value may not be a statistically accurate metric for a log-normal distribution such as AOD (see O'Neill et al. [2000] and several other published work since then including Liu et al. [2004] that has been cited). Could the authors state if they took the logarithm of the AOD values, and then reported the mean? A simple goodness-of-fit test will reveal if the data are lognormal or not. Finally, the caption of Table 2 states – 'Statistics of the ....". The word statistics should not be used here since the authors present only one value and not the standard deviation or errors associated with that value.

References: [1] O'Neill, N. T., Ignatov, A., Holben, B. N., and Eck, T. F.: The lognormal distribution as a reference for reporting aerosol optical depth statistics; empirical tests using multi-year, multi-site AERONET Sunphotometer data, Geophys. Res. Lett., 27(20), 3333–3336, 2000

***Response**: We have calculated the counts according the AOD, ANG, and AAOD value bins as demonstrated in the Supplemental Material (Figure S3). As the reviewer suggested, our statistics are now consistent with O'Neill et al. [2000]. In this study, four years of AOD data in contiguous U.S. were found to obey a lognormal distribution, even after stratifying by regions and seasons. Unlike AOD, the ANG and AAOD data for those four years follow approximately a normal and an exponential distribution, respectively. Without lengthening the paper further, we provided a brief discussion of our additional analysis in the revised manuscript and included this figure in the Supplemental Material.*

We have changed the caption of Table 3 to the following: "Mean values of MISR, GOCART, and Our work's aerosol optical properties over the contiguous U.S."