The AERONET Version 3 aerosol retrieval algorithm, associated uncertainties and comparisons to Version 2" by A. Sinyuk et al.

Reply to reviewer #2.

Authors would like to thank reviewer for careful reading of the manuscript and valuable comments.

General comments.

"The topics in the manuscript are undoubtedly urgent. The problem is that certain questions within each of these tasks require a more detailed description than is done in this version of the manuscript. I think it is reasonable to submit a number of considered questions either after, or in parallel with, publishing this manuscript. It is hardly appropriate to expand substantially the given version of the manuscript. In particular, the manuscript already contains very many figures and tables, complicating the perception of the material. The second variant is to divide the text presented into two parts: description of the AERONET Version 3 and description of new approach to estimating the uncertainties in the retrieved aerosol parameters. In principle, these are two different tasks that can be described separately."

Answer:

The main objective of this paper is to present a description of V3 AERONET **aerosol retrieval algorithm** including all the changes and new additions. In this respect, the estimation of retrieval uncertainties is a part of the V3 aerosol retrieval algorithm and should be a part of this manuscript rather than a separate publication. We understand that combining all the parts of V3 aerosol retrieval algorithm in one manuscript does not allow for discussion of every detail and nuance. However, we did our best to provide a reasonable number of details in describing each part of the algorithm. It might well happen that during further research some more details of uncertainty estimates and other parts of the V3 algorithms may be included in future publications. At this point, however, we believe that separation of the manuscript in two parts is not appropriate.

Major comments.

1. Line 223. While for the almucantar (ALM) observation geometry this is a reasonable assumption (e.g. Dubovik and King, 2000b; Torres et al., 2014), for other geometries the sensitivity to vertical structure of aerosol and gases in atmosphere can be important, especially at shorter wavelengths with relatively large Rayleigh scattering. Please provide a reference or numerical estimates

Answer:

The following sentence was added:

For example, the effect of aerosol vertical distribution on aerosol parameters retrieved from ALM and principle plane (PP) observations was analyzed in (Torres et al., 2014). It was shown that PP retrievals are more strongly affected by assumptions on aerosol vertical distribution than those of ALM.

2. Page 9 (3.2 Effects of changes in Extraterrestrial solar flux and temperature correction) Figure 5 discusses the temperature dependences of NSR. Seemingly, the temperatures in the range of 10-50o C at the selected site are distributed non-uniformly, and points on the plots differ in statistical representativeness. Can this influence the result?

Answer:

In generating Figure 5 no statistic was used. Instead: "Each point corresponds to an individual observation taken at specific value of the sun photometer sensor head temperature.". This sentence was added to discussion of Figure 5. As for the sampling, all temperature trends are smooth and consistent, and if there was a sampling problem then the data would look noisy.

3. Section 4 (Hybrid scan: concept and retrieval scan).

From materials, now presented in section 4, we can gain only a general idea of the novelties associated with the new instrument type. If they are left in about the same form that we see in the manuscript, it is reasonable to consider questions, regarding the hybrid scan, in more detail and, presumably, in a separate publication. Maybe this publication does already exist now?

Answer:

A separate publication on HYB scan does not currently exists. However, we think a future HYB publication is possible especially when more statistics from T model sun-photometers will become available.

4. How many photometers, ensuring the new scanning geometry, have been installed and already operate now? Are they installed at all four sites, data from which are used in the present study, and how long ago? Does the aeronet.gsfc.nasa.gov site present information on the type of instrument (or instruments, if they operate in parallel) that is used at arbitrarily chosen observation site? In any case, I cannot see such data. Did the cloud screening procedure change after passing to new sensing geometry?

Answer:

Information on AERONET sites with T-model sun-photometers installed and information on AERONET website, the following sentence was added:

"The information on the AERONET sites equipped with Model-T sun photometers can be found on the AERONET web site which provides an option to choose between ALM and HYB scan scenarios (https://aeronet.gsfc.nasa.gov/cgi-bin/draw_map_display_inv_v3). "

Information on four AERONET sites used in analysis, the following sentence was added:

These sites have the longest record of HYB type observations starting from the fall of 2014.

Information on T-model instruments, the following sentence was added:

Descriptions of this model is provided on the AERONET website: https://aeronet.gsfc.nasa.gov/new_web/system_descriptions_instrument.html.

Cloud screening procedures are the same for both the ALM and HYB scan geometries.

5. Results in subsection 4.2 are described very sparingly. Results in Figs. 17 and 18 can hardly be considered as an argument in favor of the good correspondence between results retrieved using two

different scanning geometries, more so considering that the authors present no statistics that was used in these comparisons. For instance, it is unclear why the authors conclude that Ðˇrt the same time the variability is increasing with increasing wavelength due to predominant contribution of fine mode aerosols to the generated statistics, and therefore much smaller AOD at the longest wavelengths which results in less sensitivity to aerosol absorption (line 496)?

Answer:

The following sentences were modified:

The statistics were generated using the data from all AERONET sites for which the HYB inversions were available by aggregating SSA retrievals in five SZA bins. Each bin is 1^0 wide centered at 50.5° (387), 54.5° (160), 59.5° (187), 64.5° (121) and 73.5° (296) SZA where the number of inversions corresponding to each SZA bin are shown in parentheses.

At the same time the variability is increasing with increasing wavelength due to predominant contribution of fine mode aerosols to the generated statistics (the aerosol loading of ~80% of sites is dominated by fine mode aerosols), and therefore much smaller AOD at the longest wavelengths which results in less sensitivity to aerosol absorption.

6. Can you present data for at least a few observation sites that would show how much the number of retrievals increased after the new geometry was introduced?

Answer:

The following sentence was added:

The extension of the SZA range in HYB scan geometry results in substantial increase in the number of inversions: e. g. Mezaira (~61%) and Kanpur (~ 57%). The increase was estimated as the ratio of the number of inversions for SZA less than 50° to that for larger SZAs.

7. Line 534. The radiometric calibration and solar spectrum irradiance uncertainties are combined in one bias because both of them affect the magnitude of sky radiances. What is the value of uncertainty, resulting from combining the radiometric calibration and solar spectrum irradiance uncertainties?

Answer:

We did not estimate the contribution to uncertainties from different sources of biases separately. Therefore, we added a qualitative statement in discussion as follows:

The combined calibration and solar irradiance bias assume the ± 5% values, which overestimate the sum of individual biases in cases when they compensate each other.

8. Subsection 5.4. In analyzing the results from retrieving aerosol characteristics, it is important for the reader to obtain information on what is the uncertainty degree of any characteristic at a specific site under certain atmospheric conditions. The authors carried out such an analysis for four sites (GSFC, Mezaira, Kanpur, and Mongu), which correspond to four different aerosol types. It is reasonable to stress this in the text of the manuscript (put simply, starting an analysis, say, for GSFC, to prescribe aerosol type characteristic for this observation site in an explicit

form). It would also be useful for the reader to see any climatologic data on characteristics for four selected sites (type of AOD distribution, relationship between fine and coarse fractions, characteristic types of the underlying surface, etc.) Then it will be easier for the reader to choose estimates of uncertainty that correspond to the specific data that he analyzes.

Answer:

We added a new table which summarizes the multi-year averages of aerosol and surface characteristics at four AERONET sites used in analysis:

The analysis is supplemented by Table 18 which contains multiyear (1995-2019) averages of aerosol and surface characteristics at four selected AERONET sites. The following abbreviations are used in the Table 14 header: FMF stands for the fine mode fraction of AOD, AE is Angstrom exponent estimated for (440-879) wavelength range, and SA is a surface albedo.

Table 18. Multiyear (1995-2019) averages of aerosol and surface characteristics at four AERONET sites selected for analysis of uncertainties in retrieved aerosol parameters. The abbreviations FMF, AE and SA stand for the fine mode fraction of AOD, Angstrom exponent estimated for (440-879) wavelength range, and surface albedo respectively.

Site	Aerosol type	AOD (440)	FMF (440)	FMF (1020)	AE	SA: 440, 675, 870, 1020
GSFC	Urban/Industrial	0.186	0.901	0.612	1.620	0.038, 0.069, 0.292, 0.297
Mongu	Biomass burning	0.427	0.914	0.630	1.710	0.064, 0.119, 0.295, 0.324
Kanpur	Urban/Dust mix	0.738	0.729	0.422	0.990	0.073, 0.142, 0.345, 0.346
Mezaira	Dust/Industrial	0.360	0.576	0.212	0.720	0.169, 0.387, 0.492, 0.510

9. Line 666. Fig. 24 shows the uncertainties (by the U27 methodology) of the RRI at 440 nm estimated for the GSFC, Mongu, and Mezaira sites. Can any recommendations be obtained regarding RRI at other wavelengths?

Answer:

The following discussion was added:

The U27 estimated for RRI at longer wavelengths are very similar to those at 440 nm. The similarity between estimated uncertainties for RRI at different wavelengths can be explained by the fact that spectrally RRI retrievals are not independent but related through the smoothness constrains (e. g. Dubovik and King, 2000).

10. Line 679. In contrast, the U27 estimated for SSA and observed variability of SSA retrievals are more consistent. Additionally, the upper and lower limit retrieval constraints of RRI (1.33 and 1.60, respectively) were reached at times, suggesting some potential instability in the retrievals of RRI. The percentage values of RRI retrievals reaching 1.33 and 1.6 (in parentheses) were estimated for all three sites for 440 nm AOD less than 0.2 and greater than 0.4. The estimates for smaller AOD bin show that RRI retrievals hit 1.6 boundary more often than that of 1.33: 1.6% (13.7%) for Mezaira, 3.1% (11.1%) for GSFC, and 2.2% (18.5%) for Mongu. The corresponding estimates for larger AOD demonstrate significant 685 reduction in the number of boundary hits,

especially that of 1.6: 0.6% (6.8%) for Mezaira, 2.5% (0.9%) for GSFC, and 0.4% (4.3%) for Mongu. The meaning of the sentences is difficult to understand.

Answer:

The paragraph was modified as follows:

The potential instability in the retrievals of RRI is further illustrated by the fact that the upper and lower limits imposed on RRI variability (1.33 and 1.60, respectively) are often reached especially for low AOD. The percentage values of RRI retrievals reaching 1.33 and 1.6 (in parentheses) were estimated for all three sites for two bins in 440 nm AOD: less than 0.2 and greater than 0.4. The estimates for smaller AOD bin show that RRI retrievals hit the 1.6 boundary more often than that of 1.33: 1.6% (13.7%) for Mezaira, 3.1% (11.1%) for GSFC, and 2.2% (18.5%) for Mongu. The corresponding estimates for larger AOD demonstrate significant reduction in the number of boundary hits, especially that of 1.6: 0.6% (6.8%) for Mezaira, 2.5% (0.9%) for GSFC, and 0.4% (4.3%) for Mongu.

11. Line 715 For this reason, the U27 estimates for the RRI are not reported in the AERONET database. Is the AERONET database of the U27 estimates publicly available?

Answer:

The following sentence was added to the conclusion part:

The Level 2 U27 estimates for retrieval uncertainty are available at AERONET website (https://aeronet.gsfc.nasa.gov/cgi-bin/webtool_inv_v3) for each AERONET site.

12. Line 816. A climatological LUT was generated from the entire Level 2 AERONET almucantar and hybrid scan database by binning U27s in AOD (440 nm), Angstrom Exponent (AE, 440-870nm), and SSA (440, 675, 870, 1020 nm). What is the contribution of hybrid scans to LUT?

Answer:

The following sentence was modified:

A climatological LUT was generated from the entire Level 2 AERONET almucantar and hybrid (~ 10% of total scans) scan database by binning U27s in AOD (440 nm), Angstrom Exponent (AE, 440- 870nm), and SSA (440, 675, 870, 1020 nm).

Minor comments

1. Line 280. Figure 3 illustrates the sensitivity of normalized sky radiances (NSR): :Possibly, not all readers are familiar with the notion “normalized sky radiances”. Please define NSR in the text or present a reference.

Answer:

The following sentence was modified to include NSR definition:

Figure 3 illustrates the sensitivity of normalized sky radiances (NSR), to the changes in BRDF parameters. The NSR constitute the input to the inversion code and **are** defined as the measurements divided by extraterrestrial solar flux and multiplied by π**.**

2. Subsection 3.4 Please make the text in the section consistent with table numbering. In the text, the aerosol parameters are considered in the following order: SSA, RRI, parameters of particle size distribution. Tables are presented in a different order: SSA, parameters of particle size distribution, RRI.

Answer:

The order of tables was changed.

3. Figure 3, Figure 22 Curves, corresponding to the same wavelength, are better to give in the same color.

Answer:

The colors were changed.

4. Throughout the text. Please explain what abbreviations (VMR, etc.) stand for, not in the figure captions, but in the text of the manuscript.

Answer:

Definitions were included in the text.