

Authors' response to the reviewers' comments

Manuscript No.: amtd-3-C1225-2010

Title: Satellite remote sensing of Asian aerosols: A case study of clean, polluted, and Asian dust storm days

General comments:

The paper "Satellite remote sensing of Asian aerosols: a case study of clean, polluted and dust storm days" using cluster analysis on AERONET data to better define aerosol types/models in East Asian region and apply the models for the aerosol retrieval in the region using an LUT approach. To objective is to improve the aerosol retrieval in East Asian region with more accurate aerosol model assumptions since aerosols compositions in the region are much more complex so that more representative aerosol models should be used in aerosol retrieval. The surface treatment is also somewhat different from the standard MODIS approach by using Eq. (5). These specific considerations are the valuable parts of the study and need to be addressed in the abstract and conclusion, which I didn't see in the current version. The organization of the paper needs to be improved, for example, it would be better to put Sensitivity Study section right before the Look-up Table section. A lot of descriptions are not accurate in the text and the English is also poor. The authors should have the manuscript professionally edited before submission to improve the English. Most important, a detailed description of the retrieval procedures outlined in Figure 4 should be added since it is critical for readers to really understand the algorithm. Considering AERONET retrieval for dust aerosols does assume non-spherical particles and this paper is try to better characterize the aerosol properties for improving aerosol retrieval, using spherical assumption for dust aerosols in category 6 is a negligence that cannot be accepted (see item 16 bellow for how to make some improvement). More itemized comments and suggestions are proved below. I suggest a major revision on the paper before accepting for publication:

- A. The first version of paper was indeed hastily submitted because of a looming deadline. In revision, all typos and grammatical errors listed below have been corrected. All suggested changes were implemented. Basically, optical properties for dust model with assumption of non-spherical particle were used in this study. For the purpose of announcement, Fig 2 is now included.

Itemized comments:

(1) Page 2652, Abstract, line 3: replace “during” with “for”.

A. done

(2) Page 2652, abstract, lines 7-8: change “However, it is still difficult to retrieve : : :” to “However, there are still some difficulties to accurately retrieve : : :”.

A. done

(3) Page 2652, Introduction, line 23: insert “various” right before “optical properties”.

A. done

(4) Page 2652, Introduction, line 24: insert “caused by human activities” right after “climate change”.

A. done

(5) Page 2653, Introduction, lines 3-4: change “Not only knowledge of the microphysical and optical properties of aerosols on the radiative transfer is needed for the retrieval of the aerosols but also exact estimation of surface reflectance provided a way to retrieve reasonable aerosol characteristics.” to “Not only the knowledge of the microphysical and optical properties of aerosols on the radiative transfer but also the accurate estimation of surface reflectance is needed to retrieve reasonable aerosol characteristics.”

A. done

(6) Page 2653, Introduction, line 6: replace “conducted” with “studied”.

A. done

(7) Page 2653, Introduction, line 7: replace “studied” with “obtained”.

A. done

(8) Page 2653, Introduction, line 11: remove “As a measure value of aerosol loading” since it is redundant with “AOT is directly related to the atmospheric load” on line 17.

A. done

(9) Page 2653, Introduction, line 21: insert “aerosol” in front of “sources” and “transformations”.

A. done

(10) Page 2653, Introduction, lines 26-29 (the last two sentences): It would be more accurate to say “To date, aerosol retrieval over East Asia has been actively studied due to unique aerosol characteristics in the region. This paper is also an attempt along this line.”

A. done

(11) Page 2654, Introduction, lines 1-11 (the 1st paragraph): It would be better to write this paragraph as “This study presents an aerosol retrieval based on interactive look-up tables (LUTs). We develop LUTs by means of statistical classification method, which is introduced in previous work (Omar et al., 2005). In this classification, aerosol optical properties were obtained from AERONET sun-sky radiometer data archive (AERONET, 2010). Aerosol retrieval is then processed by a step forward from the classified aerosol models and has the advantage of representing more accurate aerosol properties in the retrieval. The retrieved AOT from the 1 km resolution MODIS L1 calibrated reflectance data using this method is compared with MODIS Level 2 and AERONET AOT measured from the ground for validation.”

A. done

(12) Too many problems on the text and in the English that needs to be fixed. I will stop list them from now on. The authors should have the revised manuscript professionally edited before submission to improve the English.

A. The manuscript has been carefully edited by native speaker.

(13) Figure 2 and discussions on page 2656, line 21: The highest absorption (lowest SSA) was shown for category 3-4. The author should indicate that when AERONET performs retrieval of SSA, the absorption properties for fine and coarse models are assumed the same. Thus, for the cases either fine mode (categories 1-2) or coarse mode (categories 5-6) dominates, AERONET retrieved SSA is more accurate than the cases (categories 3-4) when the two modes are comparable.

A. This has been added on page 6 as;

“The AERONET inversion algorithm assumes the same absorption value for fine and coarse modes for SSA retrieval. In other words, uncertainty in SSA is lower for the dominant fine or coarse modes than for comparable models such as categories 3 - 4.”

(14) Page 2656, line 25: Since categories 5-6 can be considered as dust aerosols, categories 1-2 can also be considered as pollution aerosols and categories 3-4 as the mix of pollutions and dust.

A. Represent type of other categories has been defined as;

“Other categories can be considered a mixed type of pollution.”

(15) Page 2658, line 1: Is the AOT values at 550nm are used for the 11 AOT interval values in the LUTs?

A. SBDART controls aerosol loading with AOT at 550nm. The symbol τ_{550} is now used instead of “AOT at 550nm”.

(16) Following Fig. 3 and related discussions on Page 2657 (2nd paragraph), it would be better to show the phase function distributions (versus scattering angles) for 6 aerosol models (especially in back scattering angles) since it is very important for the satellite aerosol remote sensing. For the dusty aerosols in category 6, non-spherical assumptions should be used and the corresponding phase function can be inserted into the radiation transfer model to generate LUTs. In this simple way, non-spherical property of dust particles can be reasonably included in the retrieval. Considering the AERONET retrieval for dust aerosols does assume non-spherical particles and this paper is try to better characterize the aerosol properties for improving retrieval, using spherical assumption for dust aerosols in category 6 is a negligence that cannot be accepted.

A. Non-spherical assumption for dusty models were already used to radiative transfer and additional discussion is added on page 9 as;

“Unlike other aerosol models, such as urban- and pollution-dominated aerosols, which are well approximated by their equivalent spheres, dusty aerosols have highly irregular in their shapes (see Figure 9 from Arimoto et al., 2006). Therefore, their

optical properties differ significantly from those of spherical particles. Thus, nonspherical phase functions calculated by T-matrix code (Mishchenko and Travis, 1998) for dusty aerosol models (category 5 - 6) were used in radiative transfer calculations. The spherical particle phase functions produced retrieval artifacts in aerosol retrieval when dust was present (Dubovik et al. 2002a; b). Fig. 6 compares the phase functions for categories 5 - 6 with spherical and non-spherical assumptions at 550nm wavelength. The difference between the two categories was not significant, but non-sphericity was dominant. The phase function for non-spherical particles shifted upwards in the scattering angle range of 75° - 155° . In contrast, the phase functions for spherical particles varied significantly in the backward scattering region. For the LUTs with dusty aerosols, TOA reflectance was computed with non-spherical phase functions.”

(17) Page 2659, line 3: MOD35 cloud screening approach is used in current algorithm to determine clear-sky radiances used for aerosol retrieval. It had been pointed out by Martins et al. (2002; GRL) that MOD35 cloud screening is not sufficient for aerosol retrieval. This is because MOD35 cloud screening is mainly designed and optimized for cloud parameters retrieval and tends to be cloud conservative. Thus only using MOD35 cloud screening may result in evident cloud contamination in aerosol retrieval. This is why the standard MODIS aerosol retrieval adds more screening criteria to the MOD35 cloud screening scheme to reduce cloud contamination in the aerosol retrieval (see Martins et al., 2002; GRL).

A. We agree with this comment. Because the current algorithm has a heritage from the former version introduced in Lee et al 2007, cloud screening method by the modified MOD35 and from Martins et al(2002) were included. Additional explanation on cloud screen has been added on page 10 as;

“To determine clear sky pixels, cloud pixels were filtered out using the MODIS clear sky discrimination method (MOD35; Ackerman et al., 1998). However, the MOD35 method might not be suitable because it can mask out heavy aerosol plumes as clouds. Therefore, we used relaxed threshold values in MOD35 and the 3×3 pixel technique or inhomogeneous cloud detection (Martins et al., 2002). This is already used to former version of the algorithm (Lee et al., 2007).”

(18) Page 2660, line 13 (Fig. 4): More descriptions are needed for Fig. 4. For example, in the box with LUT, what $\rho_{Aer}(470) \rightarrow \tau_{550} \rightarrow \rho_{Aer}^*$ really means? Please provide step by step descriptions for Fig. 4 so that readers can really understand the algorithm.

A. More explanation on SSM in Fig.4 has been added on page 12 as;

“To select an optimum aerosol model, spectral shape matching (SSM) was used. This procedure compares aerosol reflectance from satellite observation and from various LUTs at a given sun-satellite geometry. The first step in SSM is finding theoretical AOT (τ_{550}^*) from a satellite estimated aerosol reflectance, ρ_{Aer}^{Sat} , at 0.47 μ m based on a LUT, which is a function of $\tau_{550} - \rho_{Aer}$. This τ_{550}^* value simultaneously provides the theoretical aerosol reflectance (ρ_{Aer}^*) at three channels (0.47 μ m, 0.55 μ m, and 0.66 μ m) for six aerosol models. ρ_{Aer}^{Sat} at those three channels were then compared against the ρ_{Aer}^* for each aerosol model, and if the minimum RMSD was found, AOT was determined as τ_{550}^* . Similar approaches have been reported in previous studies (e.g. Kaufman and Tanre', 1998; Costa et al., 1999; Torricella et al., 1999; Lee et al., 2007).”

(19) Page 2660, Section 5: This section 5 should be moved to ahead of Look-up tables section. As shown in Fig. 2, size distribution, SSA, and g are very different for the 6 aerosol models. It is worth to add sensitivity study for size distribution aside from SSA and g.

A. New Figure 4 and its explanation on page 8 have been added as;

“The aerosol size distribution is another key parameter for characterizing aerosol optical properties. Fig. 4 shows the AOT errors (1 ~ 5 %) in median radius and standard deviation equation (1). The AOT errors increased with size distribution error in each plot. Mean error values were 0.75% for median radius and 0.53% for standard deviation.

These values are much smaller than those caused by SSA and g. “

(20) Page 2661, line 19: It would be more accurate to perform linear fit in the logarithmic coordinate.

A. exponential fit gives larger correlation coefficients for two curves. Resulting equations have been added in the text (page 7 - 8).

(21) Table 2: *R* is mean radius or median radius? They are different in definition.

A. *R* is median radius.

(22) Table 3: For polluted case, MOD04 compares slightly better with AERONET than MSTAR does. Any explanation?

A. More discussion on Table 3 has been added on page 13 as;

“Table 3 shows that the MOD04 data for the polluted case agreed more closely with the AERONET data than the MSTAR data. The MOD04 AOT still overestimated the AERONET AOT > 0.08 at Beijing, but to a lesser extent than MSTAR AOT. This overestimation/underestimation of satellite retrieved values, however, was not uniform over the region. Additionally, the absolute mean differences indicate discrepancy in two cases (clean and polluted) equal to 0.073 based on MSTAR and 0.010 based on MOD04 datasets.”

(23) Fig 6: More info is contained in this plot that needs to be discussed. For example, maximal AOT in the LUT of standard MODIS retrieval is 2. AOTs larger than 2 are treated as missing data and this is why there are no (AOT and FMF) data for MOD04 in the dust plume center. The MSTAR indicates the dust plume as category 1 aerosol type (red), which is evidently wrong. These detailed features should be discussed in the text (page 2662, 2nd paragraph of section 6).

A. More discussion on Table 3 has been added on page 13 as;

“Although MOD04 exhibited a similar AOT distribution, it did not show clear sky and heavy dust cases well. The white pixels in the imagery are null data removed from the algorithm because the MOD04 retrieval algorithm classified AOTs > 2 as missing data. Although MOD04 exhibited a similar AOT distribution, it was higher than the AERONET results (Table 3), probably due to the uncertainty in the surface reflectance and the aerosol model.”

We found there was a mistake to match color to MSTAR aerosol type. Correction has been done as;

“Colors for MSRAR aerosol types are red (category 6), orange (category 5), yellow (category 4), green (category 3), sky-blue (category 2), and blue (category 1), respectively.”