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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Improvement of aerosol optical depth retrieval from MODIS spectral reflectance over the global ocean using new aerosol models archived from AERONET inversion data and tri-axial ellipsoidal dust database data" *by* J. Lee et al.

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The reviewer's comments were precise and helpful in improving the quality of our manuscript. We basically reïňĆected all the comments of the reviewer and attached the revised manuscript. The following is the response to the speciïňĄc comments. Thank you.

This study aims to improve the MODIS aerosol optical depth retrieval over ocean by introducing a new retrieval algorithm. At the heart of the new algorithm is a lookup table based on statistics of aerosol optical properties derived from the coastal AERONET inversion data and the tri-axial ellipsoidal dust database. The AOD retrievals from the new algorithm and the MODIS operational algorithm are validated against collocated AERONET AOD data. The retrieval errors/biases are further analyzed by investigating their dependence on AOD, the Angstrom exponent, the scattering angle, and the air mass factor. The authors concluded that, owing to the new aerosol models, the new algorithm in general improves the MODIS AOD retrievals over ocean, particularly for the high AOD cases, and the mitigation of the scattering angle dependence of the retrieval errors. The manuscript is well written, with a nice flow and structure. However, a couple important aspects are missing in the current version of the manuscript, as pointed out below in the major comments. Filling up these missing pieces will greatly enhance the completeness and usefulness of the present study. These revisions and a few minor (but still serious) issues should be addressed before the manuscript is accepted for publication.

Major Comments

1) More details on the new algorithm should be provided in Sections 2 and 3, including (but not limited to):

1.1) the key properties of the 23 new aerosol models and how those are compared to aerosol models in MODIS operational algorithm; The new aerosol models are the very essence of the test-bed algorithm, so at least a table should be provided in Section 3 to list their key properties (SSA, effective size, asymmetry parameter, etc). Discussions on how these new models differ from those used in the C005 algorithm will be useful and necessary. In addition, please state explicitly what aerosol properties from the aerosol models are used as input to calculate the LUT.

–> Key optical properties of new aerosol models are summarize in Table 2, and differ-

ence of TOA reflectance between new aerosol models and MODIS operational models is analyzed in Figure 4.

1.2) how the tri-axial dust database is being used to construct the new aerosol models; Section 3.3 (particularly page 7) is rather confusing. For example, the authors state [Lines 4-7] ": : :, so we decided to use the size distribution and nonsphericity from AERONET, and the refractive indices from the current MODIS algorithm: : :", and [Lines 15-16] "With regard to nonsphericity, mean "% sphericity" in the AERONET data is used with the fixed spheroid mixture...". So exactly which property from the "tri-axial ellipsoidal dust database" is taken? The input data into RTM are spectral AOD, SSA, and phase function. More detail description is added in Section 3.2. A more quantitative way to justify the use of refractive indices from MODIS algorithm (e.g. sensitivity test) is also needed. We added a sentence describing justification in using refractive indices from MODIS algorithm. "Although the refractive indices of the MODIS aerosol models are not completely consistent with those of the new aerosol models, low sensitivity of longer wavelength ($\lambda \geq$ 1240 nm) to fine-mode aerosols and relatively well-known absorption properties of dust (almost non-absorbing) are expected to result in smaller errors compared to excluding the longer wavelengths in retrieval procedure.". In addition, the authors mention [Lines 13-15] ". . .use of the TOA reflectance at these wavelengths can contribute to better FMF retrieval because of better sensitivity in discriminating particle sizes compared to shorter wavelengths, thus improving AOD retrieval." I don't quite comprehend which wavelengths are referred here, and why the TOA reflectance is mentioned here. I think these paragraphs need to be carefully revised to make more explicit and clear the contribution of the dust database to the aerosol models.

–> The paragraph is revised in a more explicit way.

1.3) clarification of the inversion procedure in the retrieval algorithm. The authors mention [Page 5, Lines 1-2] "The test-bed algorithm first retrieves AOD at 550 nm for all wavelength and aerosol models". Does it mean to retrieve AOD at 550 nm by match-

ing/minimizing the TOA reflectance at all wavelengths? Fig. 1 shows the inversion of C005 algorithm is done by spectrally matching TOA reflectance, while the inversion of the new algorithm is done by spectrally matching "AOD 550 nm" – can you please clarify how this is done? Moreover, can you please justify/explain why a different inversion procedure is used in the new algorithm, and comment on the possible consequence (see major point 2.2 below)?

–> The paragraph is revised in a more explicit way, and retrieval results using MODIS inversion method is added in Figure 6. The two inversion method retrieves almost same AOD except for negligible decrease in statistics for operational method.

2) Theoretical sensitivity tests are needed before carrying out the retrievals with the new algorithm and actual reflectance data. This not only helps with interpreting the retrieval results, but also adds more depth and value to this study by exploring the instrumental sensitivity of MODIS.

2.1) The new LUT (solution space) is constructed based on 23 aerosols models, but are they all necessary? In other words, some of the aerosol models might produce similar TOA reflectances at the 7 bands that including all of them results in redundancy and does not necessarily improve the algorithm. A theoretical calculation should be carried out, for example, by selecting one particular aerosol model to do a forward modeling with an assumed AOD value (and surface, etc). Then do the inversion to see what AOD, SSA, and FMF is retrieved back. Test for the other aerosol models to cover the SSA and FMF range and analyze how the retrieval varies can provide valuable information. Analysis for retrieval accuracy is added with Figure 5. While MODIS operational algorithm virtually handles 20,020 aerosol models (20 combination x 1001 FMF), the present algorithm assumes no mixing among aerosol models.

2.2) How much of the difference between the new and original retrieval is resulting from the different inversion processes (the method to do minimization, the choice of bands based on AOD, etc) other than the difference in aerosol models? To answer this

question, a test can be done by replacing the new LUT with the original C005 LUT and carrying out the retrievals with the new inversion procedure, and compare the retrieved AOD with the operational retrievals.

–> Difference in retrieval results from the two inversion procedures is negligible except for a little improvement from new inversion method. Retrieval results between two method are compared in Figure 6. Minor Comments:

1) [Page 3, Lines 24-33] "...a recent validation by Remer et al. (2008) ... significant underestimation of AOD over the ocean from Aqua-MODIS in particular": Fig. 1 in Remer et al. (2008) shows a slope = 0.90 and R=0.907 for Aqua-MODIS AOD over ocean. Is this really a "significant" underestimation? Can you also comment on the other possible explanations to this underestimation besides aerosol models (e.g., instrumental calibration)?

–> The sentence is revised to 'underestimation of AOD over the ocean from Aqua-MODIS for high AOD in particular'. Although instrumental calibration could be possible reason for the underestimation, it seems to be mainly due to inaccurate assumption in aerosol models since the underestimation occurs for high AOD regime only and shows negligible underestimation for dust for specific scattering angles.

2) [Page 6, Line 28; Page 7, Line 17]: "sea-salt" should be "sea salt"

Corrected.

3) [Page 9, Lines 25-27] "The major reason for the improvement in AOD is the consideration of absorbing fine-mode aerosols and AOP, and size distribution in particular, as a function of AOD": Again, to support this argument, a comparison between new and C005 aerosol models is needed (see major point 1.1).

–> Comparison between new and C005 aerosol models is added in Figure 4.

4) [Page Lines 15-17] "Underestimation of the fine particle-dominated AOD seems to be related to the high AOD because the C005 algorithm systematically underestimates

AOD for the high AOD regime, as illustrated in Fig. 4.": The causality stated here is confusing. The goal of the error attribution is to explain what is causing the error in Fig. 4. I think the general message in Fig. 5a is some of the high AOD cases can have high AE (fine-mode dominant), and some can have low AE (coarse-mode dominant), and the underestimation of the high AOD cases by the C005 algorithm happens only when fine mode is dominant.

The sentence is revised to "The underestimation of fine-mode AOD worsens for high AOD cases. This explains that the underestimation of high AOD from C005 algorithm shown in Fig. 4 is mainly caused from fine particle-dominated cases, while reliable retrieval is performed for dust aerosols.".

5) [Page 10, Lines 17-19] "However, the algorithm overestimates the observed AOD for 0.2 < AE < 0.4 even though the data show high AOD compared to the fine particle dominated case": In Fig. 5a the "overestimation" of AOD in the AE range is _0.02, while the mean AOD is _0.2 (or 0.5 for the high AOD cases). I think this is within the MODIS expected error?

–> Correct.

6) [Page 11, Lines 3-28]: The order of Figs. 6 and 7 (and the corresponding discussion) should be reversed, as Fig. 6 is a subset that explains some of the biases shown in Fig. 7.

–> Corrected.

7) [Section 4.2]: Also worth exploring is how the mean bias/retrieval errors related to SSA. Plots similar to Figs 5-8 can be made with SSA in the x-axis.

–> A plot is added for exploring retrieval errors related to SSA.

8) Please change Tables 2a and 2b to Tables 2 and 3, respectively.

–> Corrected.

9) [Figs 5-8]: Too much information is squeezed together. Plotting the mean AOD (i.e. squares and triangles) in separate panels might help. For the MB (black and grey circles), please highlight the dots that are statistically significant (i.e. MB > 1-_ of mean AOD, or MB > Expected Error, etc) in other color.

–> Corrected.

10) I believe the mean AODs (squares and triangles) in Figs. 7 and 8 need to x5, but not in Fig. 6. If this is the case, please state explicitly in the captions.

–> Corrected.

Please also note the supplement to this comment:
http://www.atmos-chem-phys-discuss.net/11/C16585/2012/acpd-11-C16585-2012-supplement.pdf

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