Atmos. Meas. Tech. Discuss., 6, C3706–C3713, 2013
www.atmos-meas-tech-discuss.net/6/C3706/2013/

Atmospheric Measurement Techniques Discussions

Interactive comment on "Role of coarse and fine mode aerosols in MODIS AOD retrieval: a case study" *by* M. N. Sai Suman et al.

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Received and published: 16 December 2013

Responses to comments by Dr. Hiren Jethva.

We thank Dr. Hiren T. Jethva for reviewing our manuscript and providing suggestions for its improvement. We provide below detailed responses to his comments.

1. We thank Dr. Jethva for appreciating importance of validation exercises in improving the algorithm and noting that such a validation exercise are very less over Indian region. We thank him for pointing out that possibly ours is second such study after Jethva et al. (2010; Henceforth referred as J10) for validating fine mode AOD of MODIS.

2. In the context of our suggestion that aerosol models being used for South Asia are inappropriate, Dr. Jethva has mentioned that we reach different conclusion then J10. J10 have carried out sensitivity analysis over an AERONET site in Northern India (Kanpur) and found that fine mode fraction is highly sensitive to error in surface reflectance in visible channel. We would like to mention that we do not contradict this assertion of J10. Error in surface reflectance has certainly big potential to affect fine mode AOD retrieval. However, for following three reasons, we believe that inappropriate aerosol model for South Asia in MODIS algorithm has major role to play irrespective of errors in surface reflectance.

   (a) Reason 1: Aerosol models used in MODIS for South Asia has higher single scattering albedo than observed using ground-based instruments. SSA data were not shown in earlier manuscript but in the revised manuscript we include it.

   (b) Reason 2: Aerosol model plays a role in retrieval of surface reflectance. Hence error in surface reflectance is not independent of aerosol model.

   (c) Reason 3: J10 also have reported significant improvement in reducing underestimation when they used more absorbing aerosol model instead of default model for South Asia.

   These aspects were not highlighted prominently in the previous manuscript. In the revised manuscript, we make it explicitly clear that while moderately absorbing model is one of the reason for underestimation, it is alone not sufficient for observed differences between ground and satellite AODs.

3. Dr. Jethva suggested in general comments that language and representation of the manuscript can be improved. We want to assure that in the revised manuscript we have paid full attention to this suggestion and taken all possible care to improve the language and representation.

Specific Comments

(The comments by Dr. Jethva are shown in italics, whereas our responses are shown in normal fonts.)

1. *Abstract: Not just correlation but also mention RMS difference.*

   In the revised manuscript, we mention correlation coefficient and slope of least square fit. Values of RMS difference which were not provided earlier now provided in the Table 1.

2. *Abstract: Use 'southern India' terminology instead of 'South India'.*

   In the revised manuscript, we refer region as Southern India.

3. *Introduction, Page 9111, line 14: there is a paper by O'Neill et al. which directly retrieves fine and coarse mode fractions from the direct spectral AOT measurements.*

   We thank Dr. Jethva for drawing our attention. Earlier we cited O'Neill et al. (2003) in other part of manuscript but we missed to cite it along with methods to separate coarse and fine mode AODs.

4. *Introduction, Page 9111, line 26: over land as well as ocean*

   We wanted to emphasis the fact that there are only few satellite sensors that provide AOD over land. In the revised manuscript, whole paragraph is restructured to highlight this emphasis.

5. *Introduction, Page 9112, line15-20: A sensitivity study conducted by Jethva et al. (2010) shows that the retrieval of FMF is strongly impacted by the assumed surface reflectance in the visible channels.*

6. *Introduction, Page 9113, first paragraph: Jethva et al. (2010) validated MODIS C005 multi-year AOD and FMF retrievals AERONET data at Kanpur. Also, they compared the different set of MODIS retrievals with the in situ size-resolved properties measured during ISRO-GBP Feb 2004 campaign over southern India. Based on these results, the paper concluded that the retrievals of fine/coarse mode AODs and FMF are strongly sensitive to the assumption of the surface albedo at visible wavelengths. The selection of aerosol model played a secondary role in the whole exercise.*

   We thank Dr. Jethva for drawing our attention to importance of surface reflectance in retrieval. Earlier we missed to provide appropriate comparison with results from J10. In response of both above comments, we have revised our manuscript and provide more discussion on this.

7. *Introduction, Page 9113, line 7: to diagnose deficiencies in the algorithm.*

   In the revised manuscript, it is corrected.

8. *Introduction, Page 9113, line 14-17: define the study region here. Along with size resolved properties, present study also compares the MODIS total AOD against ground measurements.*

   In the revised manuscript, the suggestion is included.

9. *Section 2.2, MODIS data, Page 9115, line 3: Does MODIS L3 1 deg data are of the best quality (Quality Flag=3?)?*

   No specific filtering of MODIS data has been done for the present study. The MODIS science team provides level 3 data that are calculated by averaging level 2 data over 1 deg x 1 deg grid. While averaging level 2 data, the data with quality confidence flag (QAC) zero are excluded and remaining data are weighted with QAC flag. Value of QAC flag varies from 0 to 3 where 3 being the best quality data. Since this aspect has been available in public domain for data users and

extensively reported by other researchers, we do not write it in the manuscript but provide reference to it.

10. *Section 2.2, MODIS data, Page 9115, line 24-28: Without performing a sensitivity analysis and/or showing the large discrepancies between the observations and algorithm assumptions, it is merely an empty speculation to make a statement about the appropriateness of the aerosol model. Author should have supported his statement about lower SSA by providing information on the ground-measured columnar SSA over the study location.*

    Our suggestion to use more absorbing type of aerosol model in MODIS algorithm is based on scientific reasoning as mentioned in beginning. In the revised manuscript, we provide SSA values for the comparison.

11. *Section 3: Results and discussion, Page 9116, line 15: A similar time-series plot of Angstrom Exponent will show the seasonal difference in the dominant aerosol type. I suggest to add this plot along with the present AOD plot.*

    Angstrom exponent is one of the popular way of showing spectral dependence of AOD. We try to show this information in different way which we believe is straightforward and since Angstrom exponent has an intermediary role between actual size distribution and AOD spectrum, we are of the opinion that including Angstrom exponent plot may not add further value to scientific discussion already been presented.

12. *Section 3: Results and discussion, Page 9117, 1st paragraph: This is an important piece of information retrieved from the sky-radiometer observations. The particle size distribution is reported in the manuscript. However, no data pertaining to the refractive index (real and imaginary) are being presented and discussed anywhere in the paper. This appears to be a severe weakness of the present work. Author put forward the argument based on the MODIS/ground instrument comparison that the aerosol model selection in the MODIS algorithm*

is inappropriate. This conclusion should be based on a one-to-one comparison between the aerosol model used by the satellite algorithm and one retrieved from the ground instrument. An analysis on the comparison of the PSD and SSA between MODIS algorithm and ground-based measurements is badly needed to support the argument made by the authors.

In the revised manuscript we include seasonal mean of single scattering albedo which encompasses information on refractive index.

13. *Section 4: Page 9119, Conclusion: Emphasize here that this was the first MODIS validation study over Gadanki, southern India. It is valuable because most validation studies compared MODIS retrieval with that observed by the AERONET sunphometers, which Gadanki doesn't have. However, it has its own sky-radiometer measurements of the spectral AOT and inversions which in my opinion is a valuable database for the satellite validation and aerosol climatology over that region.*

    We thank you Dr. Jethva for this suggestion. In the revised manuscript, we highlight this aspect.

14. *Section 4: Page 9119, line 15: Seasonality is captured by MODIS but with significant differences in retrieval of size-resolved properties.*

    This statement we have written in context of fine mode fraction in the conclusion.

15. *Section 4: Page 9119, line 20: the selection of aerosol type used in the MODIS retrieval may not be a source of observed discrepancies, particularly the size-separated fine and coarse mode AODs.*

16. *Section 4: Page 9119, line 23: "a more absorbing type aerosol is better suited for fine mode aerosols". Author cannot make such statement without presenting supportive measurements of the aerosol single-scattering albedo over that station.*

We believe that aerosol model being used in MODIS algorithm for Southern India is not appropriate. We provide scientific reasoning and SSA data in support of our argument as mentioned in the beginning. Sensitivity analysis done by J10 also supports this reasoning (e.g. Figure 1 and Figure 2 in J10). Mere fact that the algorithm is more sensitive to surface reflectance does not negate the requirement of having correct aerosol model in the algorithm.

17. *Section 4: Page 9119, line 24-25: "use of coarse mode sea-salt model". This could be true. However, MODIS doesn't employ sea-salt model over land. Its over ocean algorithm should have such models.*

    Our perspective on MODIS algorithm is not instrument centric or algorithm version centric. We view MODIS and its algorithm as mile stone that many future generation will rely upon and will use as building block for new algorithm. Suggestion such as one above may not be implementable immediately but may find place in future.

18. *References: Page 9121, line 20: Jethva et al. (2010) listed in the references but not cited/discussed anywhere in the text!*

    In the previous manuscript, we did not provide one to one discussion with J10 though we referred it along with studies that reported validation aspect of MODIS AOD. In the revised manuscript, we include more comparison along with Levy et al., 2007 and Lee and Chung 2013.

19. *Table 1. 'Total AOD' in place of 'Unseparated AOD*

    In the revised manuscript, we mention it as total AOD.

20. *Table 1. Correlations are not enough. Add RMS and slope of linear regression. Figure 2 and Figure 7 have these numbers which should be also listed in this table.*

    In the revised manuscript, we include this information in the table.

21. *Figure 2. Provide the uncertainty equation in caption (0.05+0.15*AOD).*

    In the revised manuscript, we include this information in the caption.

22. *Figure 3. A similar time-series plot of Angstrom Exponent would highlight the seasonality of aerosol type, i.e., smoke vs. dust*

    As mentioned before, seasonality of aerosol size properties can also be deduced from fine mode fraction and coarse mode and fine mode AOD shown in Figure 5 and 6. Adding Angstrom Exponent will not enhance scientific information of the manuscript more than what it already contains.

References

- Jethva, H., Satheesh, S. K., Srinivasan, J. and Levy, R. C.: Improved retrieval of aerosol size-resolved properties from moderate resolution imaging spectroradiometer over India: Role of aerosol model and surface reflectance, J. Geophys. Res., 115, D18213+, doi:10.1029/2009jd013218, 2010.
- O'Neill, N. T., Eck, T. F., Smirnov, A., Holben, B. N. and Thulasiraman, S.: Spectral discrimination of coarse and fine mode optical depth, J. Geophys. Res., 108, 4559+, doi:10.1029/2002jd002975, 2003.