

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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Responses to comments of Reviewer#1.

We thank reviewer #1 for reviewing our manuscript and making suggestions for improvement. Our responses are provided below.

1. *Reviewer #1 suggests that ours are not new results in context that MODIS science team has already described fine mode fraction as not an accurate product and results related to validation of total AOD are similar to our previous study (Kiran Kumar et al., 2013).*

As we have mentioned in the manuscript, size-distribution of aerosol is one the C3820

highly sought after information by scientific community. In spite of limitations of MODIS fine mode fraction, several researchers are using fine mode fraction, see for example Luan and Jaeglé (2013), Sreekanth (2013), Panicker et al. (2013), He et al. (2012), Abish and Mohanakumar (2011), Jones and Christopher (2008), Ramachandran (2007) and Kaskaoutis et al. (2007). Accuracy requirement depends on end use of the parameter and hence genuine validation efforts are in order even if the MODIS fine mode fraction is believed to be inaccurate product. Moreover as mentioned by Levy et al. (2010), the fine mode fraction has value as a diagnostic variable for total AOD. Precisely, this is the use we have put into fine mode fraction in suggesting that aerosol models in MODIS algorithm over Southern India are not representative of real aerosol properties.

As pointed out by reviewer himself/herself, Kiran Kumar et al. (2013) and the current study are different in the sense that Kiran Kumar et al. (2013) used only 2009 data set for comparison whereas current study uses April 2008 to March 2011 data set. Also, Kiran Kumar et al. (2013) did not study fine mode fraction which is the focus of the current study.

Though qualitatively Levy et al. (2010), Jethva et al. (2010) and our study have similar outcome in regard of accuracy of fine mode fraction, quantitatively we find many differences, which we believe peculiar to Southern Indian region. For example Levy et al. (2010) have found better comparison for fine mode AOD than coarse mode AOD whereas we find better comparison for coarse mode AOD. Levy et al. (2010) and Jethva et al. (2010) have not found any significant underestimation for total AOD whereas we find significant underestimation for total AOD over Southern India.

MODIS science team has opted for highly absorbing type of aerosol model for North India and South East Asia in revised algorithm (Collection 6) but left aerosol model same as moderately absorbing for Southern India (Levy et al., 2013). We believe if there has been good number of validation studies such as ours over

Southern India, it would have resulted in use of correct aerosol model that is highly absorbing aerosol model for fine mode over Southern India.

2. *Reviewer #1 mentions about importance of surface reflectance vis-a-vis aerosol model citing Jethva et al. (2010) and Levy et al. (2013), suggesting surface reflectance is more important than aerosol absorption properties.*

There is no denying of fact that fine mode fraction retrieval is highly sensitive to surface reflectance. However, sensitivity study alone in itself is not a proof of surface reflectance causing observed differences between ground-based and MODIS data. To prove that surface reflectance has caused underestimation, one would require to prove, surface reflectance is indeed wrong. Recent surface reflectance related correction in MODIS algorithm (Collection 6) has resulted in reduced AOD over India (Levy et al., 2013) and hence it has not contributed to resolve the problem of underestimation of AOD over India in general and over Southern India in particular.

We do not imply that there is no error related noise and biases in surface reflectances, But as mentioned in the responses to Dr. Hiren Jethva, aerosol model also plays significant role in retrieval algorithm. Jethva et al. (2010) have shown using sensitivity study that underestimation problem of fine mode was significantly reduced when they used highly absorbing aerosol model instead of default moderately absorbing aerosol model. Moreover Figure 4 of Jethva et al. (2010) implies that sensitivity towards aerosol model is a function of surface reflectance. When surface reflectance is increased by 0.02 as suggested by Jethva et al. (2010), MODIS total AOD will have bigger errors than before if highly absorbing type of aerosol model is not used.

3. *Reviewer #1 has mentioned about sensitivity study reported in Levy et al. (2013) in which they have not found increase in algorithm skill when coarse mode is made absorbing type and fine mode is made scattering type.*

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Very few details of the said sensitivity study is provided in the article, hence it is difficult for us to provide conclusive response on it. However, it should be noted that we have not suggested making coarse mode more absorbing type. Our suggestion is to make coarse mode further scattering type and fine mode further absorbing type. In the revised MODIS algorithm (collection 6), highly absorbing type of aerosol model for fine mode is used over Northern India, which is in line with our suggestion and if there were no benefit in using absorbing aerosol model for fine mode as we suggested, they may not have done this.

4. *Reviewer #1 has raised concern over appropriateness of use of single scattering albedo to justify our argument that both fine mode and coarse mode require revision whereas single scattering albedo values are not size resolved.*

We put forward our argument that highly absorbing type of aerosol for fine mode and scattering type of aerosol model for coarse mode on two different lines of reasoning. The first line of reasoning is based on the way MODIS algorithm works and fact that fine mode is consistently underestimated whereas coarse mode is overestimated. In the 2nd line of reasoning which is included after receiving suggestions of reviewer #2 and Dr. Hiren Jethva, is based on one to one comparison of SSA used in MODIS algorithm and observed using sky-radiometer. Composite single scattering albedo is AOD weighted mean of SSA of two modes of aerosols and hence its value will lie between the two SSA values being used. Since both aerosol models in MODIS for South Asia have SSA values higher than observed SSA, it conclusively proves that absorption (scattering) properties of aerosol in MODIS algorithm are not appropriate for Southern India.

5. *Reviewer #1 has mentioned that we have not supported our argument that aerosol model currently (collection 5) being used in MODIS algorithm are not appropriate.*

We do not agree with this opinion of the reviewer. Our argument is based on

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scientific reasoning and we have supported it with data. As mentioned in previous reply. Our argument is based on two lines of reasoning, first based on differences in size resolved aerosol properties and second based on differences in optical properties (single scattering albedo). In our previous manuscript, we did not include single scattering albedo data which might have led reviewer to this opinion but in the revised manuscript SSA data are provided.

Minor Comments

1. *Reviewer #1 has asked for providing statistics for Aqua.*

We thank reviewer #1 for this suggestion. In the revised manuscript we are going to provide statistics for MODIS Aqua.

2. *Reviewer #1 writes "Section 2.1 : How is the sky-radiometer data interpolated to the MODIS wavelengths? Are gases accounted for properly in the computation of AOD?"*

We have used linear interpolation on logarithm of wavelength and logarithm of AOD at 500 and 675 nm to interpolate it at 550 nm. Rayleigh optical depth correction is based on daily mean surface pressure values whereas ozone correction for 400 nm channel is based on OMI columnar ozone data over Gadanki. Contribution of other gases is far too small compared to aerosol optical depth for the wavelength bands used in Prede sky-radiometer. Earlier this was not mentioned but in the revised manuscript, we are going to mention this.

3. *Reviewer #1 writes "Section 2.2 : Level 2 data is typically used for these types of validation studies, why was level 3 used?"*

As mentioned in the reply to reviewer #2, decision to use level 3 is based on our previous study. In our previous study (Kiran Kumar et al., 2013), we have studied

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spatial correlation of AOD using high resolution level 2 data. We found that AOD over Gadanki was highly correlated for distances of the order of 150 to 200 km. In other words, our place of observation is characterised by relatively homogeneous region of aerosol properties. In this circumstances Level 3 data (which are based on averaging Level 2 data) are helpful to reduce error arising out of random noise and have less number of missing data compared to Level 2 data. Earlier this was not mentioned in the manuscript, but in the revised manuscript we are going to mention it.

4. *Reviewer #1 writes "Conclusion : The authors assert that Gadanki would have more sea salt than dust because it is far from desert and closer to ocean. This is an oversimplification. Dust has been shown to be a significant source of aerosol over the Arabian Sea (e.g. Tindale and Pease, 1999), and it would not be surprising for these aerosols to be transported across India. Perhaps some chemical transport model data would be helpful to support the dust vs. sea salt argument."*

We thank reviewer #1 for this suggestion. We agree that our suggestion to use sea-salt is simplification of situation, but so is the use of dust aerosol. In real atmosphere, one expects to have mixture of both dust and sea-salt for coarse mode. When we are making suggestion that sea-salt aerosol type to be used for coarse mode, we are trying to answer question which aerosol type will be more dominant for major part of a year over Southern India? Our suggestion arises from observation that coarse mode AOD in MODIS algorithm is generally over-estimated. We have evaluated our suggestion to see whether it is consistent with other known facts about the region and in this context we have written that Southern India is relatively far from desert and have ocean on its three sides.

Similar opinion is expressed by other researchers who studied aerosol properties on and around the region. Tindale and Pease (1999) have expressed surprise and mention that dust concentration over Southern Arabian sea and close to Indian coastline are less particularly in summer when high dust concentration

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is expected because of upwind African and Middle East region. Tindale and Pease (1999) citing Moorthy et al. (1997) have mentioned that sea-salt optical depth is nearly 70% of total AOD over Arabian sea during summer. They suggest this is probably due to Findlater jet which blocks dust rich air from Africa being transported toward east and dominance of air masses coming from Southern ocean which have less dust particles. Chatterjee et al. (2010) have studied rain water chemistry over Gadanki and found conspicuous presence of sea-salt. Ginoux et al. (2012) have reviewed dust optical depth globally. They have found statistically negligible number of dust events and dust optical depth over Southern India. In the revised manuscript, we are going to provide citations in support of our statement that sea-salt aerosols are more prevalent over Southern India.

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