

Interactive comment on “Evaluating the assumptions of surface reflectance and aerosol type selection within the MODIS aerosol retrieval over land: the problem of dust type selection” by T. Mielonen et al.

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We would like to thank the Anonymous Referee #2 for the constructive comments.

1) The language requires major improvement. The second co-author of the paper may certainly help in this regard. Here are few examples from the manuscript: “Our study suggests that the aerosol model combining is sensitive . . .”

- The language has gone through major revision. We did major changes to the text to

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improve the readability. For example, here is a part from the original abstract: “At all studied sites, the MODIS algorithm often selects the dust aerosol model even when dust does not seem to be present and the air masses are not coming from arid regions. This happens especially when AOD values are relatively small (< 0.3). The selection of the dust model reduces the correlation between ground based and MODIS AOD measurements in dust-free situations. Moreover, the current aerosol model selection scheme produces unphysical AE values. Our study suggests that the aerosol model combining is sensitive to the ratio of 660 nm and 2130 nm surface reflectances (slope(660/2130)). Furthermore, the value of the slope in the algorithm is mainly dependent on the Normalized Difference Vegetation Index (NDVI). The current relationship of these two parameters in the algorithm is not supported by the surface albedo climatology derived from MODIS measurements. The use of a more physical relationship improves the AE retrieval at the studied sites. However, at some sites the AOD correspondence deteriorates when the new relationship is used.”

And here’s the revised version: “This indicates that the assumptions made by the MODIS algorithm may have been incorrect. Here we focus on problems related to parameterization of the land-surface optical properties in the algorithm, in particular the relationship between the surface reflectance at 660 and 2130 nm. The retrieval assumes that there is a linear equation that relates the reflectance in these two channels, with the value of the slope (slope660/2130) determined, in part, by the infrared Normalized Difference Vegetation Index, (NDVISWIR). However, the dependence of the slope and the NDVISWIR is not supported by a MODIS based surface albedo climatology. The use of a modified relationship based on the albedo data improves the AE retrieval at the studied sites. The increase in the AE agreement fraction between MODIS and AERONET measurements is between 3 and 22 percentage units depending on the site. However, at some of these sites, the new relationship may deteriorate the total AOD correspondence. This deterioration indicates that the combination of the assumed surface and aerosol properties still do not match the actual properties under investigation.”

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p. 3428: “algorithms made to retrieve information from satellites are underdetermined”. Algorithms can be good or bad, but they cannot be underdetermined.

- We clarified in the text that: “algorithms are underdetermined in their information content”

Everywhere: change “fine aerosol” or “coarse aerosol” to fine mode aerosol or fine aerosol particles. Everywhere: please, don’t use the word “dominated” with respect to aerosols, rather use some other terminology. For example, you can explain in the beginning that the regional (or baseline) aerosol model based on AERONET climatology will be called “a fine aerosol model”.

- The expressions with “dominated” were replaced with “fine model”.

p. 3429: Uncertainties in the surface reflectance, as well as aerosol absorption are too large. Should be “as well as in aerosol absorption”.

- This was corrected.

“The slope(660/2130) also depends on the scattering angle, however, it does not have as large effect as the NDVI.” Where does it follow from? Is this the law of nature or what? At least, you should say that “In parameterization of Levy et al., (), . . .”.

- A more detailed description of the retrieval algorithm was added to the text (Section 3). The description contains all the relevant equations used in the retrieval. To clarify the above statement, we added a reference to the relevant equation.

“However, this second slope does not have as strong effect on the aerosol model combination.” You may say “retrieved dust fraction” instead of “aerosol model combination”.

- “Aerosol model combination” was changed to “retrieved fine model weighting”.

3435: “are equal for the over and under classes” You may re-phrase it as: .. for $AE > 1$ and $AE < 1$ cases.

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- Done.

3437: “for single pixels” Correct to “a single pixel”.

- This was changed to “individual pixels”.

2) The current logic of the paper is very “fuzzy”. The link between the causes and the consequences is not thought through. For this reason, I had to read some sections several times before I could arrive at conclusion of what authors tried to say, mainly based on my knowledge in the field rather than on what’s written.

- The structure of the paper and the language were revised thoroughly to remove the fuzziness. For example, the analysis with the standalone algorithm is now presented in one section for easier reading.

What is also missing in the paper is a clear discussion of why these specific parameters are studied.

- The added description of the retrieval algorithm in section 3 clarifies this.

How can you expect improve aerosol retrievals given huge uncertainty in the surface parameterization (see Fig. 5)? A small theoretical sensitivity study would tell you what can be expected at this level of uncertainty. In other words, this would help to answer the question of what accuracy in surface parameterization is required to derive AE using MOD04 algorithm.

- The sensitivity study was a good idea! We did it and it showed that in order to have less than 20 % error in the retrieved AE value, the error in the slope(660/2130) has to be less than 10 % when AOD is between 0.2 and 0.4. For larger AODs the error in the AE is smaller but for smaller AODs it can be significantly higher. The error of 20% in AE means that AE of 0.6 could vary between 0.48 and 0.72, and AE of 1.5 could vary between 1.2 and 1.8. This accuracy would still enable the separation between fine and coarse aerosol particles.

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3436: "This raises the question whether absorption capacity of the fine dominated aerosols would affect the combination of the aerosol models in the MODIS aerosol retrieval?" So, where is the answer? Without any further discussion you switch the subject.

- The answer is given in the section 3.3 where we state that " These results show that the absorption of the fine model does not affect the AE agreement, however, it has a significant effect on the AOD correspondence at some sites, like Alta Floresta and Xianghe.". This is based on the results shown in Table 3 and Figure 6 in the revised version. To clarify the text we added the following sentence after the question: "However, before we can answer this question we have to study how the aerosol model combination is affected by surface parameterizations, see below." And after the surface study we conclude that " Based on these results, it seems that both aerosol absorption and surface parameterizations could have effects on the aerosol model combination in the MODIS retrieval. In order to separate their effects, we have to study the retrieval algorithm in more detail."

"In the next step, we investigated the surface reflectance values from the C5 data for single pixels and divided the data into two classes based on MODIS AE as before. Then we calculated the monthly mean surface reflectances at 660 nm from all measurements and normalized the surface reflectance values with these mean values to remove seasonal variations." I cannot understand what was done. The predicted surface reflectance in MOD04 algorithm based on measurements at 2.1 km and parameteric formula does not depend on AE. Normalization does not make sense either.

- You're right that the MODIS aerosol retrieval has no equations relating surface reflectance to AE. However, the modeled TOA reflectance is the sum of surface reflectance and path radiance. The amount of path radiance depends on the aerosol model used. The dust model has larger path radiance and, therefore, smaller surface reflectance than the fine models at 2.13 μm . Thus the surface reflectance values are indirectly connected to the fine mode fraction and AE. This is what we wanted to show

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in this section. We normalized the surface reflectance values to remove the effects of natural variation in surface reflectance properties due to seasonal cycle of vegetation. The text was clarified.

As a continuation: "Surface reflectance should not depend on the AE, as the AERONET AE data shows." ??? How can you make any conclusion about surface based on AERONET measurements?

- This statement refers to Figure 3 which shows that the normalized surface reflectance for the MODIS measurements with AE > 1 stay almost constant as a function of AERONET AE.

3) Some statements of the manuscript are either incorrect or unfounded. 3433: "The dust model has always larger TOA reflectance values at 660nm than the fine dominated model." That may not be a true statement.

- This was added to the text for clarification: "Having AE of 0.6, the dust model has a flatter spectral dependence than any of the fine models (AE = 1.6). Thus, for a given loading index (AOD at 550 nm), the coarse (dust) model contributes more to the TOA reflectance at 660 nm than does the fine model."

3434: Please, explain the choice of selected resolution (60 \times 120) of surface albedo. You only get 9 points across the globe. How can you use these data for analysis of MODIS retrievals made at 10 km resolution? Using 0.5 by 0.5 resolution seems to be much more logical for this analysis.

- We did not compare the albedo values with actual MODIS retrievals. Instead we compared them with the assumed NDVI-slope relationship used in the algorithm (as shown in Fig. 5). The current relationship is used globally and we wanted to check if it is ecotype dependent. The surface albedo values we used were averaged for different ecotypes in these 9 areas (14 ecotypes for each area). In addition, the yearly cycle of the vegetation was taken into account with albedo values reported for every 16 days

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(23 in total for each ecotype). Therefore, we got (23x14) 322 values for each area and (9x23) 207 for each ecotype. We thought that it is enough for this kind of a general comparison. For comparison with actual MODIS retrievals we would definitely use data with the best resolution.

“Surface albedo is the ratio of the radiant flux reflected from a unit surface area . . ., thus it is not angle dependent.” This is not true. By definition, albedo is a ratio of reflected to the incident radiative fluxes at the surface, and it depends on solar zenith angle (SZA).

- One important word was missing from that sentence. It should have been: “it is not view angle dependent”.

p. 3430: Please, provide a reference to the MODIS instrument which is relevant.

- Reference to Salomonson et al. (1989) was added.

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