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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Global evaluation of the Collection 5 MODIS dark-target aerosol products over land" *by* R. C. Levy et al.

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Responses to Reviews

We would like to thank the reviewer for their time in reading and reviewing this lengthy paper. We appreciate their comments and have endeavored to address each recommendation seriously. Only the comments that require revision/rebuttal are included here.

REVIEWER #2

Adding to Section 2 a few words on the retrieval method might help in this respect: as described in Section 2 (pp 19 and 20) and section 3 (24, 13) AOD at 555nm and ETA are the primar y ïňĄtting parameters: why if 555 nm is not used in the retrieval?

How are the MODIS wavelengths (470 and 650 nm) used in the retrieval? How can the model weighing factor ETA, based on the comparison of the spectral AOD from MODIS and the forward model (using LUTs), be determined for 555 nm? Should that include the two mentioned wavelengths, in which case also the AOD at these wavelengths (spectral AOD) would be primary? I presume that the ETA is not a physical parameter because "effective" aerosol models are used, i.e. models that describe a quantity that would provide a ïňĄt over the column, rather than the actual models which would change with air mass at different heights and var ying relative humidity throughout the column? Is there such large uncer tainty in ETA and in AE, because they are no real physical parameters but related to an effective column? And why is there higher conïňĄdence in AOD? Why is spectral AOD determined from AOD at 555 nm and ETA and not directly if used in matching the spectral dependence and aerosol models (see above); if there is little conïňĄdence in ETA, how can there be such high conïňĄdence in AOD at 555 nm? Likely all these questions have been answered in earlier papers on the method, but it may help the reader if this is brieïňĆy explained here as well (with proper reference to more extensive explanation).

We have completely revised the introduction about the algorithm (sections 2.0 and 2.1), and answer many of the questions.

For example, the confusion about 0.55 μm is addressed in combination of these two text sections:

.. a vegetated surface is not "dark" in the green MODIS wavelength (e.g. 0.55 μm), and therefore, the 0.55 μm channel cannot be used directly.

And

. . .Since the LUT is spectrally consistent, when the algorithm matches the measured reflectance at 0.47 and 0.65 μm to calculated values from the LUT, the AOD at any wavelength is automatically determined. Thus, although the MODIS-observed 0.55μm reflectance is not used directly within the inversion, the AOD value at 0.55 μm can be

retrieved directly and without interpolation. Levy et al., (2007b) chose to report 0.55 μm as the primary wavelength because it falls between the two channels that contribute information. Also, 0.55 μm is consistent with the primary wavelength used by models and other community-wide applications, including the MODIS retrieval over ocean (e.g. Remer et al., 2005).

Minor comments (page nr indicated by last 2 digits, line nr) 17, 10: spectral resolution: the number of bands does not indicate the resolution of these bands; of these 36 bands only 3 seem to be used for the retrieval over land (20, 12))

TRUE

18, 16: the C004 products were not accurate enough for use in global model assimilation: what are the criteria that aerosol products can be used for global model assimilation and are the C005 products good enough?

We don"t really know, other than anecdotes from investigators working with these models. They seem able to "work" with Coll5 MODIS data where before hand, they couldn't work with the data. There is now an AMTD paper: Citation: Hyer, E. J., Reid, J. S., and Zhang, J.: An over-land aerosol optical depth data set for data assimilation by filtering, correction, and aggregation of MODIS Collection 5 optical depth retrievals, Atmos. Meas. Tech. Discuss., 3, 4091-4167, doi:10.5194/amtd-3-4091-2010, 2010.

18, 29: I would not consider Ångström exponent and ïňĄne AOD to be aerosol size pa- rameters: at best the AE is an indication of the shape of the size distribution (i.e. relative concentration of coarse and ïňĄne particles, where for concentration the presentation of the size distribution needs to be speciïňĄed) whereas fAOD would be the contribution of smaller par ticles to the total AOD.

Yes. Point noted. However, these parameters are often used as a proxy or indication of particle size, and that is how they are used here.

20, 1: is the ïňĄtting error an error on ETA?

The fitting error is on the "matching" of spectral reflectance. The object of the retrieval is to determine the effective columnar aerosol properties, which, coupled with a constrained surface contribution, best represents the MODIS spectral reflectance observations in the three channels. By "best represents", we mean a solution that provides the smallest fitting error when matching the LUT reflectance to the observations.

20, 5: why does ETA not represent a physical aerosol quantity if it describes the ratio of aerosol models to match the obser ved spectral dependence (see also general comments)? Are 2 aerosol models used to determine ETA or more?

See revision of the algorithm section (section 2). 2 aerosol "types" are mixed. The mixture with the smallest fitting error is the solution.

20, 16-20: four models are deïňĄned for the retrieval (27, 5), here I get the impression that only 2 models are used in the actual retrieval, please clarify; what are common deïňĄnitions of ïňĄne mode AOD? Provide reference and explain what the difference is between fAOD in this paper and for MODIS over ocean.

For land, we write here: "The aerosol is assumed to be a mixture of two multimodal aerosol models, a fine model that is dominated by fine-mode sized particles (e.g., radius « 1.0 μm) particles and a coarse model that is dominated by coarse-mode sized particles (radius > 1.0 μm). Both models are assigned based on season and location, and are mixed during the retrieval. The primary retrieved products are the total aerosol loading, represented by the AOD defined at 0.55 μm, and the fractional contribution of the fine model, ETA, also defined at 0.55 μm."

Over ocean, the retrieval is free to choose a solution made up a mixture of fine and coarse modes, where the choice of fine and coarse modes are NOT pre-assigned. Here, we defined the ETA term as η, which represents the fractional contribution of the fine mode, making it a true fine-mode weighting.

20, 26: indicate that QAC runs between 0 and 3 (this is done later may be should be

done here)

DONE

22, 15: are ssa> 0.95 not used? Ssa equal to or smaller than 0.95 seems quite absorbing, is there a climatology known from ground based measurements? Are the seasonal gridded maps based on climatology?

YES. See better explanation in Section 2.

22, 25: transparent assumptions and non-transparent dust: apparently transparent has different meanings here

Yes, but not sure what you are getting at.

24, 13: ETA would be independent of wavelength, isn't it? Hence the (0.55 um) should be after AOD. See also my general question abut the retrieval algorithm.

Yes, ETA is independent of wavelength because it refers to the mixture of fine and coarse –dominated aerosol types. However, because the LUT is indexed as a function of AOD at 0.55 um, the ETA parameter also refers to the portion of AOD at 0.55 um attributed to the fine aerosol type. Because spectral AOD varies with aerosol type, ETA does not represent proportion of total AOD at other wavelengths. This is a confusing detail that is covered in the cited literature and is only distracting to the main thread of the paper. We have removed reference to ETA's definition as the ratio of AODs at 0.55 μm and use only its wavelength independent definition.

24, 19: see my general comment on the retrieval algorithm: why are AOD and fAOD at 470 and 650 additional parameters while 555 nm isn 't even used in the algorithm?

Because the uncertainty of the surface at 0.55 is too large. This is stated more clearly in the text.

24, 25: Levy et al. (2009b) : there is only one Levy et al. 2009 in the references

FIXED

25, 1: "ïňĄll": apparently missing AOD are ïňĄlled? How?

I can see this is confusing. A "fill" value means a special integer value given to flag "missing" data. This Is better explained in the text.

25, 5: why is fAOD repor ted and not ETA while ETA is the primar y parameter from which fAOD is computed?

That is a good question. When we developed the algorithm, we knew that ETA had no meaning for low AOD. However, the product of an essentiall random ETA (between 0 and 1) and a small AOD would always yield a small fAOD. For qualitative mapping of fine-AOD plumes, keeping the fAOD parameter seemed like a good solution. For future collections of the algorithm, we want to always report ETA (as a solution to the algorithm) and let users decide whether and how to use the product of ETA and total AOD.

25, 22-25: similar to above: explain the difference between AERONET ïňĄne mode frac- tion and the MODIS fAOD? Why would correlations be checked if these are difference parameters? Would a good correlation suggest that they do indicate similar quantities?

Since ETA represents the fraction of fine-dominated mode, a large fraction of fine-dominated mode, should indicate a large fraction of fine-mode. Although they are different quantities, one expects that a large value of ETA would be correlated with a large value of AERONET Fine-mode weighting. However, because ETA is convolved with errors in surface reflectance, the correlation turns out to be weak.

27, 5: bi-lognormal ïňĄne and coarse: in what representation (number, volume, radius, diameter, . . .) ?

I don't understand. We mean that when you plot radius (or diameter) as the x-axis, there are two peaks with respect to the y-axis of dV/dLOGr or dN/dLOGr.

27, 5-17: the concept of weighing: why does this provide a physical parameter over ocean and also from AERONET and not from the MODIS dark- target algorithm? This is quite crucial for understanding the products and why ETA should not be used, could you explain?

Retrieval over the uniform dark ocean or from the dark background of space (AERONET) is a much easier task that trying to retrieve over a variable and bright land surface. The ocean algorithm uses 6 wavelengths in its retrieval. Three of those wavelengths are so bright over land, that the land signal so overwhelms the aerosol signal that the aerosol signal is lost in the noise. So, we cannot use these three channels. This leaves only 3 channels in the land retrieval, and even these are buried in much more "surface noise" than their counterparts over ocean. We know the ocean spectral dependence very well. Land surface spectral dependence varies wildly. There is just too much noise, introducing too much uncertainty in the land retrieval to produce a physically realistic measure of anything related to particle size. We can get the loading, which is relatively robust, but we can't get the spectral dependence that leads to particle size.

27, 25: why is the algorithm choosing the dust model? To understand this, more info is needed on how the algorithm works (see general comment). I presume that since only the two visible wavelengths are used, there would be more sensitivity to ïňĄne particles than for coarse particles? How can total AOD be well-retrieved in such cases (see 28, 8); what would be the QAC when ETA is wrong?

The QAC can be high values, because it mostly refers to the algorithm finding a good match to the spectral TOA-observed reflectance.

28, 15: why is ETA retained? If ETA is a weak parameter, as described just above, would this not result in a low QAC and hence conïňĄdence?

The algorithm does not know that the ETA parameter is weakly correlated with an observable quantity; the algorithm only "knows" whether a particular spectral fit is a

good one or not. We expected and then showed via validation efforts, that AOD is robust even when ETA is essentially random. Yet without ETA being used, the retrieval tends to retrieve non-physical values of AOD. So, we need ETA as a retrieval solution.

30, 14-16: has indeed been demonstrated that the algorithm makes the correct assumptions to surface and aerosol characteristics? Where, did I overlook it? I think that only has been demonstrated that AOD (555) is validated while other aerosol parameters retrieved are weak.

This was the major purpose of this paper – to determine whether the assumptions about surface and/or aerosol are correct. By separating into cases with light aerosol and cases of heavy aerosol, we learned where and when the algorithm's assumptions were incorrect.

31, 11: why was Venise included: on p. 26 was mentioned that over water sites would not be included.

Yes, true, but if there is "enough" land in the 50 x 50 km box surrounding the AERONET site, we have chosen to use the site in our validation study.

31, 21-24: when surface proper ties are not much different, does that imply that aerosol models should match well too, or were the aerosol models for Japan and Korea well chosen?

They are chosen, but as long as the AOD is moderate or less (e.g t<0.4) the "good" assumptions for the surface will dominate any "bad" assumptions for the aerosol type.

34, 7-11: how does that ïňĄt in with the above comment on Japan and Korea? What is the difference, if surface is not too bright in both cases?

33, 5: does that imply that MODID uses only the climatologically assigned models?

YES, based on the 1° x 1° map, the algorithm selects the appropriate aerosol model type

38, 20: This means that even though AOD cannot, or not well, be validated in the vicinity of clouds, but physically one expects that AOD would be higher near clouds.

YES

42, 15 and 25: Sometimes “Figure” is used, at other times “Fig.”. Please change to consistent notation

OK

46, 28: “assumed assigned aerosol proper ties”, are they assumed or assigned?

Well they are assumed and assigned to particular locations/seasons. We have dropped the “assigned” part.

47, 5 and 11: the basis for the assumption is the AERONET climatology (Levy et al., 2007)? Are these the maps referred to in line 11?

YES

47, 15: MODIS AE is not reliable as discussed in the paper ; for clarity, should be mentioned here that this conclusion is based on AERONET AE?

OK

Table 1, line 3: wavelength instead of wave

OK

Figures: “both” in Figure headings seems to indicate both AQUA and TERRA, this should be indicated when ïňĄrst used.

DONE

In several ïňĄgures, such as Figure 7, 9, 12 and 13, two plots are given but it’s not clear from the caption or the legend which case is displayed. Although this is mentioned in the text, it should also be mentioned in the caption. In ïňĄgure 15 is referred to left and

right whereas the ïňĄgures are plotted above each other. Suggest to use a and b.

We decided not to use A and B, but the captions are and plots are fixed.

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