Atmospheric
Measurement
Techniques

Open Access

Discussions

Interactive comment on "Validation and empirical correction of MODIS AOT and AE over ocean" *by* N. A. J. Schutgens et al.

N. A. J. Schutgens et al.

schutgens@physics.ox.ac.uk

Received and published: 11 July 2013

Response to anonymous reviewer 3

Based on the comments of the reviewers, we have now included in the introduction explicit definition of our statistic metrics (e.g. median as a bias) and why we did so. We have also substantially altered the text of those sections that pertain to our methodology.

We thank the reviewer for presenting us with extensive comments, even though the he or she was pressed for time due to deadlines.

The reviewer considers our paper to be "very interesting" but has issues with our sta-

tistical analysis. We believe these issues arise mainly out of a different understanding of what an independent dataset or random errors imply. We have used the reviewer's comments to improve the explanations given in the paper.

Our work extends upon Zhang & Reid's and Shi et al.'s work through: 1) a different statistical approach which we argue seems more appropriate 2) a different construction of the correction algorithm, which we argue is more flexible 3) corroborative evidence from the Maritime Aerosol Network 3) correction of AE and an assessment of its random error

This was also detailed in Table 1, the introduction and the summary. We have altered the text to provide more detail on points 1 and 2.

Below follow our responses to the reviewer's general comments

Q: AE is an intrinsic property of the aerosol, and is only as good as the information about spectral AOD. For AERONET, that measures spectral AOT, it is completely trivial to compute AE. On the other hand, the MODIS retrieval uses measurements of spectral reflectance, plus assumptions about boundary conditions (e.g. ocean surface) to retrieve AOD, fine-mode fraction, and choice of fine and coarse aerosol "modes", which then can be used to derive AE. AE is derived after-the-fact, by taking what is already retrieved and then performing extra calculations. If there are biases in the AOT retrieval, then I think it has to be somewhat lucky to happen to derive an unbiased AE. I am not saying it shouldn't be compared to AERONET, but trying to tune MODIS AE to become AERONET AE, is like trying to use a coefficient to turn an apple into an orange.

One more thing about MODIS data. While the resolution of a MODIS retrieved pixel is 10 x 10 km at nadir, it stretches to something like 40 x 20 km at swath edge, meaning that all analysis based on distances (in km) should more correctly be dealt with in pixels.

A: As the reviewer says, the retrieval of AOT by AERONET is simpler than that by

MODIS. Once AOT's have been determined, however, it is straightforward to calculate AE, see our Eq. 1. We should point out, we use AE determined from MODIS AOT at 470 and 860nm and not the official MODIS AE (although the difference is small). Granted this "MODIS" AE is determined from AOT at different wavelengths than the AERONET AE (440 and 870nm) but again, the difference is small (using AERONET AOT at multiple wavelengths a sensitivity study was performed).

As far as biases go: we are not saying that AE is unbiased (clearly our results show that it is biased) but its calculation (the paper's Eq 1) allows for the possibility of cancellation of biases in AOT. Supposed that both AOT are overestimated by 20%: the resulting AE would still be ok.

Finally, because of the stretching of MODIS aerosol pixels near swath edge, we have always used spatial separation in km, not pixel numbers. Centre of the pixel is used to calculate its distance to another location (e.g. AERONET site).

Q: While I usually am willing to overlook small issues about manuscript appearance, there are many faults with the presentation. The English writing is fine. However, it is clear that there was minimal proofreading. There are these annoying "?s" which shows that the paper was not finished when submitted. The figures are generally missing sufficient captions. Like how does Fig. 1 represent spatial correlation? What are the numbers in figure 2? Also, none of the acronyms (MODIS, AERONET, MISR, AOT, AE) are defined in the text. The figures seem out of order. Why is Fig 21 (Sect 4) referred to before Fig 11 (Sect 5)?

A: There were three occurrences of ?% in Sect. 3.1 which now have been corrected. Acronymns have now also been explained. We have also tried to improve figure captions, although we prefer relatively short captions and more explanation in the main text. The issue with Fig 21 appearing before Fig 4 has been corrected.

Q: I am not a statistician, but somehow the statistical analysis seems not right to me.For example, there is a statement (page 3775, line 6), where "We see that MODIS biases

increase with windspeed and cloud fraction but decrease with AOT and AE." Yes, the graph shows that bias decrease with AOT, but this really means that it becomes negative, and becomes large magnitude negative to boot. The sign of the error is important, and so is the magnitude.

A: We agree with the reviewer. As the bias becomes more negative, it decreases (obviously, it's magnitude or absolute value increases). We have chosen here to consider that the bias is a value that can be either negative or positive. We now state this explicitly in the introduction.

Below follow our responses to the reviewer's specific comments

Q: Sect 1 (Introduction): -Note that Terra is not part of the A-Train. -Acronyms need to be defined (AE, AOD, MODIS, AERONET). -Marine AERONET data is actually called "Maritime Aerosol Network (MAN)". -The information about the box whisker plots should be put as captions for at least the first of the plots.

A: We have altered the text based on your suggestions

Q: Sect 2: -What is "AERONET lev 2.0"?. -Equation 2 is not really a MODIS "random error", but an "expected error" based on known uncertainties within the retrieval, which has then been compared with a sample of AERONET data. It is not random by any means. -AOT from AERONET is reported at 500 nm, not 550 nm; how are data interpolated to 550 nm?

A: Sect 2: AERONET Version 2 direct sun algorithm lev 2.0 (we have corrected the name) is the best screened (cloudiness, malfunctions, etc) version of the AERONET direct-sunlight algorithm results. As AOT at 550nm does not exist, we have used AOT at 500 & 675 nm and Eq 1 to estimate AOT at 550nm.

It is our understanding that this official MODIS error should be interpreted as an estimate for the random error. That is: the frequency distribution of MODIS-AERONET AOT should have a standard deviation given by Eq 2. In short, we think our "random

error" and the reviewer's "expected error" are the same thing. Obviously, MODIS AOT will have the same error when observing in exactly similar conditions. But when considering, say, 1000 observations of MODIS under varying circumstances, the error will show a distribution. We have used the term 'random error', distinct and different from 'bias', as it is typically used in error definitions. We have improved the definitions of our statistics in various places in the paper.

Q: Sect 3.1 (Common sense): Let's start with the assumption to get rid of all cases with AOT > 3 (page 3771, line 13). Yes it is true that radiances may saturate in the 550 nm wavelength, however in most cases (except for super fresh dust) the radiances are much smaller (and won't saturate) in longer wavelengths. There is enough information in longer wavelengths to derive a much larger AOT in 550 nm. Next is cloud fraction Yes, the Zhang and Reid, and Shi studies have clearly shown a reduced correlation between MODIS and AERONET when cloud fraction is large, but picture the case where MODIS is retrieving in mostly cloudy skies, but AERONET is pointing to the one spot where the sky is clear. MODIS "should" be biased high in these situations. Discarding observations without neighbors is also risky, for the same reasons. Also discarding observations with high standard deviation is also risky, but I appreciate the understanding that "undoubtably good observations with strong spatial AOT gradients will be removed as well". Finally, I do not really understand the issues with glint angle >30, because except for low quality assurance cases, there are no MODIS retrievals with glint angle <40.

A: Sect. 3.1: We agree with (most of) the reviewer's comments. We do not wish to suggest that outside those criteria all observations are bad, merely that the chance of larger errors is much higher. It its important to realise that these criteria should also be applied when constructing a corrected dataset (as explained in Appendix A).

As far as the sun glint is concerned: we only use glint angles > 40. According to Zhang & Reid and Shi et al, they used angles > 30.

Q: Sect 3.2 (Co-location): From the information (and the refrence to Sect 2), I don't understand the 1 hour averages of AERONET. So 1 UTC- 2UTC, 2-3, 3-4 and so on? Why not 1 hour surrounding the MODIS overpass times? Again wondering is it 50 km or 5 pixels? Is there any "quality filtering" for the MODIS data (Quality Flags?).

A: We started by averaging the AERONET data in the way that the reviewer indicated (0-1h,1-2h,2-3h,etc). MODIS observations are later co-located with those data. Obviously different strategies exist (as the reviewer noted). Distances are in km, not in pixels. As explained in Sect 2, all data irrespective of quality flag is used (as per Remer et al. 2005).

Q: Sect 3.3 (Apparent biases): Again, maybe because of my lack of statistical understanding, but I am not sure why the choices of 1 h and 6 h, and how Fig 2, in any way represents an apparent bias.

A: In this section we try to argue 1) that co-location can create 'apparent' biases (since co-location is never perfect but always allows for some spatio-temporal separation); 2) that such biases are unimportant for our study. Although this appears to be a new insight (we have not found any discussion of this effect in earlier papers), it also is not relevant (because the effect seems small). We have removed this section.

Q: Sect 3.4 (Spatial correlations in MODIS). While there are correlations between geophysical parameters (including surface boundary conditions and meteorology) on spatial scales, each retrieval is performed independently. Each and every 10 km pixels is retrieved independently, with no regards to its neighbors. Where does the 142 km distance come from? Please elucidate on this interesting statement: "We see that MODIS observations themselves show strong correlations over these 100 km. The spatial correlations in MODIS errors are lower than those in AOT itself but still very substantial"

A: We have altered this Section based on the reviewers questions. Obviously each retrieval is performed independently, but they use the same algorithm and nearby pixels

will use very similar auxiliary information. In particular, actual aerosol conditions have spatial correlations on length scales of ~100 km. Consequently both the MODIS AOT and the MODIS error (deviation from AERONET) will be strongly correlated over ~100 km. That is essentially what we show in Fig. 1 (revised paper). In turn this implies there is no gain in using all MODIS observations co-located with a single AERONET observation. Sure, you increase the sample size but it does not add new information.

The 142 km was a typographical mistake and should indeed be 100.

Q: Sect 3.5 (Independent subsamples). I don't understand, given arguments, how using a single pixel from a collection of pixels results in an "independent subsample". Geophyiscally, it makes sense that pixels farther from the ground truth should have larger difference. It is not necessarily an "error". But really the paper is comparing the closest MODIS pixel (spatially) with an average of the closest AERONET observation (temporally).

A: The reviewer is correct that MODIS pixels further away from the AERONET site may have larger differences with AERONET that are not necessarily errors. However, over distances of 50 km, we do not see this effect. This is easily understood from the strong correlations in MODIS AOT and error over such distances as discussed in Sect. 3.4

Consequently, if one has, say, three MODIS pixels that co-locate with a single AERONET observations, those three observations are not independent. One does not obtain more information by using all three observations instead of just one (any arbitrary observation).

However, when one starts considering all available MODIS-AERONET co-locations, use of all observations definitively distorts the statistics as we argue in Fig 2 (revised paper). The reason for this is that scene conditions dictate how many dependent observations exist per co-location (this is a statistical relation, not a deterministic one). We have substantially altered the text of these sections in the hope of better addressing these issues.

Q: Section 4.1 (Comparison against AERONET). -I note this sentence: " : : : main four parameters that affect MODIS AOT error statistics, both its biases and its random errors. They are AERONET AOT and AE themselves, windspeed and cloud-fraction." Plots as these show clearly why the MODIS validation papers (e.g. Levy et al., 2010) report errors as uncertainty envelopes; while the absolute error (difference) may increase with higher AOD, the relative difference actually becomes SMALLER as the AOT increases. -What does this mean? "the co-variation of the bias in AOT with AE suggest that there are still issues with the assumed scattering properties of the MODIS aerosol types." -And this: "Note that random errors depend mainly on AOT". If there are issues in assumptions of aerosol model type (microphysical properties), then there will be a systematic error upon AOT. -Any idea why these are true? "We do see, however, a significantly higher bias for SZA <20. Similarly, we see significantly higher biases for temperatures T< 260 K and relative humidities RH< 0.2." I would expect that SZA<20 might be more likely glint contaminated, T<260 is contaminated by ice/snow or low clouds, and RH<0.2 is bone dry. It turns out the MODIS retrieval has a correction for water vapor dependence (NCEP), that if wrong may lead to biases. -For this: "As a result, MODIS AE has no significant bias as a whole but shows reduced contrast in space or time compared to AERONET." If you look at the "choice" of aerosol models in the MODIS retrieval space, and their spectral dependence, they, themselves do not have the range of AE that is observed by AERONET. -Can these statements be expanded upon and discussed? "Finally, we point out that several of the discussed parameters co-vary to a certain extent. Obviously, this is the case for the scattering angles. But there is also a weak correlation between e.g. cloud fraction and windspeed, maybe because whitecaps are interpreted as cloudiness." Why would whitecaps be interpreted as clouds?

A: Sect 4.1 We agree with the reviewers that absolute and relative errors can behave quite differently. Our Fig 20 (revised paper) suggest that although absolute errors increase with AOT, the relative errors are largest for small AOT,then decrease and finally increase again.

We see that the bias in AOT depends in part on AE (Fig. 3, revised paper). Since AE is an intensive aerosol property, related to size, not to abundance, this may suggest that assumed aerosol properties play a role in creating AOT biases. We found the reviewer's comment at the very end of page C1314 ("If you look at the "choice" of aerosol models in the MODIS retrieval space, and their spectral dependence, they, themselves do not have the range of AE that is observed by AERONET") very interesting in this respect.

Regarding the reviewer's statement "If there are issues in assumptions of aerosol model type (microphysical properties), then there will be a systematic error upon AOT.". We understand and agree with the reviewer but think that this systematic error will vary with the actual aerosol conditions. Hence, it can (in a large sample comparison as ours) appear as a random error. Note that we have also found the MODIS AOT bias to depend n AE.

Regarding the causes of errors for SZA<20, RH<0.2 etc, the reviewer offers some interesting possibilities.We have tried to analyse these cases further but the low number of cases, made this inconclusive.

We found the reviewer's comment "If you look at the "choice" of aerosol models in the MODIS retrieval space, and their spectral dependence, they, themselves do not have the range of AE that is observed by AERONET." interesting. A reference to a paper or other document that discusses this would be very welcome.

Regarding white-caps being mistaken for clouds: we do not say this is the case, merely it's a possibility. Any algorithm that uses radiance thresholds and spatial inhomogeneity tests as part of its cloud detection (and we understand that MODIS does this), could mistake whitecaps for clouds. It does not have to happen always.

_____

Interactive comment on Atmos. Meas. Tech. Discuss., 6, 3765, 2013.

C1589