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Atmospheric Measurement Techniques Discussions

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

Anonymous Referee #3

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Abridged Review of Validation and empirical correction of MODIS AOT and AE over ocean, by Schutgens et al., for AMT

Caveat: I apologize for the "abridged" nature of this review. I ran up against other deadlines, and could not get to detailed comments after section 4.2. I felt this paper to be very interesting, and I was trying to imagine physical explanations for some of your findings. I hope to see this paper again, and hopefully contribute more at that time.

Summary: This paper presents a validation of MODIS –retrieved AOD and AE over ocean, as compared to sunphotometers (AERONET and MAN). The main findings are that there are biases in satellite-retrieved AOD, and lack of dynamic range in the retrieved AE. It goes on to explain why some of the biases and errors occur, and develop

empirical corrections to handle some of these problems. This new "bias corrected" aerosol product is intended to be used for assimilation studies as well as a stand-alone observational dataset.

Overall: I find this paper to be interesting, but not yet adding much value to the literature. This paper often references the work of NRL/UND (Reid, Zhang, Shi et al), and it is not completely clear to me how this work extends upon the previous work, except for "that we take great care to create a dataset of independent MODIS vs AERONET observations and include modis AE observations as well" (page 3768, line 25). I can see why AE is attractive to evaluate and improve, but I do not necessarily agree (see General comment #1). At the same time, I just don't see the "dataset of independent MODIS" part. Each and every MODIS retrieval is performed independently of its neighbor. It is true that boundary conditions (e.g. surface properties) and aerosol properties (e.g. AOD and AE) may very well be correlated spatially and temporally, but I do not see how isolating one pixel out from its neighbors leads to a more independent data point. Furthermore, I am concerned about the lack of explanation for some of the key findings.

Anyway, as it stands right now, this paper is not acceptable for publication.

General comments:

1) 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.

Before making other comments, let me digress with a discussion of the MODIS retrieval. The standard MODIS aerosol retrieval is performed on every "box" of 20x20 pixels (500 meter resolution at nadir). Cloud masking, sediment masking and other masking is performed, and then of the remaining pixels, only the middle 50% of the pixels are saved, and averaged. This results in a single set of spectral reflectance (in 6 channels), which can be considered as be the MODIS observation. The belief is that this observation is cloud, glint, and sediment free, but there may be some contamination by any of these things. This spectral observation is fed into a retrieval code that makes assumptions about the ocean surface, possible choices of fine and coarse –sized lognormal aerosol modes, and that the final result must include some fraction of fine and coarse modes. The total loading (e.g. AOD at 550 nm), fraction of fine mode, plus knowledge of which modes were chosen, uniquely describes the spectral AOT (from which the AE can be derived).

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.

2) 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)?

3) 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.

More specific comments:

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.

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?

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°.

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?).

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.

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"

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).

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?

Section 4.2 (Comparison against MAN):

-Line 20: This sentence needs fixing: “When using the full dataset, Marine AERONET data suggest MODIS Terra AOT errors are systematically 0.01 to 0.02 lower than AERONET data suggest.”

Note, incomplete review at this time. . . See Caveat at top.

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