Atmos. Meas. Tech. Discuss., 5, C882–C888, 2012
www.atmos-meas-tech-discuss.net/5/C882/2012/

Atmospheric Measurement Techniques Discussions

AMTD

5, C882–C888, 2012

Interactive Comment

Interactive comment on "Implications of satellite swath width on global aerosol optical thickness statistics" *by* P. R. Colarco et al.

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Received and published: 6 May 2012

Review of the manuscript

"Implications of satellite swath width on global aerosol optical thickness statistics" by P. R. Colarco, L. A. Remer, R. A. Kahn, R. C. Levy, and E. J. Welton

GENERAL ASSESSMENT

Although spatial coverage is a significant facet of the design of an observing system for measuring aerosols, the methodology of the present study makes its main conclusions questionable and potentially misleading.

The authors claim that they have examined the effects of sample's width on aerosol optical thickness (AOT) statistics. However, they present instead a not-very-accurate study of the influence on AOT averages of the sample's position relative to the ground track, this influence being caused by systematic retrieval errors in the MODIS algorithm.

In the absence of such view-angle-dependent errors, there is no compelling reason why one should expect any systematic bias between mean global AOT estimates from a dataset including the MODIS full-swath measurements and that based on its sub-samples. However, a reduction of sample size could potentially cause a larger statistical uncertainty of such estimate.

While any study of sampling uncertainties can be treated as an abstract statistical exercise dealing with a "given" dataset, the nature of this dataset should be taken into consideration in "real world" research. This is especially true of the MODIS aerosol product whose retrieval errors are an order of magnitude greater than the reported sampling uncertainties and hence represent a much more significant contributor to the uncertainties in mean AOT values. This raises legitimate questions as to whether the MODIS dataset is a good choice for a sampling study in the first place.

Adequate balance between measurement and sampling uncertainties may be a decisive factor in planning future satellite missions since an increase in spatial coverage does not improve the mean AOT estimates if the retrieval accuracy is poor. It is therefore important to recognize that the requisite improvement in quantitative assessments of aerosol climate effects will not come solely from satellite data. The actual role of climatological satellite instruments is to provide observational targets against which to test the performance of the models. Although statistics of day to day variations in AOT may be useful, for climate it is more important to provide effective constraints on particle size, shape, and complex refractive index which remain essentially unknown on a global scale despite "some progress" contributed by recent "instruments designed to measure aerosol properties". One can, in fact, argue that MODIS was not specifically designed to measure aerosols, which is why its aerosol products have some challenges.

Furthermore, the threshold accuracy of 0.01 is a primary criterion for improving the accuracy with which the radiative effect of aerosols is determined over the oceans that cover 70% of the Earth. Over land both the AOT and the single-scattering albedo need to be retrieved accurately to even get the sign of the aerosol radiative forcing correctly. So, using a required accuracy of 0.01 over land and stating that it cannot be met in this study without clearly stating the caveats associated with the aerosol retrievals over land is rather misleading.

What this manuscript does show is that one should not fly in space an instrument having the MODIS measurement characteristics but a much narrower swath. However, this study has no meaningful implications for a narrow-swath instrument capable of reliably decoupling the surface and aerosol contributions to the outgoing radiance and polarization. As such, it doesn't deserve publication.

The following is a detailed assessment of the accuracy of the MODIS AOT product and the sampling methodology presented in the manuscript.

DETAILED ASSESSMENT

It would be logical to base this study on an aerosol transport model rather than on a satellite product of limited accuracy since in that case the AOT and its spatial variability would be completely decoupled from the variable reflectance properties of the underlying surface. The present study suffers from the inherent inability of MODIS observations to decouple the land surface reflectance and the aerosol contribution to the outgoing radiances. To compensate for this inability, the MODIS algorithm even allows retrieved AOTs to be negative. It is well known that the MODIS AOT retrieval accuracy is lower over land than over the oceans. As a consequence, much of the regional and seasonal AOT variability over land claimed in this manuscript is likely to be an artifact of surface variability. This would explain the significant difference in the conclusions for cases over land and over oceans.

The authors compare global annual and monthly mean AOT values taken from the level-2 MODIS aerosol product using either the full swath or certain sub-samples of it. This comparison has the following fundamental methodological flaws:

1. The test AOT accuracy standard of 0.01 is at least an order of magnitude finer than the MODIS AOT retrieval accuracy. Indeed, the "official" MODIS accuracy of +/– (0.03 + 0.05 AOT) over ocean and +/– (0.05 + 0.15 AOT) over land is between 0.1 and 0.2 for a similar dataset presented by Levy et al. (2010; hereinafter L2010) (see Sec. 5.4, Figs. 10–14). The retrieval errors are especially high for large AOTs, where 0.1–0.2 (15%–25%) biases are seen; the sign of these biases depends on the particle size (L2010, Fig. 13).

These official accuracy claims apply only to 67% of AOT retrievals and, thus, the errors are substantially worse for the remaining 33%. Needless to say, these 33% of bad MODIS AOTs are not excluded from the present analysis since it's impossible to filter them out. This raises the concern that the MODIS dataset has substantially more variability in the AOT than is actually there and that this inflated variability is affecting the sampling statistics.

Independent comparisons with AERONET show that the MODIS AOT RSTD over land exceeds 70%:

Mishchenko, M. I., L. Liu, I. V. Geogdzhayev, L. D. Travis, B. Cairns, and A. A. Lacis, 2010: Toward unified satellite climatology of aerosol properties. 3. MODIS versus MISR versus AERONET. J. Quant. Spectrosc. Radiat. Transfer 111, 540–552.

It is quite likely to be even larger for the totality of the MODIS dataset since the latter is not helped by the AERONET cloud-clearing procedure:

Mishchenko, M. I., I. V. Geogdzhayev, L. Liu, A. A. Lacis, B. Cairns, and L. D. Travis, 2009: Toward unified satellite climatology of aerosol properties: what do fully compatible MODIS and MISR aerosol pixels tell us? J. Quant. Spectrosc. Radiat. Transfer 110, 402–408.

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These levels of error by themselves disqualify the MODIS AOT dataset as an unbiased field on which to test sampling strategies. Furthermore, it suggests that much of the claimed spatial AOT variability over land is an artifact of surface reflectance variability.

That this is indeed the case is demonstrated by the bottom panel of Fig. 5. This figure shows a pattern of AOT sampling artifacts that is highly correlated with the distribution of land. Sharp discontinuities in (Full Swath – C1) follow the coastal lines almost perfectly, including areas where no major regional sources of aerosols exist.

2. A built-in feature of the MODIS retrieval algorithm over land is the allowance for negative AOTs. This can be a meaningful measure given the inability of the algorithm to provide a reliable characterization of the surface reflectance in many cases. The adverse effect of this feature is apparent in Fig. 5 of

R. A. Kahn, D. L. Nelson, M. J. Garay, R. C. Levy, M. A. Bull, D. J. Diner, J. V. Martonchik, S. R. Paradise, E. G. Hansen, and L. A. Remer, 2009: MISR Aerosol Product Attributes and Statistical Comparisons With MODIS. IEEE Trans. Geosci. Remote Sens. 47, 4095–4114.

It obviously contributes to the virtual lack of correlation between MODIS and MISR AOTs for AOT values smaller than $\sim$0.2.

The allowance of negative AOTs helps MODIS to yield a sensible global AOT average, but is a major deficiency in a study of the likely performance of a narrow-swath instrument. Indeed, the latter does not have many cross-track pixels to compensate for an unfortunate occurrence of a negative MODIS AOT over a ground-track pixel. However, a capable narrow-swath instrument like APS would not have this problem in the first place because it would not generate physically impossible negative AOTs.

3. Following L2010, the authors admit that the difference between MODIS and AERONET AOTs as a function of viewing angle "is the artifact in the MODIS AOT due to view angle dependency, ... and amounts to an overall AOT statistical difference

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of about 0.04 across the full swath."

For both over ocean and land retrievals, this MODIS–AERONET difference is close to zero for the nadir viewing angle (see Figs. 2 and 3) and is linear in its neighborhood. Thus, it would be natural to select nadir (ground-track) samples (or nadir-centered strips) for comparison with the full-swath statistics. Such samples are readily available for retrievals over land, which are not affected by the sun glint. Over ocean, reasonable sub-sample would consist of two strips located at the same angular distance from nadir on each side of the ground track, so that the retrieval artifacts can be expected to average out.

Unfortunately, the sampling strategies adopted for this manuscript are hardly reasonable (in the above sense). The authors exclude nadir data from sub-samples for both ocean and land data and, instead, take sub-samples at the edges of the full swath, where angular errors in MODIS retrievals are maximal. Note, that they could achieve reasonable sub-sampling by averaging M1 and M3 (or C1 and C3), but they, instead, average M1 and M2 (creating the SM sample), both located to the right of the ground track.

To "compensate" for this less-than-optimal choice of sampling, the authors use an empirical correction procedure based on comparisons with AERONET data from Figs. 2 and 3. This procedure is highly questionable since, as one can see from the L2010 analysis, the MODIS errors depend not only on the viewing angle but also on the AOT value, particle size, and surface properties. Thus, the required correction may be different in each case. This is admitted by the authors on p. 2804 ll. 5–10: "We acknowledge potential limitations in this approach, in that (i) we did not investigate any geographical or temporal variability in these correction terms and (ii) we cannot be confident in how the actual view angle artifact in MODIS behaves away from the admittedly limited number 10 of AERONET sites." Yet the authors apply these questionable corrections to study spatial (Fig. 5) and temporal (Fig. 6) distributions of AOT artifacts.

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4. While the authors do not show the reader the statistics of the original (uncorrected) dataset, the comparison of Figs. 2 and 3 on one hand and Figs. 4 and 6 on the other indicates a likely over-correction. Indeed, while MODIS retrievals from the M3 and C3 samples located to the left of the ground track are expected to over-estimate both AERONET and full-swath values before correction, we see from Figs. 4 and 6 that the M3/C3 curves are systematically lower than those corresponding to the full swath. Conversely, the M1/C1 samples to the right of the ground track show systematic under-estimation of the full-swath averages (while the opposite would be expected without correction). Also, one can see that the two right-hand-side averages M1 and M2 are closer to each other than to the left-hand-side M3. These trends hint that the hypothetic near-nadir sample would provide closer approximations to the full-swath averages than the samples selected in the manuscript without the need for any artificial correction procedure.

5. There is an inconsistency between Fig. 5 (bottom panel) on one hand and the left-hand panels of Figs. 4 and 6. Figure 5 shows that Full Swath AOT is systematically higher than the C1 sample over Ocean (red color), while both Figs. 4 and 6 show the opposite: C1 (blue solid curve) is systematically higher than the Full Swath (black curve).

ADDITIONAL COMMENT

The Discussion and Conclusions sections are highly repetitive.

Interactive comment on Atmos. Meas. Tech. Discuss., 5, 2795, 2012.