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Atmospheric Measurement Techniques
Discussions

Interactive comment on "Aerosol retrieval from multiangle multispectral photopolarimetric measurements: importance of spectral range and angular resolution" *by* L. Wu et al.

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To the Authors and Editors:

We would like to offer some general comments in response to this submission in the interest of open discussion. This is a very thought-provoking and important manuscript, but some points remain that we feel require additional clarification.

Page 2795

Although it is stated several times in the paper, it is important to point out that these results are valid only for aerosol retrievals over land. For aerosol retrievals over water,

the conclusions could be quite different, and this point should be emphasized.

Page 2799

Perhaps a little more explanation of the Gaussian height distribution assumption for aerosol layers would be appropriate. For the lowest layer, is this a half-Gaussian distribution, with a peak at the surface, for example? A typical assumption is that aerosols have an exponential profile with some fixed scale height, which is somewhat different from the Gaussian height distribution assumption.

Page 2800

The authors write: "In a straightforward way, the spectral variations of coarse mode aerosols can be described by a linear combination of the three coarse mode aerosols…" A more explicit description of how this combination is performed should be included.

Page 2801

When the authors write "aerosol optical thickness (AOT)," this should probably be "aerosol optical depth (AOD)." According to a World Meteorological Organization (WMO) report, "…optical thickness gives the line integral of extinction along any line of sight (e.g., sunphotometer to the sun), while optical depth is optical thickness projected onto a vertical path" (WMO, GAW Report No. 162, ftp://ftp.wmo.int/Documents/PublicWeb/arep/gaw/gaw162.pdf). While it is clear that AOT is being used interchangeably with AOD in this paper, it would be preferable if the community would adhere to this standard when AOD is the parameter of interest to avoid confusing non-expert readers.

Page 2802

Why were only 1,000 synthetic measurements performed? Was this a time limitation or was the number selected deliberately? Also, why were the parameters sampled randomly within their ranges, as opposed to systematically? Incidentally, it appears that there's a typo in the AOD range ("0.0 < $\tau \leq$ 0.70"), since Fig. 5 shows values extending up to nearly 1.5 at 550 nm. Is 550 nm the reference wavelength used for the AOD calculations? If so, that should be stated explicitly in Section 4.1. Even given the ranges stated on Page 2802, and sampling systematically through the ranges with a step size of 0.1, there are $3 \times 3 \times 30 \times 3 \times 8 = 6,480$ possible tests (in r_{eff}^f, v_{eff}^f, r_{eff}^c, v_{eff}^c, and τ, respectively). This means that the 1,000 tests sampled about 15% of the parameter space that would be sampled systematically, even with the relatively coarse step size given above. Obviously, if the AOD range extends to 1.5, then the number is 12,960 possible tests and the fraction sampled likewise decreases. A good way to address this in the paper is to show histograms of the sampling for each parameter from your 1,000 synthetic measurements.

What height or height ranges for the aerosol were used when performing the synthetic tests?

The relative azimuth is 180 degrees for negative viewing zenith angles, but does this refer to forward or backward scattering?

It is critically important to note that only a single viewing geometry (solar zenith angle of 60 degrees, principal plane) is used in this study. These results might change with a different geometry. No satellite can constantly fly in the principal plane, for example, so how would these results be relevant to a satellite instrument in a near-polar orbit?

What does "viewing angles are equally sampled between $-60.0°$ and $60.0°$" mean? If three angles are selected are they $-60°$, $0°$, and $+60°$, or do you divide the angular space ($120°$) equally and sample at $-40°$, $0°$, and $+40°$? A table showing the selected angles for different numbers would be extremely helpful. Also, is there a reason the sampling is done equal in angular space, and not in the cosine of the angles, for example? When two viewing angles are selected, why is $-60.0°$ selected and not $+60.0°$? More importantly, how representative are these results for addressing the general question of how many angles are needed to perform "accurate" aerosol retrievals?

Perhaps three well-chosen angles give significantly better results than three equally spaced angles. This limitation should be addressed somewhere in the text.

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2% random noise was added to the intensity and 0.2% was added to the "polarization degree P," which is likely "degree of linear polarization. How do you account for the difference between systematic and random errors?

Why is only the subset with an angular resolution of 13 selected for the test described in Section 4.1.1? Strictly speaking, this is also not a "subset" of the 1,000 synthetic measurements (supposing all 1,000 cases are included), but a subset of the $1,000 \times 49 \times 7$ synthetic measurement outputs. Also, why is 670 nm taken as the reference wavelength and not 550 nm as was (apparently) done for AOD?

It would be good to include SSA as an additional parameter in Fig. 3 since most readers probably have a better sense of how SSA should behave as opposed to the index of refraction.

The correlation coefficient is a poor metric to determine the agreement between two datasets. Additional metrics such as root mean squared error (RMSE), mean absolute error, and/or bias should be included, at a minimum. This will help readers have a better sense of how well the retrieval is actually performing. The mean absolute error is the metric plotted in Fig. 4, but it does not appear in Fig. 3 at all.

Page 2804

It is misleading to call selections of different wavelength ranges "different subsets of the 1000 synthetic measurements" since it is stated on page 2802 "each synthetic measurement includes 49 equally sampled viewing angles… and seven of the nine RSP wavelength bands."

The results of Fig. 4 are surprising, but not discussed. No matter how many angles are used, the error in AOD never reaches the critical threshold proposed by Mishchenko et al. (2004). However, the error in SSA quickly falls well below the threshold. If lots of cases have SSA = 1, this is maybe not a fair comparison. This result looks to be inconsistent with Knobelspiesse et al. (2012), who show in their Fig. 6 that APS can meet the AOD requirement, but not SSA, and the opposite conclusion is drawn in this work.

Additionally, Levy et al. (2013) report that 69.4% of MODIS Collection 6 AODs fall within $\pm(0.05 + 15\%)$ of the measured AERONET AODs. Figure 4 shows with two angles (including nadir) that the error is 0.12 using a similar wavelength range as MODIS, which is at least a factor of two larger than the error reported for the operational MODIS algorithm. What is the explanation for this discrepancy?

The fact that the error in m_i^f is of the same magnitude as the error in SSA is also very surprising. A quick check of some Mie results shows that changing m_i^f by 0.01 results in a change in SSA of 0.10, all other parameters being held constant. Based on this single result, an order of magnitude difference would be expected in Δm_i^f and $\Delta\omega$. Additionally, why is the reference wavelength for the refractive index 670 nm, while AOD and SSA are referenced to 550 nm?

Finally, for the parameters outside the Mishchenko envelope, it appears that five angles are sufficient to achieve results nearly equivalent to a larger number of angles. Why, then, does the abstract suggest 10 angles are required? In their response to the comments of Dr. Ottaviani on this figure, the authors refer to the performance relative to the "requirement." If the requirement is met with only two angles (e.g., v_{eff}^c), then this cannot be used to support the need for a larger number of angles. If these results are from an ensemble of cases, the standard deviation at each viewing angle should also be included in the figure, instead of the symbols. The same goes for Fig. 10.

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Again, the correlation coefficient alone is an insufficient metric to assess agreement between two datasets.

The AERONET Level 1.5 inversion products should not be used for situations when the AOD at 440 nm is less than 0.4 and the solar zenith angle is less than 50° (see Eck et al., 2013 for a discussion of this). SSA retrievals, in particular, are highly uncertain when the AOD at 440 nm is less and 0.4, so it seems likely Fig. 8 is comparing noise to noise.

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Even with a 5 km averaging of the RSP data "some measurements are still hampered by angular oscillations caused by inhomogeneity of the underlying surface"? Is there some way to flag those cases in the plots, then? How do you know this was caused by surface inhomogeneity and is not due to some other cause (e.g., cloud contamination)?

In Fig. 6, you present the scattering angle and the solar zenith angle, but what is the mean relative azimuth angle?

What is the point of only showing retrieval results from the 410 to 1590 nm and 410 to 2250 nm cases in Fig. 7? If the point is that there is "good agreement," why not only show one wavelength range?

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Again, the correlation coefficient alone does not provide enough information to assess the quality of the comparison. In fact, there is a clear bias in the retrievals as the wavelength increases. This indicates a mismatch in the spectral AODs, meaning that there is likely some issue in the retrieval of the refractive index, but this cannot be made out from Fig. 9, which looks like noise. Some further analysis and discussion are warranted.

The authors write, "We should notice that with the increase of N the retrieval performance sometimes becomes even a bit worse, this is due to the fact that the measurements at some viewing directions can be distorted by the inhomogeneity of the land surface." This is not supported by the figure in question. First, the error in the 410 to

670 nm wavelength range (purple) appears to systematically increase as N increases above five. This is not noise, which can be assessed by looking at the difference between the red and orange lines for $N \geq 5$. Moreover, this wavelength range is most sensitive to the *atmosphere*, not the surface, so how can the issue be due to surface inhomogeneity? Surface inhomogeneity should affect the longer wavelengths more because the AOD is lower. The "jump" in the 410 to 865 nm (blue) line at $N = 21$ is also interesting, since this is also outside the range of the "noise." Could it be that the choice of 21 angles selects a particular angle, like the hot spot?

Page 2808

Is the layer height also retrieved in the RSP cases? If so, how does it vary from case to case? Is there ancillary information that can be used to check the layer height retrievals?

It would be good to summarize the limitations of this study in the Conclusions.

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