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Atmospheric Chemistry and Physics Discussions

Interactive comment on "An accuracy assessment of the CALIOP/CALIPSO version 2 aerosol extinction product based on a detailed multi-sensor, multi-platform case study" *by* M. Kacenelenbogen et al.

Anonymous Referee #1

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General comments: Major revision required. This paper addresses an important topic (accuracy of satellite retrieval of aerosol properties) in a careful but largely ineffective manner. While the article contains some meaty analysis and results, the overall approach is qualitative and lacking in rigor. The article does a fine job of illustrating several problems with the CALIOP version 2 retrieval, but this does not constitute, in my opinion, a substantial or novel scientific result. These problems were understood at a qualitative level prior to launch. Major changes are required to make this paper pub-

lishable: (1) The comparison of MODIS and CALIOP retrievals should be eliminated or reduced to a few sentences to the effect that "we did not find a relationship between these two quantities." (2) The case study must be processed with the Version 3 algorithm to demonstrate whether or not it fixes the identified problems. (3) The results need to be brought to the point of specific error estimates for the extinction and optical depth properties retrieved by CALIOP.

Outline of this review: I begin with a Synopsis of the paper, followed by Specific comments (keyed to the synopsis) and, lastly, a listing of Technical comments.

Synopsis of paper: The authors use comparison data to critically examine the CALIOP retrieval of aerosol extinction (AE) and aerosol optical depth (AOD). An initial comparison between MODIS and CALIOP in terms of AOD over the continental United States finds weak correlation and poor agreement, with AOD from CALIOP apparently 60-70% lower. [Specific Comment 1] Ascribing this to error in CALIOP, the authors seek to understand the causes of CALIOP error via a case study. The case study involves, essentially, one point in time and one atmospheric column for which the authors have four types of AOD data in addition to CALIOP: ground-based measurements from AERONET, airborne measurements from a High Spectral Resolution Lidar (HSRL), and retrievals from two spaceborne sensors: MODIS and POLDER. The authors carefully describe the peculiarities of these various data sets and the temporal and spatial offsets among them. The AOD comparison shows roughly comparable values among the four sets of comparison data (values of 0.5 to 0.7) with CALIOP about a factor-of-two lower (0.3). The case study, therefore, appears to be an example of the underestimation of AOD by CALIOP which was found in the MODIS comparison over the entire continental U.S. Four potential causes of CALIOP error are investigated using, primarily, a comparison of the CALIOP and HSRL profiles of atmospheric and aerosol properties. These are [using the numbering from Section 5. Conclusions]: (i) low signal-to-noise ratio such that "attenuation of the signal by dense aerosol plumes can drive the signal within a layer below CALIOP's detection threshold, and thus pre-

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vents identification of the full vertical extent of the layer" [p. 27995], (ii) errors in the derived extinction-to-backscatter ratio (Sa) of aerosol layers, (iii) cloud contamination of the aerosol retrieval associated with a known coding bug in version 2, and (iv) error in basic calibration of the lidar signal during the day. The authors use the case study data to illustrate these issues and, in one case (issue (i)), to discuss how the version 3 retrieval will deal with them. Regarding (i), CALIOP failed to detect aerosol below 1.4 km altitude and the HSRL profile indicates that this undetected aerosol near the surface has an AOD of about 0.26. This is clearly a major source of error and sufficient by itself to explain the CALIOP underestimation of AOD. The authors state that the version 3 algorithm addresses this issue by extending the base of aerosol layers to the surface even when the signal drops below the normal detection threshold, at least in cases where the surface is clearly detected. [Specific Comment 2] Regarding (ii), when the Sa variability measured by the HSRL is applied to the CALIOP retrieval, the resulting AOD is higher by 0.12. This is a smaller error than (i) but still substantial. Whether the version 3 algorithm addresses this issue is not stated. [Specific Comment 3] Regarding (iii), a small cloud is detected by CALIOP at high resolution (1/3 km), but not removed by the retrieval algorithm due, the authors assert, to a coding bug. The resulting error is not quantified. Whether this bug is corrected in the version 3 algorithm is not stated. [Specific Comment 4] Regarding (iv), the attenuated backscatter profile from HSRL matches almost exactly with that of CALIOP once a correction is made for attenuation above aircraft level. This indicates that the CALIOP signal calibration was correct at the time of the case study. Nevertheless, the authors point to other studies that have revealed problems in the daytime calibration that can cause errors in retrieved AE and AOD. Whether the version 3 algorithm addresses these problems is not stated.

Specific Comments 1. It would be useful to get some general assessment of the accuracy of CALIOP AOD, and this is what the authors attempt to provide by comparing to AOD from a much longer established satellite sensor, MODIS. There are several flaws with this analysis. (i) The authors choose the least accurate type of data from MODIS - namely, the land retrieval. (ii) There are many artifacts and biases in the MODIS re-

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trieval. The authors mention this, but fail to develop an error analysis for MODIS that would allow them to state whether or not the CALIOP data are statistically different and to quantify this difference. (iii) The authors pre-filter the data [p.27978] but do not justify or test the affect of this filtering or even state how many data points are eliminated. (iv) Specifically, the pre-filtering cuts off high CALIOP values while imposing no such cut-off on MODIS. This appears to me to have biased and perhaps determined the result. The regressions shown in Figure 1 appear to be driven by high MODIS values and an absence of high CALIOP values. The bulk of the data (at low AOD values), in contrast, do not seem to support the conclusion that CALIOP is systematically 60-70% lower than MODIS. In fact, over the Eastern US (Fig. 1b) the opposite appears to be the case. (v) Most importantly, though, the correlations are so low that the only legitimate interpretation is that the two quantities were found to be essentially unrelated. The best R-value is 0.34, meaning that R-squared is 0.12, meaning that 88% of the variance is unrelated. This negative result is interesting but not terribly useful for assessing CALIOP accuracy. It should be relegated to a few sentences or else omitted entirely.

2. The HSRL comparison reveals premature truncation of the aerosol layer by CALIOP at 1.4 km altitude (when it actually extends to the ground). This is by far the most important and definitive result of the paper. The error that is exposed is especially important because it is systematic (not random) - that is, it can only lead to underestimation of AOD. But the reader is left in the dark as to (i) how commonly does this error occur in the CALIOP data set, (ii) what specific conditions trigger this error, (iii) do the changes in the version 3 algorithm [described on p.27989] actually fix the error in this case, (iv) what fraction of cases in general will be fixed by the version 3 changes, and (v) what remaining error can be expected in the version 3 data set? Obviously, these questions cannot be completely answered. But, to be useful, the paper must seriously engage such questions. At a minimum, the version 3 algorithm must be used to process this case and the improvement must be quantified.

3. HSRL data from many field campaigns has changed our understanding of Sa vari-

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ability, showing far greater variability than is assumed in the CALIOP retrieval. Here the authors perform an interesting experiment by using high-resolution Sa data from the HSRL in the CALIOP retrieval. In this case, the result is a substantial increase in retrieved AOD. That is interesting, but not worthy of publication unless the authors can provide quantitative guidance to the reader regarding the generality and magnitude of error likely to be present in the CALIOP data set due to this cause. [Presumably, there is no way to correct this problem.]

4. The authors show a small cloud in the CALIOP field of view that is identified at full resolution but not removed by the version 2 algorithm, resulting in "cloud contamination" of the aerosol retrieval. This is ascribed to a "coding error in the cloud clearing procedure" [p.27984] which will, presumably, be fixed in the version 3 algorithm. The authors "circumvent" this error in subsequent analysis by a manual procedure. They imply that this error causes the CALIOP retrieval to overestimate aerosol extinction (at the level of the cloud) and to misclassify the aerosol as large-particle dust rather than fine-particle pollution (which is what AERONET retrievals indicate as the particle type). These are important ideas, but they need to be demonstrated, not just suggested. Does the new, version 3 algorithm in fact remove this cloud prior to performing the aerosol retrieval? Does the resulting retrieval indicate small particle pollution rather than large particle dust? And what is the magnitude of change in aerosol extinction and optical depth? These questions can and must be addressed by running this case through the version 3 algorithm. In addition, the analysis will be worthy of publication only if it provides some assessment of the generality and magnitude of error likely to arise from this cause.

Technical comments p.27971, lines 15-23: The height determination by CALIOP is extremely accurate and well-validated and, thus, in a different category from aerosol properties like extinction and optical depth. These examples are not relevant.

p. 27972 top: "we attempt to assess the consistency..." Weak language. Weak goal. Rather, "Here we assess the consistency... and demonstrate..."

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p. 27972 bottom: "Our study is intended to help identify potential shortcomings..." Weak language and goal. Rather, "Our study identifies shortcomings... and quantifies their likely impact on retrieved aerosol properties."

p. 27976, lines 16-19: Confused sentence. "decimating" is not the right word

p. 27978, lines 4-16: These pre-filtering procedures need to be justified and their impact needs to be quantitatively assessed. How many points are excluded by each filter? How do mean values and variance change when these filters are applied? In particular, what bias is introduced by setting an upper limit on CALIOP but not on MODIS? By the way, shouldn't MODIS cloud-cover be considered in some way? Do you accept MODIS data when cloud cover is near 100% - i.e. only a few pixels are available to the retrieval?

p. 27979, bottom: "In order to understand and illustrate some of the potential reasons for discrepancies..." Weak language and goal.

p. 27982: long, inconclusive discussion of variability

p. 27983, lines 3-12: The fact that HSRL and AERONET agree on AOD is the main point to be made here. Discussing possible reasons for a small discrepancy (which is not shown to be outside of uncertainty) is distracting speculation.

p. 27983, lines 23-26: This is the key result of the case study in regard to AOD: consistency among four instruments while CALIOP is a factor-of-two lower. If the paper retains its focus on this case study, this result should appear in the Abstract and Conclusions. [However, the attempt to tie it to the continent-wide MODIS comparison is not valid, for reasons given in Specific Comment 1, above.]

p. 27984, lines 19-20 and Fig. 4b: Text states that backscatter values "are deleted underneath the highest detected cloud..." but Fig 4b does not show any blank regions beneath the purported cloud. The cloud itself is removed, but there is no other discernable change (that I can see).

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Fig. 4: show the limits of the 40-km domain upon which the CALIOP retrieval is based

p. 27990, lines 25-26: "a reported cloud... that could lead to an erroneous layer classification" Speculation is not sufficient for publication. Test it.

Fig 6: I cannot distinguish the blue and black lines.

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 27967, 2010.

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Interactive Comment