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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 #2

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GENERAL COMMENTS

As stated in the title, the manuscript describes the assessment of the accuracy of the version 2 extinction product retrieved by the CALIOP space-borne lidar on the CALIPSO satellite during a detailed case study. Both column aerosol optical depth (AOD) and extinction profiles are examined.

Given the high level of interest in the extinction and AOD data products, as is evi-

denced by the number of publications listed on CALIPSO's website, it is imperative that the accuracy of these products be assessed. As the CALIOP Level 1 (attenuated backscatter) data have supposedly already been validated, it is generally argued that the main source of error in the retrieval of extinction from CALIOP (or, for that matter, from any elastic-backscatter lidar) is the value of the extinction-to-backscatter (or lidar) ratio that is used in the extinction retrieval. As there is considerable spatial and temporal variability in aerosol types and as the lidar ratio of some aerosol types can vary widely, the error resulting from use of an incorrect lidar ratio can be considerable. For example, on the CALIPSO website the quoted lidar ratios at 532 nm for biomass-burning (smoke) and marine aerosols are, respectively, 70 sr and 20 sr. If poor SNRs led to the misidentification of a marine aerosol as a biomass burning aerosol, then the retrieved AOD could be in error by a factor of at least 350%. While this, one imagines, is unlikely, such an occurrence is presumably not impossible. Now while equations for the uncertainties in the retrieved extinction and AOD in the CALIOP Extinction ATBD on the CALIPSO website include terms for the uncertainty in the lidar ratio, it would be unhelpful, misleading, and not very useful if a lidar ratio uncertainty of 350% were used for all extinction retrievals. The CALIPSO Data Quality Statements (CALIPSO, 2009) in fact state that the aim is to determine the lidar ratio to within 30%. The question of interest to users of the CALIOP data though is just how well do the actual errors compare with the quoted uncertainties. Ideally a statistical assessment of the distribution of these errors as a function of aerosol type, location and so on is required. Such a statistical assessment can only be made by comparisons of the CALIOP retrievals with high-quality, collocated data such as the authors acquired during their case study.

This paper is then both timely and relevant. In addition, contrary to what is often argued, the authors find, at least for their limited case study, that the errors in the CALIOP version 2 extinction product are not primarily a result of errors in the lidar ratios employed, but of other errors that are supposedly fixed in the version 3 data release. Given that these error sources (related to daytime signal calibration, layer boundary location and cloud-clearing) are quite varied and have even more varied impacts that are not easily quantifiable in a general sense, data users (who are now most likely using version 3 data) would want to know to what degree these fixes have improved the product. From the submission date of this paper it is apparent, however, that the work was performed before the version 3 was released. Data users would hope then that the authors perform a similar analysis on version 3 data in the near future.

Although this paper is timely and relevant, and is generally well-structured and important error sources highlighted, there are several points discussed below that require attention before it is publishable.

SPECIFIC COMMENTS

Analysis Methods used:

(a) Comparison with MODerate Imaging Spectroradiometer (MODIS) AOD over the continental USA.

There is significant spatial and temporal variability in aerosol loading and characteristics, so comparing column AODs measured by instruments potentially so temporally and spatially collocated as CALIPSO and MODIS Aqua, both of which fly in the A-Train, is a good way to reduce the effects of this variability (although the MODIS AOD product itself has significant scatter, especially over land (Levy et al., 2010). In their current analysis the authors find poor correlation between MODIS and CALIOP AODs. It is disappointing, however, that they cannot say with certainty, which of the several possible error sources is the main reason for this lack of correlation, and, therefore, the value of this part of the paper is rather reduced. (This lack of certainty is a consequence of the unknown contributions of the error sources described above that are supposedly fixed in the version 3 data release.)

(b) One-day, multi-instrument case study.

Ideally, this is a good way to ensure that the data are spatially and temporally coincident. While the authors find that there is significant variation in the AODs from the

reference instruments, they find that this variation is rather less than the difference between these measurements and the CALIOP AOD. This is the significant finding.

However, their subsequent, extensive discussion of variability and autocorrelation analyses reported by others is not really relevant here, as consistency of atmospheric conditions, or lack thereof, at other times and locations cannot guarantee that conditions will be consistent or inconsistent in the present case. In the comparison of the HSRL results with those of CALIOP, for example, the only way to determine whether the retrieved extinctions and AODs from the different instruments are comparable is first of all to confirm that the input attenuated backscatter profiles are themselves directly comparable. This the authors attempt to do. However, the comparison of the 40-km resolution CALIOP retrievals with HSRL results at a finer horizontal resolution is a bit confusing and could do with clarification. (In the process of comparing the attenuated backscatter profiles, the authors find that the CALIOP data are contaminated by undetected cloud signals. It should be pointed out that MODIS too has cloud clearing issues. Levy et al (2010) report that MODIS AODs are not reliable near cloud.)

Frequent reference to “assumed” lidar extinction-to-backscatter ratios:

The authors frequently state that that CALIOP’s extinction retrieval makes “assumptions” as to the value of the lidar ratio (e.g. p. 27968 l. 22, p.27969 l. 17, p. 27972 l. 26, p. 27979 l. 18, p. 27987 l. 23, p. 27988 l. 23, p. 27995 l. 9 & 11 and so on - even in the title of subsection, 4.3.2). (To be fair, the authors of this paper are not alone in using this potentially misleading language.)

A reading of the CALIOP algorithm papers featured in a dedicated “Special Collection” in J. Atmos. Ocean. Tech., summarized by Winker et al (2009), reveals that the lidar ratio is not assumed. The selection of the lidar ratio, which is supplied to the extinction algorithm for retrieving extinction profiles and optical depths though a pre-defined layer, involves several steps. These steps are signal calibration, determination of layer (called a “feature” in CALIPSO parlance) boundaries, classification of the (non-molecular) feature as either cloud or aerosol, and further classification of the aerosol feature as one of several types, each of which has a related lidar ratio.

The algorithm for classification of the aerosol layer into the various subytpes incorporates a sophisticated analysis of multi-dimensional probability distributions based on characteristics of the lidar signals and geographic location and so on. In addition, the lidar ratios associated with each aerosol were determined after an analysis of the characteristics of six distinct aerosol classes identified after an extensive clustering analysis of AERONET sunphotometer measurements from different sites around the world. So the lidar ratios are not assumed. They are estimated from the characteristics of the lidar signal combined with an aerosol optical model that was itself based on observations.

It may be argued (e.g. p. 27987 lines 16, 17), however, that the CALIOP algorithms assume that the lidar ratio is constant with altitude, but this too would be somewhat misleading. Because the aerosol classification model used by CALIOP assigns a unique lidar ratio to each identified aerosol type and because each feature is defined as a region composed of one aerosol type (and detected at one horizontal resolution) extinction profiles are indeed retrieved using a single lidar ratio for each feature. However, because CALIOP detects features at different horizontal resolutions and layers of dissimilar types can adjoin each other vertically and horizontally, a single, contiguous aerosol layer can have a "complex" structure in which the lidar ratio varies in a stepwise fashion in the vertical direction. Bear in mind that the HSRL (and Raman) systems do not make instantaneous measurements of the lidar ratio at each point in the vertical either. They determine aerosol transmittance from their molecular channels. As the single-shot profiles are noisy, they usually need averaging in height and time (or along-track distance) before a lidar ratio can determined. So, it could be argued that these systems also make "assumptions" about the spatial scale of the lidar ratios. They are just different scales from those used by CALIOP.

In summary, while the authors could argue that CALIOP's aerosol subtyping algorithm is unreliable where the SNR is low or that CALIOP's aerosol model is inappropriate

in certain situations (or even generally if they have the evidence) it is misleading for them to claim that CALIOP makes incorrect "assumptions" as to the lidar ratio. I would suggest that the authors select their wording more carefully.

Confusing and inconsistent definition of aerosol transmittance:

There are two concerns here. First, the authors use equations for the two-way transmittance that are functions of one variable (Equation 2) or two variables (Equations A1 to A6). Consistency is needed, and as different transmittances are measured over paths with different start and end points, the use of two variables is to be preferred, as in Equation (A1).

The second concern is the use (on page 27964 and Appendix A) of the symbol z as both a range from the lidar (e.g. line 16) and as a height (line 19). The terminology becomes even more confusing when the authors define "0" as the "height of the CALIOP lidar", when we know that CALIPSO is orbiting at about 700 km. This all needs some tidying.

TECHNICAL COMMENTS

Page 27968, line 22: "backscatter-to-extinction ratio (Sa)". Normally this symbol is used for the "extinction-to-backscatter ratio", just as you define it on page 27975 line 5. (Corrected in Author Comment AC C11255 Dec. 18, 2010))

p. 27971, line 15: Jones et al., 2009. In the References section you have Jones and Christopher 2010. Is this the reference you mean?

p. 27971, line 17: Gonzi et al. (2010) is Gonzi and Palmer in the References.

p. 27971, line 23: Kuhlman et al. 2010 is Kuhlman and Quaas in the References.

p. 27973, line 1: "are being introduced" should probably now be replaced with "have been introduced". You should update your paper and state that the since the analysis for this paper was carried out, CALIOP version 3 has actually been released.

p. 27974, Equation 2: You have z as both a dummy variable and as the limit of the integral. The dummy variable should be changed to something else, e.g. z', or r.

p. 27976, line. 2,3: Piironen et al. is Piironen and Eloranta in References.

p. 27976, line. 18: "decimating". Because of the etymology relating to one tenth or one in ten, this word is not ordinarily used with exact fractions or percentages like the "factor of 20" you use. It could be replaced by a word like "reducing" or "sub-sampling"

p. 27978, line 3: "on the vertical" or "in the vertical", which you use elsewhere?

p. 27978, line. 21: (Kendal, 1957) is Kendal and Maurice in References.

p. 27979, line . 21: "peer reviewed" should be hyphenated.

p. 27986, line. 12: "on the vertical" or "in the vertical"?

p. 27987, line. 18: "on the vertical" or "in the vertical" as you have in line 20?

p. 27987, line. 20 and 22: "compared to" should be "compared with" when comparing similar things - lidar ratios here.

p. 27988, lines 21, 23: The comparisons of the ranges of variability of lidar ratios from CALIOP and the HSRL are over different height ranges and need modification. Rather than a range of 29 to 83 sr for the HSRL, a range of 53 – 83 sr appears closer to the mark.

p. 27989, position of section 4.3.2 relative to 4.3.3 and other subsections: I would have thought that the logical order of the subsections would have been 4.3.3, the issues related to signal calibration, cloud clearing and averaging; 4.3.1, the performance of the feature detection algorithm and, finally, 4.3.2, the selection of the lidar ratio for the detected feature.

p. 27989, line 22 – p. 17990 line 7. This appears to be a significant result and I am surprised that it does not have greater prominence, along with the other significant

finding on p. 27983 on the relative difference between the CALIOP-derived AOD from the other reference AODs and the variation between the other AODs.

p. 27991, line. 10: "across a range altitude of" should be "across an altitude range of".

p. 27993, line. 14: Changing "… differences between both profiles below …" to "… differences between both profiles less than …" may help avoid any confusion here as you are also talking about various height regions.

p. 27994, line. 7: "under and above". I suggest either "under and over" or "below and above", with a preference for the latter.

p. 27998, Eq. 8 : In line 8 you define this as the "extinction-to-backscatter" ratio, which it should be given its use in Eq. (A9) and (A10). So Eq. (A8), should be Sa = sigma_a(z) / beta_a(z). (Corrected in Author Comment AC C11255 Dec. 18, 2010)

p. 28002, 3: Powell et al. reference. Give proper reference to Proceedings, publisher and page numbers.

p. 28004, line. 9 – 12: Vaughan et al reference. Update and give proper reference to Proceedings, publisher and page numbers.

p. 28010, Fig 2(a): The Figure is very small and I needed a magnifier to read it. The back trajectory inset is too small to read even with a magnifier. However, these comments are based on the "Printer Friendly version". I have just checked the on-line version and, when magnified 150 - 200%, the figure can be read well enough.

p.28015, last line of caption for figure 7: Put regression results and uncertainties in parentheses: (1.19 ± 0.03), (0.00 ± 0.00).

References

CALIPSO Version 2 Data Quality Statements, 2009, available on the web at. http://eosweb.larc.nasa.gov/PRODOCS/calipso/Quality_Summaries/CALIOP_L2ProfileProd

Levy, R. C., Remer, L. A., Kleidman, R. G., Mattoo, S., Ichoku, C., Kahn, R., and Eck, T. F.:Global evaluation of the Collection 5 MODIS dark-target aerosol products over land, Atmos. Chem. Phys., 10, 10399–10420, doi:10.5194/acp-10-10399-2010, 2010.

Winker, D. M., Vaughan, M. A., Omar, A., Hu, Y., Powell, K. A., Liu, Z., Hunt, W. H., and Young, S. A.: Overview of the CALIPSO mission and CALIOP data processing algorithms, J. Atmos. Ocean. Tech., 26, 2310–2323, doi:10.1175/2009JTECHA1281.1, 2009.

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