Interactive comment on "The CALIPSO Version 4 Automated Aerosol Classification and Lidar Ratio Selection Algorithm" by Man-Hae Kim et al.

Anonymous Referee #4

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We thank the referee for their careful reading of our manuscript and their thoughtful comments. We have reproduced the referee's comments below (in black) and included our responses in-line (in blue).

Review of "The CALIPSO Version 4 Automated Aerosol Classification and Lidar Ratio Selection Algorithm" by Kim et al.

This manuscript details and evaluates changes to the new version 4 CALIOP aerosol classification algorithm. Major highlights, the inclusion of a "dusty marine" type and improvements to smoke classification in the troposphere, and a new stratospheric aerosol subtyping algorithm. Changes in the algorithm lead to improved extinction retrievals when compared to AERONET and MODIS over the ocean. The manuscript is well written and thoroughly details modifications to the algorithm. Therefore, I recommend that this manuscript be accepted following minor revision.

Major Comments:

1. For evaluating CALIOP extinction using MODIS, why not include MODIS deep blue AOD, which provides AOD over land, including bright surfaces?

The MODIS Deep Blue retrievals would undoubtedly be useful in evaluating CALIOP extinction and AOD estimates over desert regions and other highly reflective land surfaces. However, investigating regional variations in CALIOP AOD (or regional AOD differences between CALIOP and MODIS) is not an integral part of this study. Instead our primary goals are to (i) explain the mechanics of the V4 algorithm and highlight the ways that the V4 algorithm differs from the V3 algorithm; and (ii) illustrate the effects of the algorithm changes on the CALIOP data products. As part of doing part (ii), we use MODIS as a "constant external reference". And as long as we consistently use the same reference value (i.e., as long as we always compare V3 and V4 to the same MODIS data product), it really shouldn't matter which reference we choose.

Two factors motivate our choice of the MODIS Dark Target data set as our reference.

1. As noted in the discussion paper (see lines 24–25 on page 31), numerous previous publications have compared MODIS and CALIOP V3 AOD estimates. All of these studies used Dark Target; none used Deep Blue. By choosing Dark Target as our reference, we readily facilitate comparisons between our results and those published previously.
2. In discussing the reviewer's suggestion, we find ourselves highly persuaded by the Deep Blue vs. Dark Target comparison done by Sayer et al., 2014.

   Due to the complexity of the global Earth (surface and atmospheric) system, and the optimization of the algorithms for global rather than regional applications, neither algorithm consistently performs better than the other. To make some general comments, over much of the global land surface, the AOD retrieved by the algorithms and the level of agreement with AERONET are similar, such that ***it may not matter for many applications which of DB or***

> ***DT a user chooses***. *DT often has a better correlation with AERONET than DB, but DB has (outside of tropical regions) greater spatial coverage, and tends to have smaller error compared to AERONET values in low-AOD conditions.* ***DB and DT often exhibit much smaller AOD differences than would be expected given their estimated individual uncertainties****, which should not be taken to mean that they have converged on the truth, but is a reminder that they should not be considered to be independent data sets.*
>
> (The additional emphasis simply reinforces the point made earlier; i.e., 'as long as we consistently use the same reference value, it really shouldn't matter which reference we choose.')

In particular, this might help to validate the impacts of improved surface detection in Figure 15e.

The "improved surface detection" in V4 allows CALIOP to retrieve estimates of aerosol extinction coefficients and optical depths in regions where the signal was previously considered to be totally attenuated by overlying layers that were mistakenly identified as being opaque. A huge majority of these overlying layers are clouds. Since MODIS cannot detect the aerosol layers below these clouds, MODIS data products cannot help evaluate the accuracy of CALIOP's subtype assignments in these aerosols.

Minor Comments:

Page 2, Line 2: "Aerosol subtyping..." This sentence doesn't make sense to me.

The original text was "Aerosol subtyping is important all by itself for identifying aerosol by type. But it is also important for the CALIOP level 2 retrievals of aerosol optical properties."

The revised text is "While CALIOP's aerosol subtype classifications are useful as a wholly independent data product (e.g., Nowottnick et al., 2015; Sun et al., 2018), knowledge of aerosol subtype is also critically important for the CALIOP level 2 retrievals of aerosol optical properties."

Page 2, Lines 12 – 16: These findings (dust in marine boundary layer and smoke layers classified as marine) were also reported in Nowottnick et al., 2015. Consider adding a reference to this paper.

Done

Page 5, Line 11: Is Rmas is defined as the ratio of the total attenuated backscatter to the molecular backscatter or the ratio of total attenuated backscatter to molecular attenuated backscatter? Some clarification would be useful to the reader. Also, is the molecular depolarization ratio assumed to be the same as in Omar et al., 2009? If so, please refer to that or provide to the reader.

Equation (1) in this manuscript is identical to equation (11) in Omar et al., 2009, as are the definitions of all quantities therein. As suggested, we have added a reference to the Omar paper.

Page 5, Lines 21-22: "First, . . ." This sentence is confusing, please consider revising.

The original text was "First, δ_p^{est} is a noisy quantity that has a positively skewed distribution that is exacerbated by solar background noise during the daytime."

The revised text is “First, δ_p^{est} is a noisy quantity that is asymmetrically distributed, with a large positively skewed tail that can be considerably increased by solar background noise during the daytime.”

Page 6, Lines 9 – 12. In both V3 and V4 versions, why is polluted dust reduced over land compared to night? I’m assuming it’s due to better signal-to-noise at night, but an explanation might be useful.

The dominant source of this difference is the day-night differences in depolarization ratio SNR. See our reply to the previous comment; larger daytime δ_p^{est} values result in more dust relative to polluted dust.

Page 6, Line 12: “AODdifferences”. Missing a space.

Fixed

Page 7, Line 9: I agree that a simple assumption of the PBL height is sufficient, but some justification for the threshold value (2.5 km) from literature or a figure that shows 2.5 km is a good global approximation should be included here.

We added a reference to this paper: McGrath-Spangler, E. L., and A. S. Denning (2013), Global seasonal variations of midday planetary boundary layer depth from CALIPSO space-borne LIDAR, J. Geophys. Res. Atmos., 118, 1226–1233, doi:10.1002/jgrd.50198.

Page 7, Lines 9-15: If I’m understanding the new modification to the algorithm correctly, polluted continental cannot be classified if the top of a layer is greater than 2.5 km. How does this impact the identification of long-range sulfate transport (ex. Asian pollution reaching North America)? This limitation might be noted here.

The more general limitation is that pollution which is lofted above 2.5 km will be misclassified as smoke – or clean continental if the integrated attenuated backscatter is very low. To acknowledge this limitation, the following sentence was added to the end of section 2.1.3: “A limitation of identifying smoke layers according to altitude is that pollution lofted by convective processes or other vertical transport mechanisms can be misclassified as elevated smoke.”

Page 8, Line 14: What is the integrated color ratio threshold for cloud vs. aerosol discrimination? The same as in Omar et al., 2009? Please include this in the discussion.

The color ratio threshold in the CALIOP cloud-aerosol discrimination (CAD) algorithm is not a single value, but is instead a function of latitude, longitude, and altitude. See Liu et al., 2009 and Liu et al., 2018 for details.

Page 9, Line 6: Consider explicitly stating the CALIPSO data and what version were used to make Figure 5.

We added “V4.1” to the modified caption for Figure 5. Note that figure 5 shows mid-layer temperatures for layers specifically identified as stratospheric aerosols (i.e., at temperatures below –70°C). As stated in the opening sentences of section 2.2, the classification of stratospheric layers as aerosols and clouds is a new feature first introduced in the version 4.1 data products. Previous releases did not report a stratospheric aerosol layer type.

Page 11, Lines 13-14. Is the tropopause altitude coming from GEOS output?

Yes

Page 11, Line 20. “aa”, replace with “a”.

Done

Page 11, Lines 20-22. Does this misclassification have a significant impact on the extinction product?

The lidar ratios currently specified for volcanic ash and dust are identical at 44 sr for both wavelengths, so in this situation the extinction coefficient and optical depth estimates will be identical irrespective of the aerosol type assigned.

Page 12, Line 4. “..”, replace with “."

Done

Page 14, Line 7. “releasesreleases”, replace with “releases”.

Done

Page 16, Lines 6-9. Nice results using SCARF in the vertical. Is applying SCARF horizontally possible?

Perhaps…but that’s something we wouldn’t consider attempting until the version 5 data release at the very earliest

Page 19, Lines 23-24. Could you provide an example of detection of a tenuous layer?

See Figure 13 in Liu et al., 2018

Page 20, Line 4. “demonstratesan”, replace with “demonstrates”

Done

Page 22, Lines 19-20. There also is regions where polluted continental is the dominant aerosol type over southern Africa. So, the catch-all “PC/smoke” type works well in the region.

Page 23, Lines 11-12. Why does the overestimation of the estimated particulate depolarization ratio primarily affect dust/polluted dust over land?

This happens because the relative fraction of dust and polluted dust detected over land is typically much higher than over water.

Page 24, Line 18. “Whilewhile”, replace with “While”.

Done

Page 24, Line 19. Consider omitting “correctly”, since the occurrence of “dusty marine” cannot be independently validated.

We replaced “correctly” with “more realistically”

Page 24, Line 24-25. What are there less nighttime stratospheric aerosol features than during the day in V4?

To reduce/eliminate potential confusion, we have rewritten lines 23–25. The original sentences read as follows: "Stratospheric features detected in V3 are classified as cloud or stratospheric aerosol in V4. Stratospheric features in V3 are changed to cloud more frequently for nighttime. Similarly, stratospheric aerosol in V4 is less at nighttime than daytime compared to stratospheric features in V3." This is the new text: "The generic stratospheric features previously identified in V3 are now classified as clouds or aerosol in V4. During the daytime, these V3 stratospheric features are more frequently identified as clouds, rather than aerosols. At night the situation is reversed: nighttime V3 stratospheric features are most often classified as aerosols."

Page 25, Line 8. "V3 or V4". Should this be "V3 and V4"?

The original text was "either/both V3 or V4". The revised text is "either V3 or V4".

Page 25, Line 22. What is "AVD"?

Atmospheric volume description; see page 20, line 12 in the discussion paper

Page 28 – Why does the daytime AOD decrease from V3 to V4 over parts of the ocean, while the nighttime does not?

In V3, mixtures of dust and marine aerosol were misclassified as polluted dust more frequently in the daytime relative to night. This is because of the noisiness of the daytime signal. These dust/marine mixtures were reclassified as dusty marine in V4, with a smaller lidar ratio. Since more layers changed from polluted dust to dusty marine in the daytime relative to night, the reduction in AOD is greater in the day over some parts of the ocean. During the night, the change in AOD is dominated by the increase in marine lidar ratio.

Page 30, Line 18. What is "STS"?

Supercooled ternary solution; see page 8, line 8 in the discussion paper

Page 32, Lines 21-23. "Resolution. . .CALIOP and MODIS over land are excluded from further consideration in our analyses." However, MODIS over land is compared to CALIOP in Table 8 and CALIOP AODs are biased higher in V4. Consider adding a sentence to explain this result. Also, see Major Comment #1 regarding the possible inclusion of MODIS deep blue in this evaluation.

We made some initial comparisons of CALIOP, MODIS, and AERONET AODs retrieved over land. These comparisons are illustrated in Figure 16 and summarized in Table 8. As we state in the paper, "the inconsistency between the comparisons with AERONET and MODIS points to the need for further validation studies, especially over land." This is the justification provided for limiting additional CALIOP–MODIS comparisons to over oceans only, where MODIS retrievals are considerably more reliable. We revisited our reasoning in light of your comments, and remain convinced that our initial choice was (and is) appropriate.

Page 33, Line 8. Consider omitting "(perfect agreement. . ..)."

The phrase is correct as written; "perfect agreement" would indeed result in a slope of zero.

Figure 16: What is causing the AOD hotspots in V4 over Alaska and central North America? The lidar ratios from V3 to V4 for elevated smoke are similar and improvements to the surface detection in this region show a decrease in AOD (Figure 15e).

Figure 15e only shows the changes in AOD that can be attributed to improved surface detection (i.e., as determined according to the flowchart in Figure 14). With regard to Figure 16, the more relevant panel in Figure 15 is the daytime (right-hand) panel of 15a, which shows the total CALIOP AOD change from V3 to V4. (The nighttime panel of 15a is irrelevant in this context, because Figure 16 shows comparisons to MODIS, which only estimated AOD during the daytime.) According to the color scale in Figure 15, the increases in CALIOP daytime AOD in the "hot spot" regions are somewhere between 0.05 and 0.10. This seems to us to be consistent with the changes shown in Figure 16; e.g., the V3 AODs in central North America range between ~0.050 lower than MODIS (pale blue color) to 0.125 higher (reddish brown color), whereas the V4 AODs are between ~0.05 and ~0.15 higher.

Figures & Tables:

Figure 1: Caption – Consider forward referencing the justification for using 2.5 km as a threshold in the manuscript (page 6 in section 2.1.1 and section 2.1.3).

We added a reference to section 2.1.3

Table 1: Last line – "Canadians", replace with "Canadian".

We changed "Canadians fire" to "Canadian fires"

Figure 7: Since depolarization and color ratio are inputs to the new stratospheric typing algorithm, consider adding those quantities to the figure.

It's our opinion that Figures 7, 8, and 9 provide sufficient information to illustrate our points, and would be made overly-complicated by adding even more panels. Instead we have added text to the captions of these figures saying that "Additional imagery for this scene, including 532 nm depolarization ratios and attenuated backscatter color ratios, can be found at https://www-calipso.larc.nasa.gov/..."

Table 4: Consider adding "Tropo." to the "Aerosol" header in the 5th column.

Since V3 did not separately identify stratospheric aerosols, this additional notation would be redundant.

Figure 15: Is it possible to adjust the color bar to resolve differences in V3 and V4 AOD more clearly (use a finer delta AOD)?

We experimented with **LOTS** of different color bars for this figure, and the one we've used, while still not perfect, was nevertheless the best of the bunch.

Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2018-166, 2018.

References

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