

## ***Interactive comment on “Optimizing Saharan dust CALIPSO retrievals” by V. Amiridis et al.***

**Anonymous Referee #2**

Received and published: 25 July 2013

### **Review of “Optimizing Saharan dust CALIPSO retrievals” by Amiridis et al.**

This paper builds upon current literature suggesting the necessity of a geographically varying dust lidar ratio for CALIPSO aerosol extinction retrievals. The authors focus on Saharan dust and dust mixtures over North Africa & Europe and provide substantial evidence for using a dust lidar ratio of 58 sr rather than 40 sr as implemented in the current CALIPSO algorithms based on comparisons with AERONET and co-located MODIS level 3 aerosol optical depth. They also propose two changes to the averaging strategy used in the production of the CALIPSO level 3 aerosol profile product with the goal to improve average dust extinction profiles by accounting for dust/polluted dust mixtures and accounting for other aerosol types differently. The metric for improved agreement between the current CALIPSO level 3 dust extinction climatology and the revised climatology algorithm proposed by the authors is the BSC-DREAM8b

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dust model.

A growing body of literature supports the notion that dust lidar ratio varies regionally and this should be accounted for in CALIPSO aerosol extinction algorithms and by that of future space-borne LIDAR systems. Since dust is one of the most influential natural aerosol sources with respect to global radiative forcing, this issue is important to address for improving global climate models. Therefore, this paper is well within the scope of Atmospheric Chemistry and Physics. Though the suggestion that the CALIPSO dust lidar ratio should be revised over northern Africa and Europe is not new with this manuscript, this is one of the first papers tackling the practical details of implementing such a revision in regional monthly averages. Further, the proposed methods of averaging non-dust aerosol into CALIPSO level 3 averages are new, making the content of the manuscript relevant, novel and noteworthy.

Altogether, this is a strong manuscript that is comprehensive and clearly written. Methodologies are thoroughly documented and sufficient background material is summarized to place this work in the context of current literature on the topic. Most of my specific comments request additional detail or provide suggestions to improve upon an already superb manuscript. I do not believe most comments will change the papers' conclusions, but I request the authors please pay special regard to the following specific comments as the first may influence quantitative conclusions and the second is a main point in the paper that needs elaboration.

- The CALIPSO AOD averaging methodology implemented in section 3.2 causes a low bias in the mean AOD when quality screening is used. Mean AOD should be computed by averaging the quality-screened aerosol extinction profiles and then vertically integrating the mean aerosol extinction profile to avoid this low-bias. (See specific comment 3).
- Please provide justification for assuming extinction = 0.0 /km for aerosol species that are not dust or polluted dust and show the impact of this assumption alone.

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(Specific comment 10).

Given the high quality of this novel manuscript, the timeliness of its content and its scientific value, I recommend this paper for publication in Atmospheric Chemistry and Physics after the authors please address my comments.

**Specific comments:**

1. Page 12, line 19. Using only extinction  $QC = 0$  may bias the averages low because extinction  $QC = 16$  indicates cases where the layer is opaque which is a perfectly acceptable scenario that occurs for the densest layers. Additionally, it is important to quality screen by extinction uncertainty. This was implemented in Section 3.2, but not here. Why not? Does including/excluding these additional quality screening constraints change your conclusions or statistics upon which your conclusions are based?
2. Page 15, line 21. The CALIPSO extinction quality screening metrics different in Section 3.2 from those used in Section 3.1 (page 12, lines 16-21). It is recommended that the same quality screening metrics be used in both sections not only to avoid biasing statistics derived from the analyses (quality screening procedures are insufficient in Section 3.1), but it would also make the CALIPSO analyses consistent throughout the paper.
3. Page 16, lines 2-4. Mean AOD is computed here by integrating the quality screened dust extinction profiles and then averaging the AODs. Though it has not been documented in the literature, computing mean AOD this way will be biased low. The reason is because when the profiles are quality screened, the optical path length changes. For instance, say a profile has only one aerosol layer extending from 4 km to the surface which had a CAD score of -5 which would be removed by quality screening. Next to this profile is another single aerosol layer

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extending from 4 km to the surface with a CAD score of -100. The second profile passes quality screening. Mean AOD is computed in this paper by integrating both of these extinction profiles independently and then averaging the AODs. The result will be the average of zero AOD in the first profile and a non-zero AOD in the second profile which will lead to a mean AOD that is biased low because the optical path lengths are not equal solely due to quality screening.

The alternative way is to average the quality-screened dust extinction profiles into a mean dust extinction profile and then integrate to acquire a mean AOD. This method assumes that the extinction of the 'bad' aerosol layer that we removed in the example above is the same as the 'good' aerosol layer in the second profile. This is a reasonable assumption – that the layer is horizontally homogeneous – and is used by models when assigning aerosol into grid cells.

The low bias in mean AOD computed by averaging the AODs can be quite large compared to the alternative method; sometimes by a factor of two or more. The attached Figure 1 shows CALIPSO level 3 mean AOD for every latitude/longitude grid cell in July 2007, night, all-sky sky condition, computed by averaging the AODs (method 1; vertical axis) and computed by integrating the mean aerosol extinction profile (method 2; horizontal axis). Colors represent the number of latitude/longitude grid cells on a logarithmic scale. A low bias is always present in the former method with respect to the latter method.

It is recommended that AOD be computed by integrating the quality-screened dust extinction profiles rather than the method currently employed.

4. Figure 3, top row. Suggestion...it would be better to visualize these as 2D histograms where the colors represent the number of cases within a certain CALIPSO AOD / MODIS AOD bin. That way the central tendency would become more evident. As it is displayed, the tendency of the outliers is highlighted. I want to know where samples are most frequent in the black blob near the origin where all of the points are bunched on top of each other.

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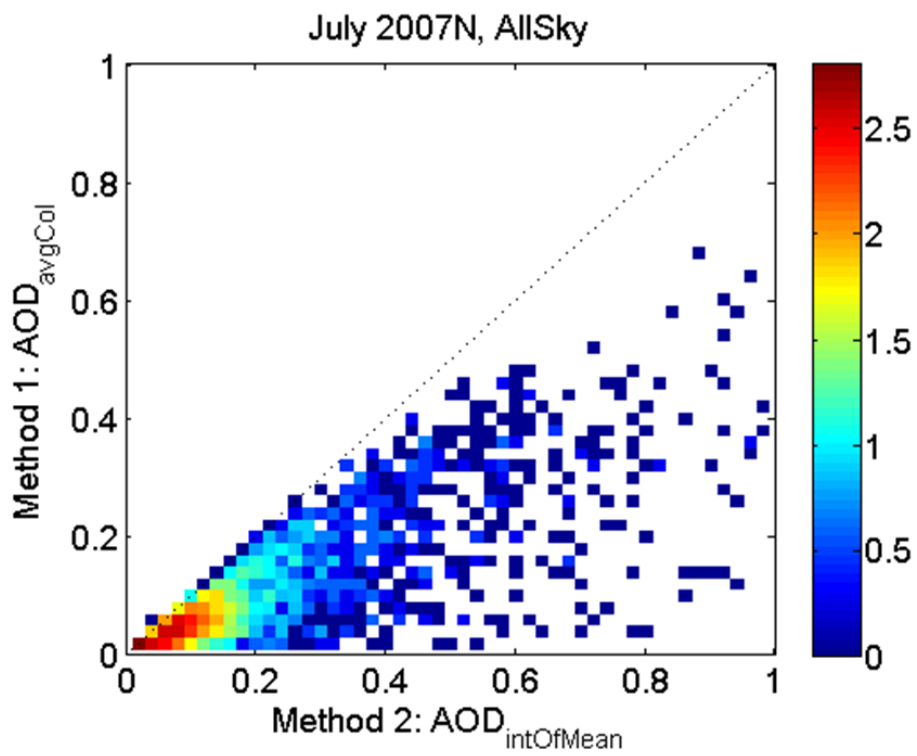
5. Figure 3 caption. The caption says that the upper panel has no filters applied while the lower panel has “filters for dust presence,..”. Does this imply that aerosol types other than dust are included in the top row? If so, why? The discussion is focused on dust and the impact of changing the dust lidar ratio is shown by comparing the left and right panels. With all of this, it seems like we should not be looking at all aerosol types in the top row, only dust.
6. Figure 3 caption. The text says that the filters applied to the bottom row are for dust presence, cloudiness, and MODIS sampling. Are CALIPSO quality screening filters applied to all panels in this figure? They should be. Either way, it is recommended that the authors please clarify when these quality screening filters are or are not used.
7. Figure 3 caption vs. page 17, line 2: The figure caption says “no filters” whereas the text says “without constraints” (page 17, line 2). It is recommended to use the same terminology in both instances.
8. Page 17, line 8. The AOD bias of the original CALIPSO product is written as -0.07. It should be rounded to -0.08 based on the value in Table 2.
9. Page 17, line 9. The slope of the linear regression is written as 0.73, but it is listed in the top row of Table 2 as 0.704.
10. Page 26, line 3. Provide an argument to justify assigning an extinction value of 0.0 /km to aerosol types other than polluted dust and dust. Lines 2-3 state that the extinction is lower below 0.5 km after making this assumption because the marine aerosol extinction was set to 0.0 /km instead of ignored in the average. However, no benefit or rationale is provided. One benefit that could be proposed is that it makes the vertical profile of extinction homogeneous all the way to the surface instead of becoming larger in the lowest 0.5 km, but how do we know the dust extinction does not increase in the lowest 500 meters? Many aerosol

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extinction profiles are largest near the surface. Please explain the rationale for making this assumption in the text. What does it mean physically or statistically? How do the AOD comparisons change with and without this assumption?

Assigning extinction = 0.0 /km for all aerosol types other than polluted dust and dust will drive the Version III mean AOD down. On the other hand, ignoring all other aerosol types in the average will drive the mean up. Why is the former better than the latter?

11. Figure 5 caption. The text describing the green and red lines on the middle panel is inconsistent with the legend text on the figure. The caption text should label the mean layer depolarization reported by CALIPSO as the green line (not the red line) and the re-calculated particle depolarization (i.e., “corrected”) as the red line (not the green line).
12. Figure 9 color map. Consider using a color map that goes from blue to white to red. The current color map makes it difficult to separate positive and negative biases as well as changes in biases between the panels. This is only a suggestion.
13. Figure 8. The biases in Figure 9 change sign between North Africa (negative bias) and central Europe (positive). With this in mind, the profiles in Figure 8 should be evaluated for these two regions separately since we expect the profile shapes to differ since the vertical distribution and mixture of aerosols are different in these two regions. Pure dust would be more representative over Northern Africa perhaps making the Version II and Version III profiles similar while mixtures of dust and polluted dust over Europe could cause these profiles to be dissimilar.



**Fig. 1.** CALIOP level 3 mean aerosol optical depth computed by two methods (see specific comment 3)

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