Atmospheric Chemistry and Physics
Discussions

Atmos. Chem. Phys. Discuss., referee comment RC2
https://doi.org/10.5194/acp-2022-56-RC2, 2022

Comment on acp-2022-56

Anonymous Referee #2

Referee comment on "Retrieving instantaneous extinction of aerosol undetected by the CALIPSO layer detection algorithm" by Feiyue Mao et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2022-56-RC2, 2022

Review of "CALIPSO retrieval of instantaneous faint aerosols" by Mao et al.

The space-borne lidar CALIOP on board CALIPSO satellite has been providing global measurements of aerosol and cloud backscatter profiles since 2006. Successive improvements in algorithms and calibration procedures have resulted in several versions of the products. Nonetheless there is always scope for further improvements. In particular, it has been known that aerosols with weak backscatter sometimes fall below the CALIOP layer detection threshold and several works have focused on this aspect as has been pointed out by the authors. In this paper the authors attempt to retrieve what they call "instantaneous faint" aerosols using the CALIOP backscatter data in both the stratosphere and troposphere and compare the results with SAGE III on ISS. Firstly it is not clear to me what the authors mean by "faint" aerosols---are these background aerosols or aerosols that just fall below the detection threshold but otherwise retain the intensive optical properties of the nearby detected layers. The methodology is nothing new and Kim et al. (2017) have used the same 20 km horizontal and 300 m vertical averaging for their extinction retrievals. The Kim et al. (2017) paper did a much more comprehensive study of the weak aerosols unlike this manuscript which lacks in some important details and other aspects, as described below. I do not believe this paper presents enough innovative ideas or interesting new results that will be useful to the community. I regret that I am not able to recommend this manuscript for publication in Atmospheric Chemistry and Physics. I have the following comments in no particular order:

- The authors seem to use a constant altitude bin of 300 m to average the level 1 (L1) backscatter profiles in the entire altitude range from 0-36 km. This is not tenable, because CALIPSO L1 backscatter profiles have varying resolution with altitude, with 30 m from surface to 8.3 km, 60 m between 8.3-20.2 km, 180 m between 20.2-30.1 km and 300 m above 30.1 km. Properly accounting for these differences will require setting the binning at 900m as was done in Kar et al. (2019) for the level 3 stratosphere aerosol product.
- I am surprised that the authors are talking about the "instantaneous faint" aerosols in the extinction range 10^{-4}-10^{-5} km^{-1} and yet do not mention the estimated uncertainties

for these extinction profiles at all. When they are claiming to do better than the standard CALIPSO level 2 (L2) and level 3 (L3) products, they should discuss the resulting uncertainties for their extinctions to bolster their claims. Kim et al. (2017) had discussed in detail the uncertainties in their retrievals particularly those coming from the lidar ratios used. The lack of any such discussion in this paper is a major drawback.

- In their retrieval algorithm they mention excluding the aerosol and cloud layers detected by the CALIOP L2 algorithm and all data below those layers similar to the methodology employed in Kar et al. (2019). However one important filter has been left out which has to do with the thin cirrus clouds. These clouds often fall below the layer detection threshold and can significantly contaminate the "faint" aerosol profiles they are trying to retrieve particularly in the UTLS area. Kar et al. (2019) had used a filter on the volume depolarization ratio to take out these ice clouds. In fact cloud clearance can be an issue with SAGE occultation measurements as well, which affect the data below 20 km (Thomason and Vernier, 2013, https://doi.org/10.5194/acp-13-4605-2013). It is not clear if the authors have used any filter for cloud-clearing of SAGE III data. Further note that the SAGE III-ISS 521 nm extinction product has low bias between 20 km and 25 km at mid latitudes possibly relating to the ozone interference (Knepp et al., 2022, https://doi.org/10.5194/amt-2021-333). These issues should have repercussions for the CALIPSO/SAGE III comparisons the authors have attempted.
- The authors use a lidar ratio of 50 sr in the stratosphere and 28.75 sr in the troposphere. In Figure 3, they are retrieving "faint" aerosol in between and in continuity with the smoke layers retrieved by CALIOP L2 product, assuming that the "faint" aerosol is also smoke and referring to "the continuous nature of this aerosol layer". For smoke, CALIOP L2 uses a lidar ratio of 70 sr, so the "faint" aerosol extinctions retrieved using a lidar ratio of 28.75 sr will have a significantly low bias. I am also intrigued by the distinct band of "faint" aerosols above 10 km extending from 15°S-55°S—is this background aerosol, smoke? Indeed how confident are the authors that it is aerosol at all? Similarly in the ASR plot Figure 3e, what are all those clumps between 10-30 km? It all just looks like noise to me although the ASR values are quite significant (~1.3) and about the same as within the pink box. Similarly in Figure 7, the authors are showing the plume of "faint" aerosols "connected with the VFM aerosol features"—i.e Siberian smoke extending from 10°N-60°N. Once again, they should use the more appropriate lidar ratio for smoke (70 sr) rather than that (50 sr) for stratospheric background aerosols. Since the authors use coincident extinction data from SAGE III-ISS, have they tried to obtain the lidar ratio (in Figure 4b, for instance) using the extinction from SAGE III and backscatter from CALIOP following the method given in Kar et al. (2019)? It will be interesting to see how those compare with the values they are using.
- It seems to me that in Figure 4, the layer at ~15 km is detected and retrieved by standard CALIOP L2---wonder how that compares with the profiles the authors retrieve. In any case the "faint' layers between 15-20 km in this Figure do not look quite faint to me, and is likely the aerosol that just missed the layering threshold of standard L2.
- As the authors have mentioned, CALIOP has been experiencing low energy laser shots since late 2016 primarily impacting the SAA region and accordingly they have excluded the SAA region. However those low energy shots have been spreading to other latitudes as well and can lead to artifacts in the data including false layer detections at all altitudes, particularly in the dayside. These effects can impact the extinction retrievals the authors are attempting and can be alleviated using the prescription given in the data advisory.
- Line 173-174—"Further, we can see that the retrieved aerosol extinction is much less than the detection limit (0.01 km^{-1}) of the CALIPSO Level 2 product" and lines 234-235—"Instantaneous retrieval of faint aerosol at 20 km horizontal resolution provides a chance to deeper understand and quantify the aerosol impact on climate beyond the current CALIPSO Level 3 Stratospheric Aerosol Profile product". I think the authors are missing the rationale behind the L2 and L3 products. In my understanding

CALIOP L2 first detects a ”layer” using a range-dependent threshold and then assigns an aerosol subtype to it, for which a lidar ratio is available. This lidar ratio varies from 23-70 sr. The layer detection scheme for relatively low SNR measurements like CALIOP is quite complicated (Vaughan et al., 2009, doi:10.1175/2009JTECHA1228.1) and was designed to minimize false positive detections which leads to some undesired missed detections. However, overall it has worked very well and without this and (hopefully) proper assignment of lidar ratios for those different types of aerosols, CALIOP products would not be as useful as they have been. The next generation detection scheme for lidars uses 2D algorithms using both 532 nm and 1064 nm backscatter measurements and will lead to much more accurate detections including those of weakly scattering particulates (see Vaillant de Guelis et al., 2021, https://doi.org/10.5194/amt-14-1593-2021). On the other hand, in the L3 stratospheric aerosol product, which is built from the L1 profiles, the retrieved extinctions are of the same order as the authors retrieve here. The L3 product has low spatial resolution (5^ox20^o in lat/lon necessary to increase the SNR and produces a reliable picture of the known stratospheric features) and is geared towards modelling applications. In other words, the L2 and L3 products have different goals and limitations. L2 products in the stratosphere employ different lidar ratios for different subtypes (ash, sulfates, smoke) unlike in the L3 product where a constant value is used for background as well as the full-aerosol mode. If the authors propose to retrieve the “instantaneous faint” aerosols in between the layers of different subtypes (as in Figures 4 and 7) then they should use the appropriate lidar ratios as mentioned above---this entails using the subtypes defined in CALIOP L2 or they can define their own subtypes.

- Section 3.3. The authors assume all of the stratospheric perturbation in the northern mid/high latitude is coming from the Siberian wildfires. Much of this may actually be from the Raikoke volcanic eruption (June 2019) instead (Kloss et al., 2021, https://doi.org/10.5194/acp-21-535-2021, Knepp et al., 2022, etc.).
- Lines 226-229 and lines 250-252. I don’t understand how from one browse image the authors can show “faint” aerosol “propagating” from 60^oN to 10^oN. By the way the CALIPSO transect shown in Figure 7b passes through the well-known Asian Tropopause Aerosol Layer or ATAL (Vernier et al., 2011, https://doi.org/10.1029/2010GL046614, Fairlie et al., 2020, https://doi.org/10.1029/2019JD031506, etc.) region. How do they know it’s all smoke from Siberia (or, sulfates from Raikoke) rather than at least partly being contributed by ATAL? In fact the ATAL feature mostly falls below the CALIOP layer detection and is seen in the adequately averaged L1 data as in CALIOP L3 product.
- Line 84, line 188—The aerosol product discussed in Thomason et al. (2010) paper related to the SAGE III instrument on Meteor 3M spacecraft, not the ISS.