Referee 2

The submitted paper titled "Assessment of tropospheric CALIPSO Version 4.2 aerosol types over the ocean using independent CALIPSO-SODA lidar ratios" retrieved aerosol extinctions and lidar ratios from a synergetic use of CALIOP L1 profiles and CALIPSO-SODA AODs then assessed lidar ratios used in the CALIOP version 4 aerosol algorithm. The results of this study are very meaningful and may be very helpful to develop further version of the CALIOP aerosol retrieval algorithm. The manuscript is well organized but needs minor revision before publication.

R: We appreciate the reviewer's positive comments and suggestions. Our responses are highlighted in blue.

1) line 55-56: better to move to Section 2 (method). If you declare that you used data for only over ocean, you don't need to mention about plluted dust over desert land in line 65.

Following the reviewer's suggestion, we have moved line 55-56 to section 2 and removed the explanation about polluted dust classification over desert.

2) line 81: So, this is your motivation of this study which is very simple. please describe limitations of previous studies in more detail to emphasize this study. You mentioned the spatiotemporal coverage is extremely limited. Is there any other related studies covering larger regions (global) or long period of time? Your study show any spatiotemporal vatiations which are not discussed in previous studies? Considering a long introduction, your motivation is too simple.

This is, to the best of our knowledge, the first time in which independent lidar ratios are used to characterize the six aerosol types over the ocean. Moreover, the reported lidar ratios (and spatial distributions) in our paper are a unique contribution of Li et al. (2021). Three previous studies have only focused on either specific regions or an individual aerosol types, with a different dataset as the one reported here. We have added the following paragraph to emphasize the knowledge gaps that motivate our much-needed studies:

"…While a few satellite-based studies have endeavored to quantify lidar ratios, they have focused on specific aerosol types, namely, dust (e.g. Liu et al., 2015; Kim et al., 2020) and clean marine aerosols (Dawson et al., 2015). A global assessment of lidar ratio for the six CALIPSO aerosol types over the ocean is, thus, lacking. A detailed lidar ratio characterization is central for refining lidar ratio lookup tables in future CALIPSO versions, as well as potentially improving the aerosol classification scheme, with the final goal of producing more accurate retrievals of aerosol extinction coefficient and optical depth.

In this study, we compare CALIPSO version 4.2 aerosol products and lidar ratios to a CALIPSO-based research product: the CALIOP Synergized Optical Depth of Aerosols (CALIPSO-SODA). We derive the CALIPSO-SODA lidar ratios by applying a Fernald-Klett inversion (Fernald, 1972; Fernald et al., 1984; Klett, 1985) to the CALIOP attenuated backscatter coefficients and the SODA AODs. Our goal is to determine how well the prescribed CALIPSO V4 lidar ratios compare to the retrieved CALIPSO-SODA lidar ratios for each CALIPSO aerosol type over the ocean. In addition, we are interested in analyzing the spatial variability in lidar ratio for each aerosol type and providing global maps that can guide future improvements of lidar ratio selection for CALIPSO products. "

3) line 89: You have introduced only level 2 product. What about the CALIOP level 1 product used in your study? You had used VFM for cloud screen only for the range of 1

The reviewer is correct. We have added the following information. "Lidar attenuated backscatter is taken from CALIPSO Level 1B, as described in Painemal et al. (2019)".

4) - 8.2 km? what about clouds out of that range? The title of subsection is "CALIPSO V4 and SODA data". But there is nothing about SODA.

An effective range up to 36 km of CALIPSO makes possible detecting clouds at virtually any altitude. We have slightly modified the sentence to read: "cloud mask with 333 m horizontal resolution below 8.2 km and 1 km above, up to 36 km.
SODA product is explained in section 2.3. In the revised section, we have moved the SODA description to section 2.1. (CALIPSO V4 and SODA data).

5) line 117: You mean that any aerosol layers below BL are considered as clean marine, even if the CALIOP algorithm classify as other aerosols such as dusty marine, dust, or polluted continental? It could be acceptable for remote ocean but may wrong for coastal regions. How can you justify this?

Computation of CALIPSO-SODA lidar ratios are independent of aerosol typing, which is why L2 makes the general assumption that the BL lidar ratio is clean marine. In other words L1 and L2 are designed to work independent of CALIPSO aerosol retrievals, especially when no aerosol classification is provided by V4. However, we apply both L1 and L2 assumptions to our analysis, depending on whether a given aerosol type is likely observed in the boundary layer or the free troposphere (Table1). This is why we wrote in the original submission: "…Finally, given that CALIPSO aerosol typing depends on the aerosol layer height (Table 1), we characterize clean marine, dusty marine, and polluted continental smoke using CALIPSO-SODA lidar ratios based on the 1L assumption; dust, polluted dust, and elevated smoke aerosols are described by means of the CALIPSO-SODA 2L assumption, to isolate the lidar ratios from elevated layers from those in the boundary layer (likely dominated by marine aerosols)." While dust is a CALIPSO aerosol type that can occur both in the boundary layer and the free troposphere, the lowest aerosol layer height is typically above the computed boundary layer height (line 123 in the original submission). We have noticed that in some specific areas, the aerosol base height could be at times within the boundary layer. However, accounting for those cases is challenging because dust in the boundary layer (as seen by CALIPSO) does not necessarily reach the surface. In other words, the 2L assumption offers a tractable way to derive lidar ratio for dust and smoke, which, on average, fits the assumption that aerosol layers overlie the marine atmospheric boundary layer.

To avoid any misunderstanding, we have rephrased the following sentence: “Thus, the 2L technique is applied irrespective of the occurrence of the Clean Marine type in V4.” to “Thus, both 1L and 2L techniques are used to compute lidar ratios independent of the V4 aerosol typing. However, as discussed in Section 2.3, we select one assumption over the other depending on the likeliness that a given aerosol type occurs in the boundary layer or free troposphere.”

6) line 130-175: Why did you select VFM_max+2km as a top height for the retrieval? Is it only because Painemal et al. (2019) showed best agreement with HSRL for that criteria? What did they compare here in Painemal et al. (2019)? Coulmn AOD from CALIPSO-SODA and HSRL AODs from surface to VFM_max+2km? It should be very careful here because you retrieve only below VFM_max+2km, but CALIPSO-SODA is a coulmn integrated AOD from surface to TOA. You ignored aerosols above the VFM_max+2km (line 157). It could be negligible but you showed the discrepancy up to ~70% (line 154) which is quite large. Based on this results, it looks better to select higher altitude as an upper limit for the retrieval. Authors should expain more acceptable reasons for selecting VFM_max+2km as an upper limit for the retrieval and specify resulting unceartainty in the retrived lidar ratio. Authours mentioned uncertainty of the retrived lidar ratios due to Stratospheric AOD (line 173), but tropospheric aerosols above VFM_max+2km is much more important to discuss.

The rationale was to minimize the effect of profile segments with low signal-to-noise-ratio, which otherwise would had added uncertainties to the retrieved lidar ratios. The VFM_max+2km was indeed adopted because it features the best agreement with the HSRL lidar ratio in Painemal et al. (2019). In the original manuscript, we reported sensitivity calculations by modifying the altitude criterion to VFM_max+1km and VFM_max+3 km, and the differences relative to VFM_max+2km were negligible. Further justification for VFM_max+2km can be found in Kacenelenbogen et al. (2011) who found that CALIPSO (V3) aerosol-layer top height is less than 2km lower than the maximum detectable aerosol retrieval from the HSRL. While the reviewer raises a good point, our interpretation for the lidar ratio difference between VFM_max+2km and that using the entire 36-km column is that the discrepancy is explained by the low SNR at high altitudes of the attenuated backscatter. The fact that the differences is reduced during nighttime is also consistent with higher SNR at night, in the absence of background solar radiation (Figure 2). As we only use tropospheric features for truncating the attenuated backscatter profile, we wanted to have an initial estimate of the effect of stratospheric AOD to bound uncertainties in the retrievals. We agree with the reviewer in that assessing the effect of tropospheric aerosols above VFM_max+2km and the stratosphere is relevant. As global observations of free tropospheric aerosols are unavailable, we can only discuss studies that intercompare episodic lidar observations and CALIPSO retrievals, which show that the contribution of atmospheric aerosols 2km above the VFM_max is generally modest (Burton et al., 2013).

7) Line 209: 2L assumption for polluted dust and elevated smoke is acceptable. however, dust aerosols may frequently exist near the sea surface, especially near the continents. Have you checked this?

See our response to comment 5)

line 236: better not to conclude like this. present uncertainties of each data here.

In the preceding sentences, we briefly summarized intercomparisons between HSRL, MODIS, CALIPSO, and SODA AOD. Based on the close agreement between HSRL, MODIS, and SODA AOD, line 236 is well justified. In the revised manuscript, we have included the mean differences between different products to better justify our statement:

"Similarly, Painemal et al., (2019) found a better match between airborne HSRL and SODA AOD (slope of 0.96) than that for V4 (slopes of 0.71), as well as a better regional agreement with MODIS AOD Collection 6 (mean differences <0.06 and < 0.18 for SODA and V4, respectively)"

line 258-260: "misclassification of ~ tenuous aerosol layers that are not detected by the CALIPSO algorithm" This may be a reason why the authors should select higher upper boundary for the retrieval instead of VFM_max+2km.

The under-detection of tenuous layers is not limited to layers above VFM_max as they can occur at any altitude of the profile. A fundamental problem with including attenuated backscatter at high altitude is the low SNR, which can yield systematic biases in the retrievals. For instance Young et al. (2013) found a positive bias in AOD for samples with low SNR. In other words, extending the profile higher in the free troposphere does not guarantee retrieval improvements. In the revised manuscript, we have added information about the SNR-driven bias discussed in Young et al. (2013).