Review report amt-2023-59 manuscript

The current study deals with the development of a joint retrieval algorithm utilizing CALIOP and MODIS observations. In the algorithm, four aerosol species (water-soluble, light-absorbing, dust and sea-salt) are assumed and for each one of them optical and microphysical properties are derived for 2010. The obtained products are compared against those provided by the official CALIOP and MODIS products as well as against AERONET observations. Moreover, the authors have performed an analysis of the aerosol-induced direct radiative effects. Overall, it is an interesting study which has a lot of potential. However, there are several parts in the manuscript which must be improved thus helping the reader to understand the approach and the scope of each step of the applied methodology (Section 3.1). Another weak point of the study is the poor interpretation of the results presented in Section 5. To be more specific, the discussion should not be limited only in the description of the plots but it should be associated with a physical interpretation. I would also suggest the authors to revise the English writing style throughout the text. As a conclusion, I believe that the submitted paper fits to the AMT purposes but it is needed a major revision before being accepted for publication. I hope that my comments, which are listed below, will help the authors to improve their work.

1. **Line 35:** Aerosols interact also with the longwave radiation.
2. It is better to use the term radiative effect rather than radiative forcing since the latter one is related to the induced perturbations of the radiation budget attributed to anthropogenic activities.
3. **Lines 46-48:** Since you are mentioning the Aeronet optical properties derived by almucantar retrievals you must cite the relevant publications from Oleg Dubovik.
4. **Lines 51-53:** Can you be more specific? Which imagers?
5. **Lines 55-58:** Why is important to mention the aerosol subtypes in the CALIOP Version 3 data since they are not used in the current study?
6. **Lines 70-81:** I suggest to describe explicitly which are the advantages and disadvantages of the CALIOP and MODIS instruments and how complement each other. The current description is poor and vague. It is needed a better description supported by findings of previous studies. What do you mean "*To observe the global three-dimensional distribution of the aerosol composition, we have developed two aerosol composition retrieval methods that use the observations of CALIOP and the Moderate Resolution Imaging Spectroradiometer (MODIS) onboard the Aqua satellite. One is the CALIOP retrieval, which estimates the aerosol composition from the CALIOP observation in the day and night time.*" Have you upgrade the raw CALIOP retrievals or you just processing them for the comparison against those given by the CALIOP-MODIS retrieval?
7. **Line 79:** Why only these aerosol components are considered in the CALIOP-MODIS retrieval?
8. **Lines 96-97:** Please rephrase this sentence.
9. **Lines 96-102:** How do you match the VFM product and the regridded L1B CALIOP data since they are not reported at a common horizontal/vertical resolution? Have you performed an analysis showing how much "sensitive" are your results depending on the selected CAD score?
10. **Lines 120-121:** Specify the source of the Aeronet observations (sun-direct, almucantar retrievals, spectral deconvolution algorithm) that you are processing.
11. **Lines 163-165:** Can you elaborate further this statement?

12. **Lines 195-199:** This paragraph is not so clear and it is needed a rephrasing and a better explanation.

13. **Equation 17:** Do you mean temperature differences instead of variations of the heating rates?

14. **Lines 353-354:** The CALIOP-MODIS retrieval products are compared against CALIOP/MODIS observations? It is not clear to term "simulations" used here.

15. **Figure 5:** In the manuscript there is a description of what it is shown in scatterplots and interpretation is rather poor (Lines 385-388). Why the AOD532nm collocated data are clustered in vertical lines and they are not scattered as for AOD at 1024nm?

16. **Figure 7:** Can you provide an interpretation of the obtained findings?

17. **Figure 8:** It would be useful to discuss how the joint CALIOP-MODIS retrieval modify the raw AODs given by CALIOP and MODIS. For instance, the maximum AODs in the Bodele Depression reproduced by MODIS are not evident neither in the CALIOP patterns nor in the CALIOP-MODIS AODs. Is there any explanation on that? Moreover, in East Asia, the CALIOP-MODIS AODs are close to those given by MODIS. In general, it seems that the utilization of the MODIS data causes a convergence between the CALIOP and the CALIOP-MODIS AOD retrievals. For the CALIOP retrievals you are using the official products in which specific lidar ratios are implemented. However, these values might not be representative as it has been shown in Floutsi et al. (2023). Can you reproduce the CALIOP plots after implementing the upgraded lidar ratios?

18. **Figures 9-12:** The discussion in the manuscript focuses on the figures description without an interpretation of the key findings.

19. **Lines 451-456:** It is not clear which Aeronet data are used exactly. For the AOD is better to use the sun-direct measurements whereas for the other properties (SSA, AF, fine/coarse radii) you are relying on the almucantar retrievals. Is this correct? I think that the number of the collocated samples is very low (particularly for AOD). How many Aeronet stations are used? Can you provide a map depicting the Aeronet sites?

20. **Lines 514-518:** I think that it is missing here a comparison with other relevant studies (e.g., Korras-Carraca et al. (2022))

21. **Figure 17:** I am impressed with the predominance of the positive TOA DREs induced by LA particles over continents (in most parts) and in the outflow regions in the Tropical and the Southern Atlantic Ocean. Is this possible attributed to the low SSAs?

22. **Summary and conclusions:** I suggest to reduce the length of the text.