We thank you for taking the time to review the manuscript and for your helpful comments. We have revised the manuscript in response to your comments. We believe that the manuscript has been greatly improved thanks to your suggestions.

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.

We changed "solar radiation" to "solar and terrestrial 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.

We changed "SDRF" to "SDRE".

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.

We added the reference papers of Dubovik and King (2000), Dubovik et al. (2006), and Synuk et al. (2020).

4. Lines 51-53: Can you be more specific? Which imagers?

SeaWIFS, MODIS, and OMI are used in the retrieval methods of Higurashi and Nakajima (2002) and Kin et al. (2007).

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?

The description of the version 3 was removed.

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?

We developed the CALIOP retrieval based on the similar algorithm to the CALIOP-MODIS retrieval, and the method is different from the raw CALIOP retrievals. We are now preparing the paper of the CALIOP retrieval. However, the description of the CALIOP retrieval is confusing to the reader. We removed the description in the revised manuscript.
Following your comments, we have modified the paragraph as follows: "To observe the global three-dimensional distribution of the aerosol composition, we have developed a new aerosol composition retrieval method that use the CALIOP and MODIS observations. The CALIOP-MODIS retrieval optimizes the aerosol composition to both the CALIOP and MODIS observations in the daytime. The columnar properties of aerosols are available from the MODIS multi-wavelength information, and $\tau_a$ is retrieved accurately (e.g., Shi et al., 2019), but aerosol vertical profiles cannot be obtained, and strong surface reflection (e.g., snow, desert) makes the retrieval difficult (Hsu et al., 2013). CALIOP observations exclude the data at the layers contaminated by the surface reflection and provide information on the vertical profiles of aerosol optical properties and particle shapes (spherical/non-spherical), but only limited wavelength information. Additionally, CALIOP does not detect the tenuous layers in the daytime due to the low signal to noise ratio. This results in the underestimation of $\tau_a$ (Omar et al., 2013; Kim et al., 2018). The synergistic use of both instruments decreases the influences of the surface reflection and provide the more accurate columnar properties and vertical profiles of aerosols. Furthermore, the particle size information is obtained from the combined spectral information of the CALIOP and MODIS observations (Kaufman et al., 2003)."

7. Line 79: Why only these aerosol components are considered in the CALIOP-MODIS retrieval?

Sulfate, black carbon, organic carbon, dust, and sea salt are assumed in most numerical models. We introduced the similar components to the numerical models for the comparison with the numerical model results, and the data assimilation in the future. It is difficult to retrieve sulfate and organic carbon separately, because sulfate and organic carbon are fine and less light-absorbing particles. Therefore, water-soluble is defined as externally mixed aerosols of sulfate, organic carbon, etc. This is described in Sect. 1.

8. Lines 96-97: Please rephrase this sentence.

We have revised the paragraph.

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?

Firstly, the cloud contaminated data of the L1B CALIOP data were removed by the VFM. Then, the L1B data within the horizontal and vertical windows of 10 km and 120 m were collected and averaged. We revised Sect. 2.1.
At the beginning of this study, the CAD score of 20 was used to discriminate clouds and aerosols. However, many hotspots of ECs were found in the retrieval results. Therefore, a more rigorous score of 70 was adopted.

10. Lines 120-121: Specify the source of the Aeronet observations (sun-direct, almucantar retrievals, spectral deconvolution algorithm) that you are processing.

We used the almucantar retrievals. The source was specified in the revised manuscript.

11. Lines 163-165: Can you elaborate further this statement?

In the revised manuscript, we described the aging processes of BC particles at the beginning of the paragraph, and added the reference of the observed spatiotemporal changes of BC mixing state.

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

The paragraph was modified as follows: "To reduce the computational time, we constructed the lookup tables of $\alpha_a$, $\omega_0$, and the phase matrix for each model using the above-mentioned particle models and size distributions. The inputs of the lookup tables were $V_{dry}$ and $r_{m,dry}$ of WS, LA, DS, and SS, and relative humidity. The outputs were $\alpha_a$, $\omega_0$, the phase matrix, and the size distribution of each component at the input relative humidity. Finally, $\alpha_a$, $\omega_0$, phase matrix, $g$, $S_p$, $\delta_p$, and size distribution of total aerosols (WS+LA+DS+SS) were calculated according to the external mixture. These optical properties are used in the forward models of CALIOP and MODIS observations.

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

We calculated the difference of the heating rate with and without aerosols. "T" in the equation was replaced by "HR" in the equation.

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

We applied the CALIOP-MODIS retrieval to the synthetic data of the CALIOP and MODIS observations, which was created by the simulations using the forward models in Sect. 3. We modified the sentences.

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?

The plots of AOD at 532 nm are aligned vertically in the lines because we controlled the total volume of aerosols by giving AOD at 532 nm in the simulations.
The detailed explanation for the retrievals over the ocean was added in the revised manuscript as follows: "In general, the small value of the ocean surface albedo is an ideal situation for the satellite remote sensing of aerosols. However, the retrieval results for $\tau_a$ of WS over the ocean are worse than those over the land because SS is taken into account, in addition to WS, LA, and DS, in the ocean surface cases. In the simulations, the random errors are added to the ocean surface wind speed. Since $r_{m,dry}$ of SS is determined by the given ocean surface wind speed and is not optimized in the CALIOP-MODIS retrieval, the random errors cause the difference of $r_{m,dry}$ of SS between the simulation and retrieval. The difference affects $\tau_a$ of SS. Since both WS and SS are less light-absorbing particles, $\tau_a$ of WS is overestimated (underestimated) when $\tau_a$ of SS is underestimated (overestimated). This opposite sign is seen in the ocean cases of Table 3."

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

The EC of LA and SS were overestimated and the EC of WS and DS were underestimated at all altitudes. The overestimations of LA and SS were compensated by the underestimation of WS and DS. Consequently, the errors for the EC of total aerosols were small (Table 4.). We described these in the revised manuscript.

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 CALIOPMODIS 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?

We described the regional distributions of AOD in the revised manuscript. In the global scale, the CALIOP-MODIS retrieval was between the CALIOP and MODIS standard products, but the results were different by the regions.
The dust source of the Bedele depression in the Sahara was not clear in the CALIOP standard and CALIIO-MODIS retrieval products. The CALIOP-MODIS retrieval utilizes the MODIS measurements but the dust source of the Bedele depression was not clear. We think this may be due to the sparse observations of the CALIOP in the longitude direction.
Do you mean the retrieval of the extinction coefficient from the CALIOP L1B data using the lidar ratios of Floutsi et al. (2023)? It is not easy for us and is beyond the scope of this study.

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

We discussed the results compared with the global maps of Kinne (2019), Gkikas et al. (2021), and Korras-Carraca et al. (2021) in the revised manuscript.

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?

We used the AOD derived from the sun direct measurements, and the SSA, AF, fine/coarse radii of the almucantar retrievals in the Level 2 data product. The sampling number is 91 for the 51 AERONET stations. We added the map of the AERONET stations as a supplement (Figure S1). The CALIOP does not has swath observations, and our retrieval was conducted every 5 km along the track of the CALIPSO satellite. Therefore, the sampling number is low. We are now processing the CALIOP and MODIS data from 2007 to 2021. We will conduct the further validation study using the long-term data.

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

Carraca et al. (2022))

We compared the SDRE of this study with the results of Kinne (2019) and Korras-Carraca (2021) and discussed the differences.

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?

Yes. Korras-Carraca et al. (2021) also shows the similar distribution of the positive TOA DRE.

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

We reduced the length of the text.