Thanks very much for the time and efforts that you have put into reviewing the previous version of the manuscript. We really appreciate all your comments and suggestions that have enabled us to improve the manuscript. Attached is a point-to-point response to reviewer's comments. We have studied comments carefully and have made correction which we hope meet with approval. Revised portion are marked in red in the revised paper.

Reviewer #1:

1. This study displayed the spatiotemporal and vertical distribution characteristics of AOD with the CALIOP data as well as AOD retrievals from other satellite sensors and reanalysis AOD data at a global scale. It also analyzed the associations between AOD and meteorological factors. The detailed analyses by region and by aerosol type contributed to our understating of the variation trends of atmospheric aerosols.

Response: Thank you for your positive comments on our work. We have revised it in accordance with your comments or suggestions. For detailed revisions, please refer to the following sections.

2. In the introduction section, the author provided a detailed introduction on the importance of studying the atmospheric aerosols; however, the summary of previous studies and findings is lacking, making it hard to evaluate the contribution of this study to this field.

Response: Following the suggestions of the reviewers, we have revised the introduction to highlight the contributions of our study. Some previous studies have been added, and the main revisions are as follows:

Lines 89-101 in the revised paper:

"Although these efforts have significantly improved our understanding of the vertical distribution of aerosols, only a limited number of studies have utilized CALIOP observations to examine the partitioning of the total AOD (TAOD) and the AODs due to different aerosol subtypes within different altitude regimes. Bourgeois et al. (2018) reported the amount of TAOD present in the PBL and FT on a global scale using CALIOP data together with the PBL heights (PBLHs) obtained from the ERA-Interim (European Centre for Medium-range Weather Forecasts Re-Analysis-Interim) archive. Shi et al. (2020) investigated the characteristics of aerosol in the residual layer and its effects on the surface PM2.5 over China using ten-year CALIOP data. Vinjamuri et al. (2020) explored the vertical distribution of smoke aerosols against the PBL and average injection height of smoke aerosols over the upper Indo-Gangetic Plain using CALIOP attenuated backscatter lidar profile. In addition to providing total aerosol extinction profiles, the CALIOP classifies the total aerosol profiles into different source types with different physical characteristics using an aerosol classification algorithm. Therefore, the availability of long-term (>10 years) continuous observations from CALIOP makes it possible to deepen our understanding of the interannual variations and trends of tropospheric type-dependent aerosol loading partitioned within different altitude regimes and their meteorological drivers."

Compared with existing studies, the main contribution of our study is to obtain the climatology of TAOD and type-dependent AOD partitioning within different altitude regimes and its long-term trends using CALIOP observations. In addition, another recommended highlight is the examination of the relationships between the interannual variability of aerosol loading within the boundary layer and free troposphere and the meteorological drivers.

References:

1. Vinjamuri, K. S., Mhawish, A., Banerjee, T. and Sorek-hamer, M.: Vertical distribution of smoke aerosols over upper Indo-Gangetic Plain, Environ. Pollut., 113377, doi:10.1016/j.envpol.2019.113377, 2019.
2. Shi, Y., Liu, B., Chen, S., Gong, W., Ma, Y., Zhang, M., Jin, S. and Jin, Y.: Characteristics of aerosol within the nocturnal residual layer and its effects on surface PM2.5 over China, Atmos. Environ., 117841, doi:10.1016/j.atmosenv.2020.117841, 2020.
3. Bourgeois, Q., Ekman, A. M. L., Renard, J.-B., Krejci, R., Devasthale, A., Bender, F. A.-M., Riipinen, I., Berthet, G. and Tackett, J. L.: How much of the global aerosol optical depth is found in the boundary layer and free troposphere?, Atmos. Chem. Phys., 18(10), 7709–7720, doi:10.5194/acp-18-7709-2018, 2018.

3. In the data and methods section, the method used for data assimilation may not be appropriate. The VSM data (1-degree spatial resolution) and WS data (0.5 degree * 0.625 degree) were at higher spatial resolutions than the CALIOP data (2 degree * 5 degree). Thus, the VSM and WS data should be averaged to match the CALIOP grid, but the author used bilinearly interpolation to assimilate the data. The PBLH data from MERRA-2 were also assimilated by bilinearly interpolation, which may lead to systemic bias.

Response: We are very grateful to the reviewers for their scientific advice, which has been fully considered in the revised version. Based on the reviewer's suggestion, we modified the method in the original manuscript from a bilinear interpolation to a simple averaging method. The result is that we made updates to the following five figures in the main text (i.e., Figures 4, 13, 16-18). Overall, the change in resampling method has a negligible effect on the results. For example, the distribution patterns of climatology of TAOD and AODs due to different aerosol types partitioned within the PBL and FT varied little (see Fig.4). Similarly, their trend distributions also changed little, both in terms of intensity and spatial patterns (see Figs.13 and 16). Moreover, the spatial distribution of the correlation coefficients between the partitioned AODs within the PBL and FT and meteorological drivers remain unchanged (see Fig.17). Also, the trend patterns of meteorological drivers have not changed (see Fig. 18). Nevertheless, we have double-checked the corresponding descriptions in the text.

Finally, we choose the average method recommended by the reviewers to present the results of this work. Consequently, "bilinearly interpolated" in the original manuscript was changed to "aggregated".

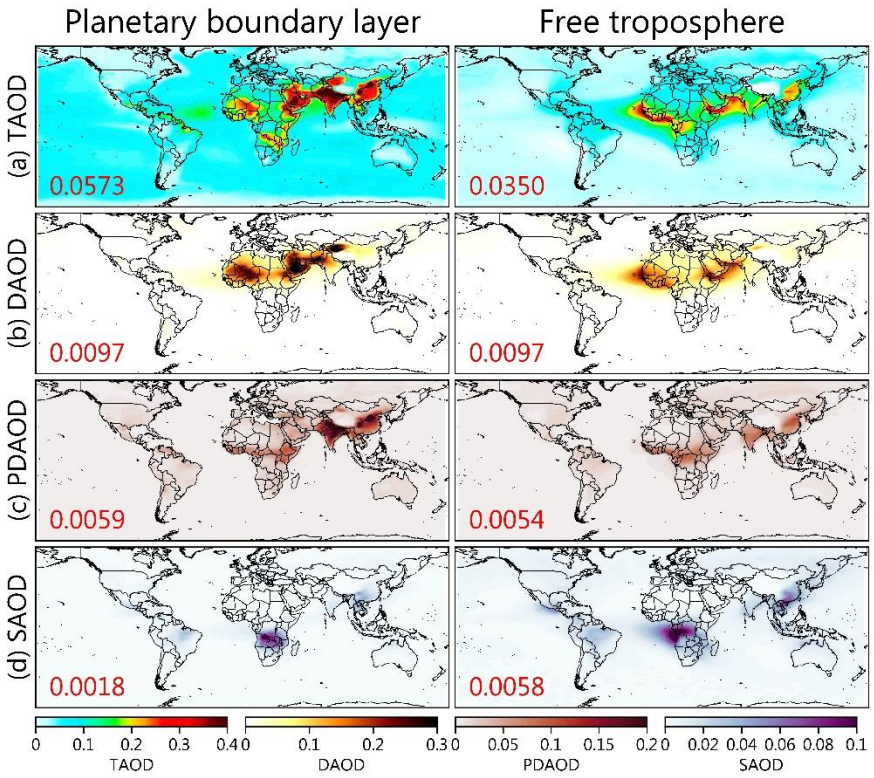

Figure 4. Spatial distributions of multi-year averaged AODs for (a) total aerosols, (b) dust, (c) PD, and (d) smoke in the planetary boundary layer (left-hand panels) and free troposphere (right-hand panels). The global average is labeled in the lower-left of each panel.

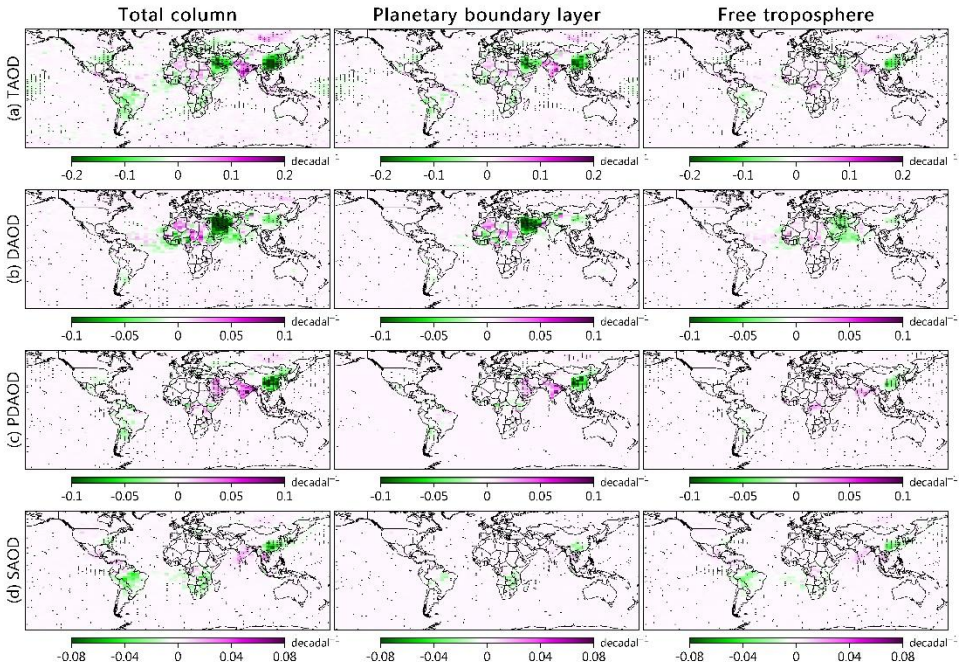

Figure 13. Spatial distributions of annual trends (unit: decade^{-1}) in (a) TAOD, (b) DAOD, (c) PDAOD, and (d) SAOD in the total column (left-hand panels), PBL (middle panels), and FT (right-hand panels), during the period 2007–2019. The grid points with trend values that are statistically significant at the 95% confidence level are marked with black "×" symbols.

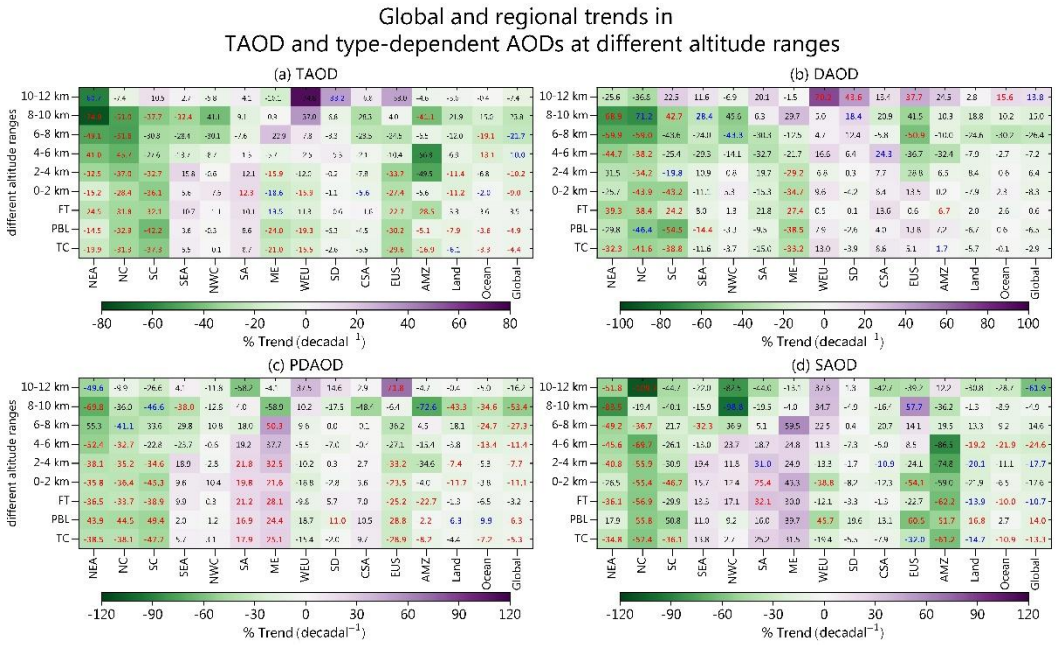

Figure 16. Global and regional percentage trends (unit: % decade^{-1}) in TAOD (a) and type-dependent AODs, including (b) DAOD, (c) PDAOD, and (d) SAOD at different altitude ranges, during the period 2007–2019. The colored squares represent the magnitude of the trend value; the numbers represent the corresponding trend value; and the numbers with red and blue fonts denote that the trend values are statistically significant at the 95% and 90% significance levels, respectively. TC: Total column; PBL: Planetary boundary layer; FT: Free troposphere.

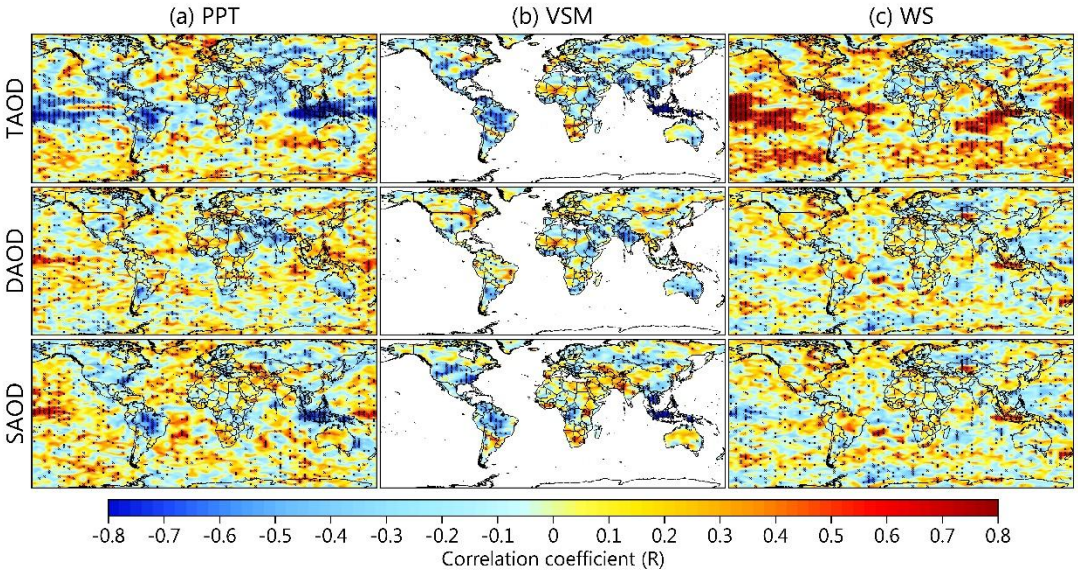

Figure 17. Spatial distributions of the correlation coefficients (*R*) for TAOD, DAOD, and SAOD versus (a) precipitation (PPT), (b) volumetric soil moisture (VSM), and (c) wind speed at 10 m (WS) for 2007–2019. The grid points with *R* values that are statistically significant at the 90% confidence level are marked with black "×" symbols.

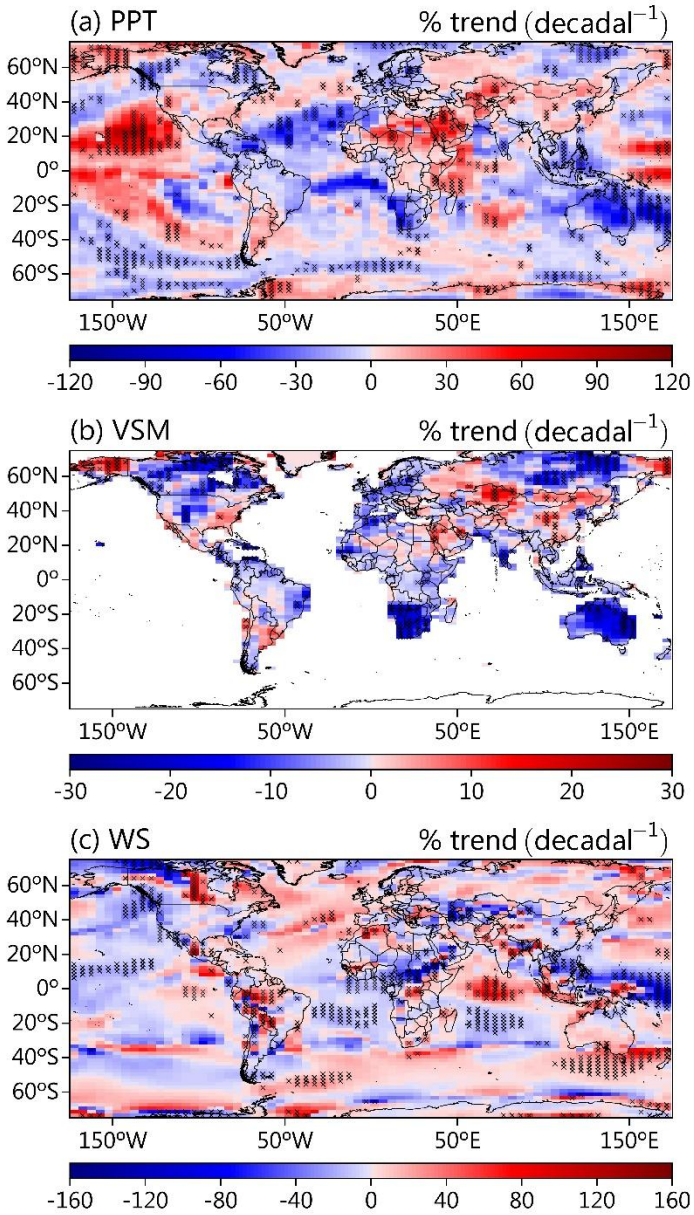

Figure 18. Spatial distributions of annual trends (unit: % decade^{-1}) in (a) precipitation (PPT), (b) volumetric soil moisture (VSM), and (c) wind speed at 10 m (WS) during the period 2007–2019. The grid points with trend values that are statistically significant at the 95% confidence level are marked with black "×" symbols.

4.The result section lists too many numbers without a summary of findings, making it hard to follow. Please only highlight important numbers to support your findings and other numbers can be moved to SI.

Response: The reviewers' suggestions are greatly appreciated and we have streamlined the conclusion section to highlight the important findings of this study. Please refer to the revised manuscript for details. In addition, combining your suggestions with those of another reviewer, we have added some outlooks for future work, as follows:

Lines 730-733 in the revised paper:

"Although CALIOP provides early afternoon and morning observations, two temporal points and a 16d repeat cycle are insufficient to evaluate the diurnal variations of aerosol properties within different altitude regimes. Thus, the observations of a near-full diurnal cycle of aerosol properties [e.g., the Cloud-Aerosol Transport System (CATS) onboard the International Space Station] (Lee et al., 2019; Cheng et al., 2020) should be incorporated to address this limitation in future work."

References:

Lee, L., Zhang, J., Reid, J. S., and Yorks, J. E.: Investigation of CATS aerosol products and application toward global diurnal variation of aerosols, Atmos. Chem. Phys., 19, 12687–12707, https://doi.org/10.5194/acp-19-12687-2019, 2019.

Cheng, Y., Dai, T., Li, J., and Shi, G.: Measurement Report: Determination of aerosol vertical features on different timescales over East Asia based on CATS aerosol products, Atmos. Chem. Phys., 20, 15307–15322, https://doi.org/10.5194/acp-20-15307-2020, 2020.

5. Line 58, the phrase "on the other hand" should follow "on the one hand". The conjunctions in this paragraph should be carefully considered. For example, the usage of "Furthermore" (line 70) and "More importantly" (line 71) could be adjusted.

Response: As suggested by the reviewers, the conjunctions in this paragraph have been double-checked and revised accordingly; please see the revised manuscript for details.

6. Line 141, why these three subtypes of AOD have been paid special attention in this study? The description in line 255-259 can be moved to here.

Response: Thanks to the reviewer's suggestion, the description in lines 255-259 has been moved here.

7. Line 149-150, the logic is not clear. I would say that the better aerosol extinction detection sensitivity during nighttime is resulted from the lack of solar background illumination rather than is resulted from the decreased aerosol extinction detection sensitivity during daytime.

Response: Thanks to the reviewers, this sentence does have a logical expression problem. The original sentence has been changed to *"Note that although the lack of solar background illumination during the night, which leads to the CALIOP lidar has a better aerosol extinction detection sensitivity at nighttime than during the daytime, we do not use the nighttime data in isolation for the analysis here; instead, the average values of daytime and nighttime data (including extinction profiles and sample statistics for all aerosol types and different aerosol subtypes) are utilized.".*

8. Line 389, I do not see the contrast with the phrase "In contrast". What exactly did the author want to compare?

Response: The original sentence has been changed to *"Over land (ocean), the contribution of the integrated AOD within these five specific altitude ranges is 70.82% (87.52%), 23.59% (9.41%), 4.82% (2.28%), 0.53% (0.51%), 0.18% (0.21%) and 0.06% (0.07%), respectively. "*