We thank the reviewers for their thoughtful, valuable, and detailed comments and suggestions that have helped us improve the paper quality. Our detailed responses (Blue) to the reviewers' questions and comments (*Italic*) are listed below.

Reviewer 2:

*General comments: The manuscript entitled "Aerosol Characteristics in the Three Poles of the Earth Observed by CALIPSO" focuses on aerosol characteristics of the Arctic, Antarctic, and Tibetan Plateau by using CALIPSO L3 data and HYSPLIT model.*

*The results show that the AODs over three regions have obvious spatial and temporal feature. Different type of aerosol has remarkable spatial and seasonal. Overall, this manuscript is clear and well written. Some concerns are needed to address.*

We highly appreciate the positive evaluation about our study along with the valuable comments that have helped us improve the paper quality a lot.

*1. Page 1, Line 18-19, the sentence should be "The annual average AODs over the Arctic, Antarctic, and TP are 0.046……", or "The annual mean values of AOD over the Arctic, Antarctic, and TP are 0.046……".*

The sentence has been corrected as suggested.

*2. What is the basis of selecting the simulation points of backward trajectory? I recommend authors to add a simulation point over the eastern TP?*

We are sorry for this confusion; the selection of back trajectory simulation sites is kind of subjective. The main selection basis is the relatively uniform distribution of sites so that the simulation results can retrieve the source of air masses in the study area.

Based on this suggestion, a simulation site over the eastern TP have been added, and the corresponding results are analyzed and added at Lines 444-449: **"Similar to the site on the northern slope of the TP, the back trajectories of air masses at the eastern slope site are greatly affected by the Tarim Basin and Qaidam Basin in spring, but are mainly affected by the Iranian Plateau and the western part of the TP in autumn and winter. Differently, in summer, the back trajectories of air masses are not only from the Tarim Basin and Qaidam Basin, but also from the southern part of the TP with about 27.54% of air masses."**.

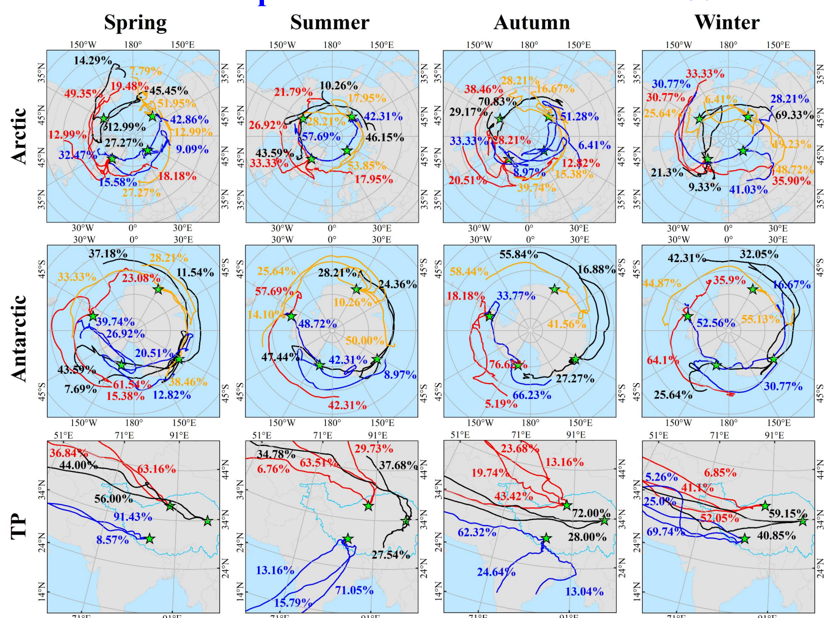


Figure 8: The seasonal climatological characteristics of the back trajectories (January 2007 to

December 2019) at each of the Arctic, Antarctic, and TP sites, separated by spring, summer, autumn, and winter.

*3. Page 7, Line 178, the authors described "decrease with the increase of latitude in any season", however, Figure 2e shows some areas with high AODs at high latitudes of Antarctic in spring.*

We appreciate this careful comment, and have corrected this sentence at Lines 188-191: **"In general, aerosol loadings are found larger in the southern part of the Atlantic Ocean in the Antarctic and decrease with the increase of latitude, while high AODs could exist in some regions at high latitudes of the Antarctic such as the Antarctic Peninsula, especially in spring and winter."**

*4. Page 7, Line 190, "high aerosol concentrations in the Arctic and Antarctic mainly occur in winter and spring", The aerosol concentration of the Arctic should be higher in late fall to early spring, not just winter and spring (Figure 3).*

Thanks for helping figure this out. We have changed the corresponding description and added at Lines 203-205: **"The high aerosol concentration mainly occurs from late autumn to early spring in the Arctic, while in winter and spring in the Antarctic."**

*5. Page 7, Line 174, "the AOD averaged between Jun 2006 and Dec 2019"; Page 7, Line 187, "the monthly variations of multi-year (June 2016 - December 2019) average AODs"; Page 8, Lines 207-208, "the monthly AODs along with their standard deviations from June 2007 to December 2019". Why not use the AOD data for same period?*

We highly appreciate these careful comments and feel sorry for our writing mistakes. We actually used the same period of June 2006 - December 2019. We have corrected them in the revised version.

*6. Page 8, Lines 219-221, "First, there are anthropogenic emission sources over the TP region. Second, the TP is located in Central Asia surrounded by highly polluted areas, which is easily affected by external aerosol transport". The corresponding evidence or reference is needed.*

Following this suggestion, we added scientific references to support our descriptions in this section including

Hu, Z., Huang, J., Zhao, C., Jin, Q., Ma, Y., and Yang, B.: Modeling dust sources, transport, and radiative effects at different altitudes over the Tibetan Plateau, Atmospheric Chemistry and Physics, 20, 1507-1529, 10.5194/acp-20-1507-2020, 2020.

Li, C., Bosch, C., Kang, S., Andersson, A., Chen, P., Zhang, Q., Cong, Z., Chen, B., Qin, D., and Gustafsson, Ö.: Sources of black carbon to the Himalayan–Tibetan Plateau glaciers, Nature Communications, 7, 12574, 10.1038/ncomms12574, 2016.

Liu, Y., Sato, Y., Jia, R., Xie, Y., Huang, J., and Nakajima, T.: Modeling study on the transport of summer dust and anthropogenic aerosols over the Tibetan Plateau, Atmos. Chem. Phys., 15, 12581-12594, 10.5194/acp-15-12581-2015, 2015.

Zhao, C., Yang, Y., Fan, H., Huang, J., Fu, Y., Zhang, X., Kang, S., Cong, Z., Letu, H., and Menenti, M.: Aerosol characteristics and impacts on weather and climate over the Tibetan Plateau, National Science Review, 7, 492-495, 10.1093/nsr/nwz184, 2020.

Zhu, J., Xia, X., Che, H., Wang, J., Cong, Z., Zhao, T., Kang, S., Zhang, X., Yu, X., and Zhang, Y.: Spatiotemporal variation of aerosol and potential long-range transport impact over the Tibetan Plateau, China, Atmospheric Chemistry and Physics, 19, 14637–14656, 10.5194/acp-19-14637-2019, 2019.

*7. Page 8, Lines 219-221, "the wind speed in winter half-year in the Arctic region is higher than that in summer half-year". However, in Lines 199-200, "On the other hand, stable atmospheric status with less precipitation occurs in the Arctic winter". What is the real situation? It needs a verified evidence from satellite or reanalysis data.*

We are sorry for the confusion. The wind speed in Lines 219-221 represents the wind speed near the surface, while the atmospheric stability in Lines 199-200 represents the vertical thermal stability. In order to avoid confusion, we changed the wind speed to the near-surface wind speed. In addition, we used the ERA-5 reanalysis data to investigate the atmospheric conditions over the Arctic region to support our descriptions at Lines 218-220 "**As shown in Figure S1, the Arctic region has a smaller monthly average convective available potential energy (CAPE) in winter half-year, while the monthly average wind speed at 10 m above the surface is higher.**"

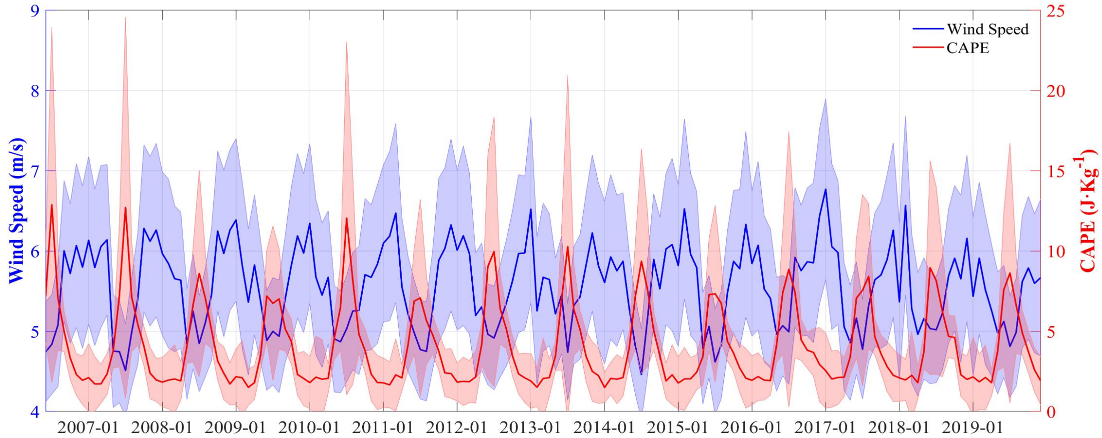


Figure S1: Monthly average wind speed at 10 m above the surface (red line) and its standard deviation (red shadow), and monthly average convective available potential energy (CAPE) (blue line) and its standard deviation (blue shadow), for the period from June 2006 to December 2019 over the Arctic.

*8. Page 11, Line 287, "due to the northerly jet over the TP carrying dust aerosols to the internal TP". Generally, there is westerly jet over TP. Please explain the existence of "the northerly jet over the TP.*

We are sorry for our incorrect description, and this sentence has been changed at Lines 340-343: **"In spring and summer, the proportion of dust aerosol is relatively high, because the dust aerosols originating from the Taklimakan Desert are transported to the internal TP through the northwesterly wind under the topographic blocking (Liu et al., 2015; Jia et al., 2015)."**

References:


Liu, Y., Sato, Y., Jia, R., Xie, Y., Huang, J., and Nakajima, T.: Modeling study on the transport of summer dust and anthropogenic aerosols over the Tibetan Plateau, Atmospheric Chemistry and Physics, 15, 12581-12594, 10.5194/acp-15-12581-2015, 2015.

Jia, R., Liu, Y., Chen, B., Zhang, Z., and Huang, J.: Source and transportation of summer dust over the Tibetan Plateau, Atmospheric Environment, 123, 210-219, 10.1016/j.atmosenv.2015.10.038, 2015.


*9. Page 11, Lines 287-288, "In autumn and winter, the emission of anthropogenic aerosol increases". Lines 290-291, "the increase of biomass combustion". Some evidences or references* *are needed .*

We agree and added scientific references to support our descriptions in this section such as:


Carter, E., Archer-Nicholls, S., Ni, K., Lai, A. M., Niu, H., Secrest, M. H., Sauer, S. M., Schauer, J. J., Ezzati, M., Wiedinmyer, C., Yang, X., and Baumgartner, J.: Seasonal and Diurnal Air Pollution from Residential Cooking and Space Heating in the Eastern Tibetan Plateau, Environmental Science & Technology, 50, 8353-8361, 10.1021/acs.est.6b00082, 2016.

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, Atmospheric Chemistry and Physics, 20, 15307-15322, 10.5194/acp-20-15307-2020, 2020.

Tao, S., Wang, W., Liu, W., Zuo, Q., Wang, X., Wang, R., Wang, B., Shen, G., Yang, Y., and He, J.-S.: Polycyclic aromatic hydrocarbons and organochlorine pesticides in surface soils from the Qinghai-Tibetan plateau, Journal of Environmental Monitoring, 13, 175-181, 10.1039/c0em00298d, 2011.


*10. Page 11, Lines 309-310, "while in the near-ground area (altitude < 2 km), dust and polluted dust have a larger extinction coefficient". However, there is a high value of the dust extinction coefficient above 9 km in Arctic in winter (Figure 6j), what is the possible reason?*

This is a very good question. We are also puzzled that there is a large extinction coefficient layer above 9 km in the Arctic in winter. Through a lot of literature research, the exact reason has not been found while it could be associated with the long-range transport of dust aerosols from mid-latitudes, which generally lie at heights around 7 km (Garrett et al., 2010). To make sure if this phenomenon is true, we conducted a further analysis of the original data and found that there are more outliers in the extinction coefficient of the Arctic region in winter, and outliers are defined as the observed data ($x$) falling outside three standard deviations ($\delta$) above and below the mean ($\bar{x}$), as follows:

$$x < \bar{x} - 3 \times \delta \ or \ x > \bar{x} + 3 \times \delta$$

The vertical distribution of the seasonal averaged aerosol extinction coefficient over the Arctic, Antarctic and TP plotted using the quality control data is shown in the figure below.

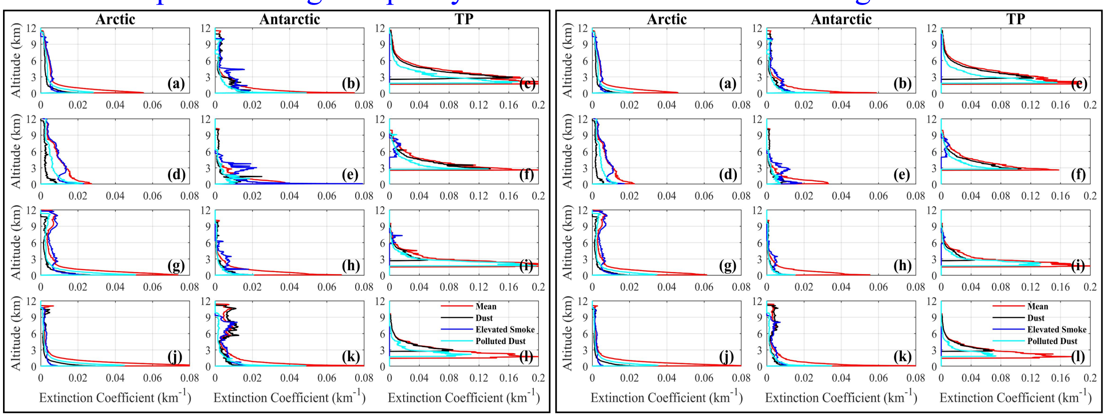


Figure 6. The vertical distribution of the seasonal averaged aerosol extinction coefficient at 532 nm over the Arctic, Antarctic, and TP using original data (left panel) and quality control data (right panel). The vertical distribution of the seasonal (Spring: (a) ~ (c); Summer: (d) ~ (f); Autumn: (g) ~ (i); Winter: (j) ~ (l)) averaged aerosol extinction coefficient (June 2006 to December 2019) at 532 nm over the Arctic (left panel), Antarctic (middle panel), and TP (right panel), including the mean extinction coefficient (red solid line), dust extinction coefficient (black solid line), Elevated smoke extinction coefficient (blue solid line), and polluted dust extinction coefficient (cyan solid line) over the Arctic (a, d, g, and j), Antarctic (b, e, h, and k), and TP (c, f, i, and l).

From the results in the above figure, the quality control of the extinction coefficient will not affect the vertical distribution of the seasonal averaged aerosol extinction coefficient, but will only affect some abnormal values, making the extinction coefficient profile smoother. Since the result is the average value of the extinction coefficient profiles for 13 years (June 2016 to December 2019), we believe that the result after quality control is more reasonable. Therefore, we replaced the result in the manuscript and revised the corresponding descriptions. By comparison, we believe that the high value of the dust extinction coefficient above 9 km over the Arctic in winter is more likely a false signal, which is mainly affected by the abnormal value.

Note that the data quality control as described above has been added into section 2.2.

Reference：

Garrett, T., Zhao, C., and Novelli, P.: Assessing the relative contributions of transport efficiency and scavenging to seasonal variability in Arctic aerosol, Tellus Series B-Chemical and Physical Meteorology, 62, 190-196, 10.1111/j.1600-0889.2010.00453.x, 2010.

*11. Page 12, Lines 316-318, "the extinction coefficient of dust and elevated smoke increases significantly above 5 km, and the polluted dust aerosols have large extinction coefficients under 5 km". Why do the dust and polluted dust occur at different altitudes?*

We are sorry for our unclear descriptions. We have modified the description to "the extinction coefficient of dust and elevated smoke demonstrates bimodal distribution with the second peak values above 5 km, and the polluted dust aerosols show unimodal distribution with peak value under 5 km".

*12. Page 12, Lines 320-321, "From the perspective of seasonal variation, the vertical distribution of dust-related aerosol extinction coefficient is larger in spring (c) and summer (f) than in autumn (i) and winter (l)". However, as shown in Figure 6i, the polluted dust extinction coefficient at 3 km is significantly higher in autumn than in spring and summer.*

Thanks for helping figure this out and we agree with the reviewer. To be accurate, we have made corresponding modifications at Lines 380-383: **"From the perspective of seasonal variation, the extinction coefficient of dust aerosol is larger in spring (c) and summer (f) than in autumn (i) and winter (l). In contrast, the extinction coefficient profile of polluted dust aerosol shows larger values in spring (c) and autumn (i)."**

*13. Page 12, Lines 331-333, "Different from the above aerosol types, the highest OF of elevated smoke occurs at a height of about 2.5 km, and occurs at 8 km and 4 km, respectively in the Arctic and Antarctic regions." The meaning is unclear.*

Thanks for helping figure this out. We have modified the description to make it clear at Lines 394-397: "**Different from the above four types of aerosols, the elevated smoke is found more at higher altitudes extending up to 8 km and 4 km with the highest OF at about 2.5 km in the Arctic and Antarctic regions, respectively, which indicates that the main source of elevated smoke is external transport.**"

*14. Page 11, Line 292, Page 12, Line 325, has the effect of topography in each region been considered when analyzing the vertical distribution of various aerosols? For example, the average altitude of TP is 4 km, while in the Antarctic is 2.3 km.*

This is a good question. In principal, the topography in each region definitely affects the vertical distribution of aerosols due to their effects on meteorology. However, the impact of topography is not investigated in this study due to two considerations. One is that we more focus on the aerosol characteristics along with their vertical distribution at each study area, rather than the differences of aerosol vertical distributions among different study regions. The other is that for vertical distributions of aerosol characteristics at each study region, we have investigated the potential contribution from emission sources and meteorology. The potential impacts from topography are partially included in the meteorology factor. To be more confident, we added a brief discussion to indicate this at Lines 386-387: "**Note that the vertical distribution of aerosol characteristics could also be influenced by the topography in each region, which is out of the scope of current study.**"

*15. Page 13, Line 347, "(10 × 2 × 12 × 13)". What do they represent respectively?*
We are sorry for this confusing description. The numbers show that we simulated at 10 sites, 2 times per month, 12 months per year, and a total of 13 years (from 2007 to 2019) , and now the description has been changed at Lines 411-413: **"A total of 3,432 (11×2×12×13: 11 sites, 2 times per month, 12 months per year, and a total of 13 years from 2007 to 2019) back trajectories were computed at a height of 500 m above the surface at all eleven sites."**

*16. Page 14, Lines 371-377, from Figure 5c, it can be found that there are more dust aerosols over north and northeast TP, however, the backward trajectory does not catch the contribution of the dust from Qaidam Basin.*
This is a good question. The back trajectory simulation does not show the contribution of the dust from the Qaidam Basin, mainly due to the cluster analysis of the back trajectory. As mentioned in section 3.3, the air masses trajectories are merged into several groups based on the total spatial variance (Draxler and Hess, 1998). The basic principle of the clustering process is as follows: the difference of backward trajectories within the cluster is the smallest, while the difference of backward trajectories between the clusters is the largest. Therefore, some air mass trajectories with small contributions may be lost. In addition, error in the distance can also affect back trajectories of air masses (Stohl, 1998).
Based on the suggestion, a new simulation site over the eastern of the TP has been added in Figure 8, from which we can found that the dust from Tarim Basin and Qaidam Basin has a greater contribution to the dust aerosol over the TP, especially in spring and summer.

References:

Draxler, R., and Hess, G.: An overview of the HYSPLIT_4 modelling system for trajectories, dispersion and deposition, Australian Meteorological Magazine, 47, 295-308, 1998.

Stohl, A.: Computation, accuracy and applications of trajectories - A review and bibliography, Atmospheric Environment, 32, 947-966, 10.1016/s1352-2310(97)00457-3, 1998.