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 1:
Using CALIOP data during 2006-2019, the authors presented a detailed picture of aerosol vertical profiles in three key background regions, i.e., the Arctic, Antarctic, and Tibetan Plateau. Given aerosol's important role in climate research and we are not fully clear how aerosol varies, especially with regard to the vertical profile, this work fills a big gap in this regard. Therefore, I suggest to accept this submission after following issues are addressed.
We highly appreciate the positive evaluation about our study.

1. *Suggest to add extra analyses based on AERONET data to support CALIOP results or to cite published results to support the results presented here, for example, the seasonal variations.*
   We agree with the reviewer and more descriptions about the studies of aerosol properties based on AERONET measurements were added with citations at Lines 229-240: **"Similar patterns of multi-year averaged seasonal variation of AOD over the three study regions were also observed using the AERONET data, which have high accuracy and are widely used in aerosol characteristics and satellite-based AOD inversion verification studies (Holben et al., 1998; Martonchik et al., 2004; Russell et al., 2010; Yang et al., 2019). Over the TP, the multi-year averaged AOD reaches the maximum in April and the minimum in December, while the aerosol composition varies greatly among different sites (Cong et al., 2009; Pokharel et al., 2019). High AOD mainly occurs in spring associated with the Arctic haze, and low AOD occurs in summer over the Arctic (Breider et al., 2014; Grassl and Ritter, 2019; Rahul et al., 2014). Monthly mean values of AOD have also been investigated using the AERONET sites (Novolazarevskaya, Dome Concordia, and South Pole) over the Antarctic, which are similar to that found using CALIPSO data, with values ranging from 0.02 to 0.04 from September to March (Tomasi et al., 2015). It should be noted that due to the daytime limitation, only the AODs during the short summer period were analyzed over the Arctic and Antarctic using AERONET measurements."**

   References:

Holben, B., Eck, T., Slutsker, I., Tanre, D., Buis, J., Setzer, A., Vermote, E., Reagan, J., Kaufman, Y., Nakajima, T., Lavenu, F., Jankowiak, I., and Smirnov, A.: AERONET - A federated instrument network and data archive for aerosol characterization, Remote Sensing of Environment, 66, 1-16, 10.1016/s0034-4257(98)00031-5, 1998.

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2. *Pls add the standard deviation of monthly mean in Fig. 3.*

We appreciate the suggestion and added the standard deviation of monthly AOD mean in Figure 3. In addition, we also added related description at Lines 225-228: **"Meanwhile, the standard deviation of AOD is also calculated and shown as error bar in Figure 3. It can be seen that the standard deviation of AOD over the TP is larger than that over the Arctic and Antarctic, indicating that the variation of AOD over the TP is more significant."**

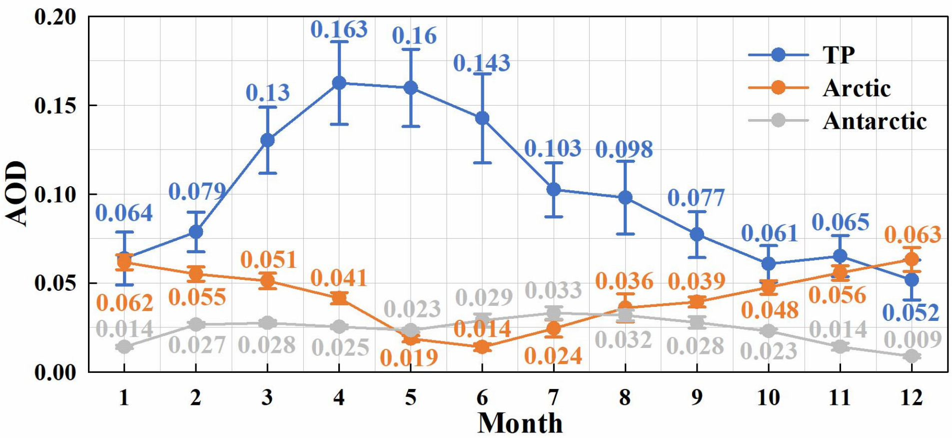

Figure 3: The monthly averages (dots) and standard deviations (bars) of AODs (June 2006 to December 2019) over the Arctic, Antarctic, and TP.

3. *Pls add some words on how to distinguish aerosol types by CALIOP measurements and uncertainty associated with this method. My understanding is that it is very hard to separate polluted dust from smoke, if so, some words discussing uncertainty about occurrence of some specific aerosol types should be added.*

   We agreed with the reviewer that it is difficult to separate polluted dust from smoke partially due to the fact that they have similar optical properties. As we know, the validation of aerosol subtypes is a challenging task for at least two reasons. First, aerosol types have high spatial and temporal variability, which makes it difficult to evaluate the satellite grid observations using the fixed ground site measurements or in-situ airborne measurements. Second, due to the different instrument errors and observation methods by various instruments (such as AERONET, CALIPSO, and MODIS), the definition of aerosol types is often quite different. All of these may lead to large deviations in the verification of aerosol types (Zeng et al., 2021).

   Following the reviewer's suggestion, we added descriptions about the potential uncertainties at Lines 267-275: **"Compared with the aerosol type information from AERONET, MODIS, MISR, and OMI, aerosol types obtained using the CALIPSO are widely used to investigate the aerosol characteristics at a local or global scale. However, the uncertainty assessment of CALIPSO aerosol types is still a challenging task (Kahn and Gaitley, 2015), especially for aerosol types which have similar optical properties, such as polluted dust and smoke (Zeng et al., 2021). Aerosol subtypes from the CALIPSO V3 dataset were evaluated with the AERONET product by previous studies, which showed the consistency of all aerosol types except for smoke and polluted dust aerosols (Burton et al., 2013; Mielonen et al., 2009). In V4 CALIPSO aerosol classification algorithm, several refinements were conducted to improve the accuracy of aerosol type classification (Kim et al., 2018)."**

   References:

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Zeng, S., Omar, A., Vaughan, M., Ortiz, M., Trepte, C., Tackett, J., Yagle, J., Lucker, P., Hu, Y., Winker, D., Rodier, S., and Getzewich, B.: Identifying Aerosol Subtypes from CALIPSO Lidar Profiles Using Deep Machine Learning, Atmosphere, 12, 10. 10.3390/atmos12010010, 2021.

4. *Could you pls present some results on seasonal trend of AOD since long-range transport of external sources to these three regions is seasonal dependent.*

Thank the reviewer for the valuable suggestion. We have added some results on the seasonal trend of AOD in Lines 257-265: "**Figure S2 also presents the temporal variation of seasonal average AOD from the summer of 2006 to the winter of 2019 over the TP, Arctic, and Antarctic. As expected, AOD over the three study regions has an obvious seasonal variation trend. For the TP, the average AOD is about 0.15 in spring, which is the most serious pollution season in the whole year, while AOD is about 0.05 in winter, which is the cleanest season in the whole year. Boreal winter (summer) and summer (winter) are the most polluted and cleanest seasons over the Arctic (Antarctic), respectively. In addition, the standard deviations of seasonal AODs over the TP are between 0.0 and 0.12 due to the influence of transported aerosols from surrounding regions, which is greater than that of 0.0 to 0.05 over the Arctic and Antarctic.**"

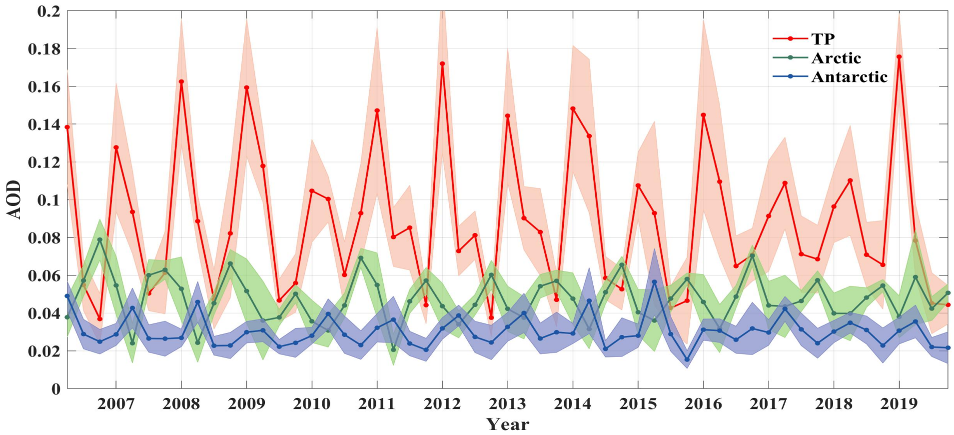

Figure S2: Temporal variation of seasonal average AOD from the summer of 2006 to the winter of 2019 over the TP (red), Arctic (green), and Antarctic (blue). The shaded area represents the standard deviation.

5. *L35-40, suggest to change to "depends on aerosol characteristics and underlying surface.*
   Modified.

6. *L50, references not suitable, suggest add original AERONET references, for instance, Dubovik and King, 2000; Dubovik et al., 2006.*
   Thanks for helping figure this out. We changed it.

7. *L58, it looks strange because sentence before talk AERONET, but after that, you compare passive and active satellite remote sensing, there is no words on passive satellite remote sensing.*
   We appreciate the comment and agree with the reviewer. We have added descriptions about passive satellite remote sensing at Lines 58-69: "**Passive satellite remote sensing also can be used to obtain aerosol properties. In general, passive remote sensing can only obtain two-dimensional aerosol characteristics, but cannot obtain aerosol vertical structure information. Several AOD retrieval algorithms based on passive remote sensing have been developed over the past decade, such as Dark Target (DT), Dark Water, Deep Blue (DB), and Multi-Angle Implementation of Atmospheric Correction (MAIAC), structure-function algorithm, and so on (Hsu et al., 2013; Hsu**

et al., 2004; Kaufman et al., 1997; Levy et al., 2013; Lyapustin et al., 2018; Martonchik et al., 1998; Tanre et al., 1988). In terms of aerosol type, Multi-angle Imaging SpectroRadiometer (MISR) instrument, which has nine view angles along the flight path (Diner et al., 1998), is sensitive to the size and shape of aerosols (Diner et al., 2008). Ozone Monitoring Instrument (OMI) includes ultraviolet bands, which can be used to retrieve aerosol optical parameters, such as absorbing aerosol optical depth, single scattering albedo, and aerosol index (Marey et al., 2011; Torres et al., 2007).”

References:

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2007.

8. *L97, discussion of dust transport to the TP is originally discussed by Huang et al., 2007 and further supported by Xia et al. (2008), with regarding long-range transport from south Asia, some references should be added including Xia et al. (2011); Lu et al. (2012); Zhao et al. (2015). A detailed discussion on this issue can be found in a overview paper (Xia et al., 2021, AR).*

   We agree with the reviewer and more references including that suggested here have been added, such as:

Cong, Z., Kang, S., Kawamura, K., Liu, B., Wan, X., Wang, Z., Gao, S., and Fu, P.: Carbonaceous aerosols on the south edge of the Tibetan Plateau: concentrations, seasonality and sources, Atmospheric Chemistry and Physics, 15, 1573-1584, 10.5194/acp-15-1573-2015, 2015.

Huang, J., Minnis, P., Yi, Y., Tang, Q., Wang, X., Hu, Y., Liu, Z., Ayers, K., Trepte, C., and Winker, D.: Summer dust aerosols detected from CALIPSO over the Tibetan Plateau, Geophysical Research Letters, 34, 10.1029/2007gl029938, 2007.

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9. *L182, pls add standard deviation to the mean value.*

   Thanks for helping figure this out. We have calculated the standard deviation of the annual mean AOD value, and related description has also been added at Lines 194-196: **"the annual average AODs over the Arctic, Antarctic, and the inner region of the TP are 0.046, 0.024, and 0.098 with the standard deviations of 0.003, 0.002, and 0.009, respectively."**

10. *L190-195, it seems transport of dust to the TP mainly occurs in summer, on the other hand, transport of fine particles from South Asia mainly occurs in dry season.*

    We agree with the reviewer and the corresponding description has been modified at Lines 205-213: **"The aerosol loading over the TP is easily affected by the surrounding regions where there are many anthropogenic and natural aerosol sources. Specifically,**

the dust aerosols in the Tarim Basin and Qaidam Basin have a greater contribution to the TP in spring and summer, especially in the northern part of the TP in summer (Huang et al., 2007; Xia et al., 2008; Xu et al., 2020). Meanwhile, a large number of fine aerosol particles exist in South Asia and the northern Indian Peninsula due to forest fires and anthropogenic burning during the dry season. The aerosols are lifted and transported to the Himalayas under the influence of large-scale atmospheric systems such as the South Asian monsoon and the Siberian high, which affects the southern part of the TP (Cong et al., 2015; Engling et al., 2011; Han et al., 2020; Xu et al., 2014; 2015).”

References:

Huang, J., Minnis, P., Yi, Y., Tang, Q., Wang, X., Hu, Y., Liu, Z., Ayers, K., Trepte, C., and Winker, D.: Summer dust aerosols detected from CALIPSO over the Tibetan Plateau, Geophysical Research Letters, 34, 10.1029/2007gl029938, 2007.

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