Response to Reviewer #3:

The manuscript investigates relationship between the PBLH and surface PM based on ground-based and onboard lidar, ground environmental and meteorological observations, reanalysis data, and so on. The relationships at different topographic and meteorological conditions over China are specially considered. Although most, if not all, variables show a relatively low correlation with the PBLH, the comprehensive and systematic study reveal the difficulties to drew the relationship between PBLH and surface PM. Generally, the manuscript discusses an important topic, and the methods and discussions are solid and meaningful.

Response: We are very grateful to the reviewer for his/her valuable and constructive comments on our work. All of these comments and concerns raised by the referee have been carefully considered and incorporated into this revision. Our detailed responses to the reviewer's questions and comments are listed below.

General Comments:

1. Some general information about the environmental and meteorological stations used for the four regions should be presented, such as number of stations used in each region, the basic types of them (are them all in the city?). Is there any quality control carried out for the results?

Response: Thanks for the valuable suggestion. We added Table R1 to section 2 to summarize the data. Table R1 not only reports the number of meteorological and environmental stations in each region, but also gives general information about the data used from other sources. The station locations are not all in the cities, but are widely distributed in both urban and rural areas. However, in this large-scale study, we stratify by geographic region, and do not consider the differences between the rural and urban areas specifically.

Table R1. Description of data.

Observations	Variables	Location	Temporal resolution	Time period
Environmental Stations	$PM_{2.5}$	~1600 sites*	Hourly	01/2012-06/2017
Meteorological Stations	WS/WD	~900 sites**	Hourly	01/2012-06/2017
MPL	PBLH, extinction	Beijing	15seconds	03/2016-12/2017
AERONET	AOD (550nm),	Beijing	~Hourly	01/2016-12/2017
MODIS	AOD	Whole China	Daily	01/2006-12/2017
CALIPSO	PBLH	Orbits in Figure 1d	Daily	06/2006-12/2017
MERRA	PBLH	Whole China	Hourly	01/2006-12/2017

* 224 sites over NCP; 105 sites over PRD; 215 sites over YRD; 159 sites over NEC

** 37 sites over NCP; 92 sites over PRD; 34 sites over YRD; 76 sites over NEC

These meteorological and environmental data are routinely measured and quality controlled by government agencies. The $PM_{2.5}$ dataset has been evaluate by other study, and shows relatively high reliability (Liang et al., 2016). There are quality flags along with the meteorological measurements, so error data can be eliminated. These points have been incorporated into the revised Section 3.1.

2. Figure 2 can be reorganized for better comparison. The CALIPSO and MERRA results can be shown in the left and right panel, respectively, and, then, results from the same season can be directly compared.

Response: Per your kind comment, we revised this figure.

3. The MERRA PBLH is not well introduced in the text. Meanwhile, after Figure 2, most results are compared with the CALIPSO results. The MERRA data can be used to evaluate the CALIPSO data, and if they are not used in the discussion for relationship with the PM, why the authors still discuss it in the manuscript.

Response: Thanks for pointing this out. We have added a brief introduction to the MERRA data in Section 2.2.3. As the reanalysis data take account of large-scale dynamic forcing, they are used to produce the climatology pattern of PBLH, and compared with those derived from CALIPSO. We found that the CALIPSO and MERRA retrievals exhibit some mutual features in the seasonality, which is roughly coupled with the seasonal climatology of $PM_{2.5}$. However, we do not focus on the detailed MERRA PBLH values, so we removed the original Table 1 in the main text.

In fact, the reanalysis data bear the model uncertainties, and do not include the impact of aerosols except based on the limited upper atmospheric measurements assimilated (Simmons, 2006). As results, these data poorly represent the effects of aerosol-PBL interactions (Ding et al., 2013; Huang et al., 2018), and offer limited ability to investigate detailed PBLH-PM relationships. As a result, we use only the observation-based retrievals (CALIPSO PBLH or MPL PBLH) to produce the PBLH-PM relationships over China. This discussion has been incorporated into the revised Section 3.1.

4. Section 3.5 and Figure 10 that show the relationship between multiple gases and PBHL are the only part discussing about the gases. Again, relatively poor corrections are obtained, and also considering that this study focuses on the relationship of PBHL and PM, it is not necessary to present those results. This will keep the manuscript more focused.

Response: Per your kind guidance, we deleted this section and Figure 10.

5. Even the relationship between PM and PBLH is relatively weak, how would it possible to further discuss the aerosol absorption feedback in section 3.6.

Response: We deleted this section as suggested, and only mention that the feedback of absorbing aerosols could be a potential influencing factor that merits further analysis.

6. Considering the relatively low correlations shown in the paper, the conclusions are too strong. For example, in the abstract, the authors mentioned that "(line 31) A generally negative *correlation is obtained between PM and the PBLH", while the largest correction obtained is only 0.36 from Figure 3. Multiple 'strong correlations' are mentioned in conclusion section.*

Response: We appreciate your kind suggestion. Indeed, since $PM_{2.5}$ is controlled by many other factors (e.g. emission, wind, synoptic pattern, stability, etc.), the correlations between PBLH and $PM_{2.5}$ are not very strong under most conditions. We revised the statements in conclusions section to avoid overly strong statements, and state that "Albeit the PBLH-$PM_{2.5}$ correlations are generally negative for the majority conditions, their magnitude, significance, and even sign vary greatly with location, season, and meteorological conditions". We also emphasize that relatively strong PBLH-$PM_{2.5}$ correlations only occurred under certain conditions. According to our analysis, heavy aerosol loading, the plains area, and weak wind speed would be favorable conditions for relatively strong negative correlations between PBLH and $PM_{2.5}$. These points have been incorporated into the revised Section 4.

Moreover, we previously used the Pearson correlation coefficient derived from the linear relationship. However, the PBLH-$PM_{2.5}$ relationships are nonlinear under most conditions as shown in the figure here. Thus, the nonlinear relationships would contribute to the low Pearson correlation coefficients. To partly address this problem, we included a new fitting method based on an inverse function ($f(x) = A/x + B$) to characterize the PBLH-$PM_{2.5}$ relationships, and set the weighting function as the normalized density. As shown in Figure R1 (the revised Figure 5), the nonlinear inverse function fits show better performance with the data, and characterize the behavior of the most dense area in the scatter plot with improved correlation coefficient (-0.49). Therefore, we include the new fitting method in the revised manuscript, which shows better performance in characterizing the PBLH-$PM_{2.5}$ relationships.

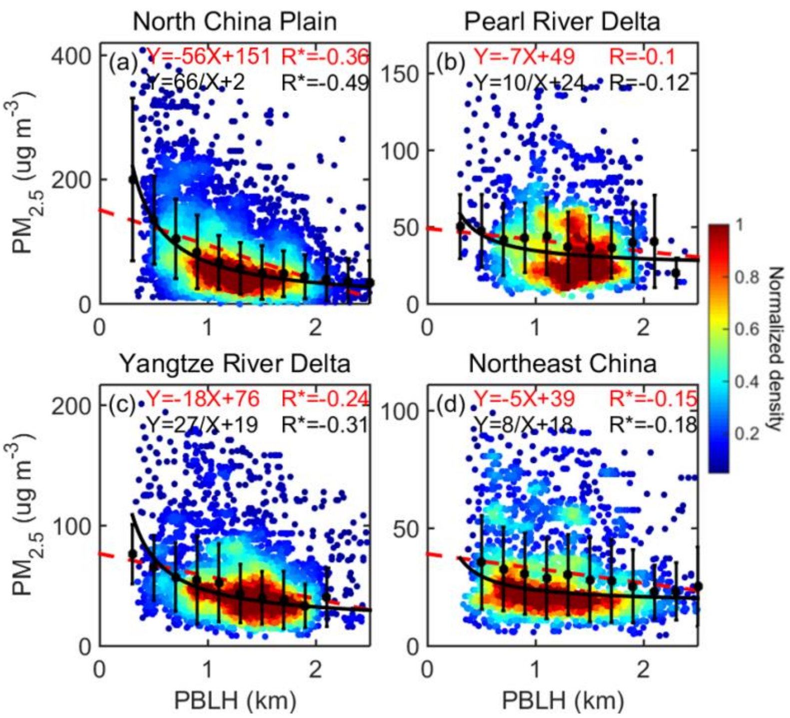

Figure R1. The relationship between CALIPSO-derived PBLH and early-afternoon $PM_{2.5}$ over

(a) NCP, (b) PRD, (c) YRD, and (d) NEC. The black dots and whiskers represent the average values and standard deviation for each bin. The red dash lines indicate the regular linear regressions, and the black lines represent the inverse fit ($f(x) = {}^{A}/_{x} + B$). The detailed fitting functions are given at the top of each panels, along with the Pearson correlation coefficient (red) and the correlation coefficient for the inverse fit (black). Here and in the following analysis, R with asterisks indicates the correlation is statistically significant at the 99% confidence level. The color-shaded dots indicate the normalized sample density.

7. Besides the conclusions, some relatively strong statements in the manuscript should be reconsidered. For example, on line 146, "This method can handle all possible weather conditions and aerosol layers. . .. . .."

Response: Per your kind suggestion, we checked the manuscript and revised or delete these improper statements.

References:

Huang, X., Wang, Z. and Ding, A.: Impact of Aerosol-PBL Interaction on Haze Pollution: Multi-Year Observational Evidences in North China. Geophysical Research Letters, 2018.

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Simmons, A., ERA-Interim: New ECMWF reanalysis products from 1989 onwards, ECMWF newsletter, 110, 25-36., 2006.

Liang, X., S. Li, S. Y. Zhang, H. Huang, and S. X. Chen (2016), PM2.5 data reliability, consistency, and air quality assessment in five Chinese cities, J Geophys Res-Atmos, 121(17), 10220-10236.