Authors' Response to Referees' Comments

Anonymous Referee #1:
Comments on "Planetary boundary layer height from CALIOP compared to radiosonde over China"

General Comments

The planetary boundary layer height (PBLH) is an important length scale in weather, climate and air pollution models. The CALIOP-derived PBLHs can construct the PBLH climatology on a global scale. The problem is that the validity of CALIOP-derived PBLH should be examined and the uncertainties of CALIOP-derived PBLH should be known. In this paper, the authors compared the CALIOP-derived PBLH to the radiosonde-derived PBLH in China. The results suggest that they agree very well. The authors also analyzed the difference in the PBLHs derived from the two methods, and showed the spatial distribution of deviations. The results in this paper can help to understand the applicability of CALIOP-derived PBLH in China, and provide the basic information for further investigations. However, some details of the dataset should be further specified, and the English writing should be further improved. Therefore, I recommend the manuscript for publication in ACP, pending minor revisions.

Response: We are very grateful to referee #1 for his/her positive comments on our work, which are quite constructive and helpful. All of these comments have been explicitly considered and incorporated into this revision. For clarity purpose, here we have listed the reviewers' comments in plain font, followed by our response in italics.

Specific Comments

1. The author declare that the method of Sawyer and Li (2013) was used in this study (in page 6 line 9-10). I suggest that the authors should give a concise introduction of this method, so that the readers can understand how the PBLH is derived from CALIOP in this paper rather than the cited paper. Is this method also applied to the radiosonde data to derive the PBLH? Because the measurement time is almost at noon, the potential temperature profile should exhibit the typical structure of convective BL. Thus the method of maximum potential temperature gradient is suitable for determining the PBLH. Why not use the maximum gradient method? The authors should explain the reason.

Response: Per your kind suggestions, we gave an concise introduction of this method of Sawyer and Li (2013) in section 2.1 of this revision by adding the following sentences:

"By combining wavelet covariance and iterative curve-fitting, Sawyer and Li (2013) developed a novel algorithm (hereafter called SL2013), which can be applied to robustly derive PBLHs from both radiosonde and lidar measurements due to the fact that prior knowledge of instrument properties and atmospheric conditions has been considered. The measurement time of our study is almost at noon, the potential temperature profile more often than not exhibit the typical structure of convective BL. However, due to the potential uncertainties caused by the sensitivity of vertical resolution, and the wide range of sounding time (local time) at different sites across China, SL2013 tends to exhibit advantages over the method of maximum potential temperature gradient. This is most likely because SL2013 is flexible and simple enough for automatic analyses of long-term sounding data at multiple sites, and is able to compensate for noisy signals and low vertical resolution in the soundings. Therefore, SL2013 has been applied to extract PBLHs from radiosonde observations."

2. The derived PBLH should be the height above the ground. However, shown in Fig. 2, the derived PBLH is above the sea level. Is the terrain height derived from CALIPSO or obtained from other data source? The authors should specify this issue. As shown in Fig. 2, the terrain surface is not very clear in some places.

Response: We totally agree with you, so we redrew Fig.2 (i.e., Fig.R1 as below). In the figure caption, we described PBLHs as altitude above ground level. The terrain height is directly extracted from CALIOP. Meanwhile, we added in Fig.2 a gray line to better indicate the terrain height clearly.

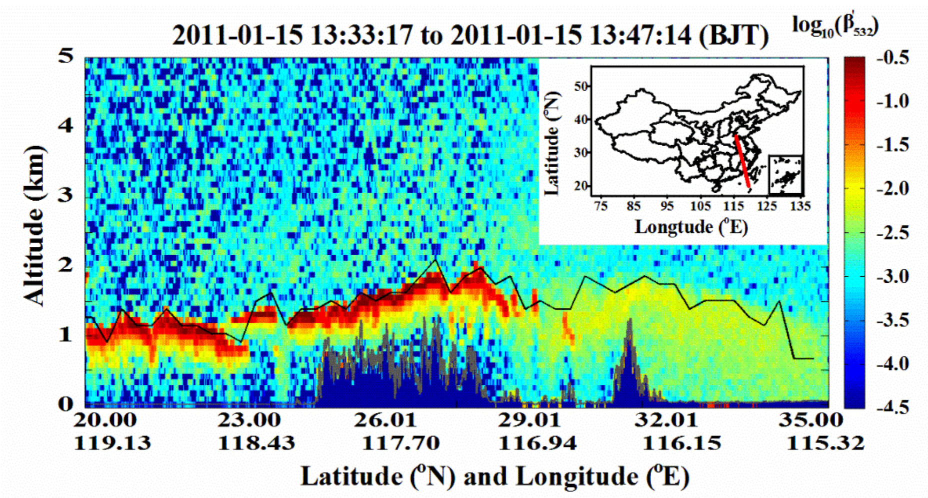

Fig. R1. Curtain plot of attenuated backscatter coefficient as observed from CALIOP aboard CALIPSO on 15 January 2011. The black line indicates the derived PBLH (above ground level) and the grey line immediately on top of the blue region *represents the terrain surface (directly from CALIOP data). The red line in the inlet map corresponds to the ground track of CALIOP/CALIPSO over southeastern China.*

3. In page 9 lines 3-4, the authors state "Note that over regions where BL is not convective the retrieved values are not representative of the PBLH (Liu and Liang, 2010)". Also in this section (Section 2.3), the authors describe the method how to eliminate the effects of clouds on the CALIOP-derived PBLH. In other words, the CALIOP data in clear days are used to derive the PBLH, and the BL should be convective. Moreover, the passing time of CALIPSO is 13:30 BJT. Thus it can be expected that the PBLH at this times not very low. However, Table 1 shows that the minimum PBLHs in different seasons are 0.2-0.4 km. I think these values are unbelievable. On the other hand, Table 1 shows that the maximum PBLHs in different seasons are 4-6 km with the largest value in winter. I think these values are also unbelievable. It is likely that uncertainties are introduced in the CALIOP-derived PBLH. Then the problem, to what extent the CALIOP-derived PBLH over China is reasonable, arises. I suggest the author discuss this problem and provide additional information about the statistics of the CALIOP-derived PBLH. For example, by setting the reasonable range of PBLH based on the up-to-date knowledge, the percentage of the derived PBLHs that are in this range can be calculated and compared.

Response：Thanks for pointing this out. Due to the increasingly polluted atmosphere in China, more stable boundary layers have been frequently observed (e.g., Quan et al., 2013; Gao et al. 2015; Miao et al, 2016). This will inevitably lead to retrieved PBLH values that are not representative of the actual PBLH (Liu and Liang, 2010), even though all the CALIOP data are from 1330 LT overpasses. Also, the large uncertainties are most likely due to the algorithm itself used in extracting CALIOP-derived PBLH. To avoid confusion caused by original Table 1, we added the following description in order to provide more information concerning the statistics of CALIOP-derived PBLH in section 3.2:

"As shown in Table 1, we noticed that the maximum PBLHs can reach up to 5-6 km, especially in winter. Therefore, we set the CALIOP-retrieved PBLHs to be within 0.25 and 3km, which seems as a reasonable height range for the midday PBL, highly consistent with the processing methods by McGrath-Spangler (2012). Statistics showed that only 2.1% of all data higher than 3km and 8.8% lower than 0.25km, which have been excluded for further analyses".

Reference:

Gao, Y, Zhang, M, Liu, Z, Wang, L, Wang, P, Xia, X, Tao, M, Zhu, L.: Modeling the feedback between aerosol and meteorological variables in the atmospheric boundary layer during a severe fog–haze event over the North China Plain. Atmos. Chem. Phys., 15(8): 4279–4295, doi: 10.5194/acp-15-4279-2015, 2015.

Liu, S., Liang, X.-Z.: Observed diurnal cycle climatology of planetary boundary layer height. J. Clim., 23, 21, 5790-5809, doi:10.1175/2010jcli3552.1, 2010.

Miao, Y., Liu, S., Zheng, Y., Wang, S.: Modeling the feedback between aerosol and boundary layer processes: a case study in Beijing, China. Environ. Sci. Pollut. Res., 23(4): 3342–3357, doi: 10.1007/s11356-015-5562-8, 2016.

McGrath-Spangler, E.L., Denning, A.S.: Estimates of North American summertime planetary boundary layer depths derived from space-borne lidar. J. Geophys. Res.--Atmos., 117, 2012.

Quan, J., Gao, Y., Zhang, Q., et al.: Evolution of planetary boundary layer under different weather conditions, and its impact on aerosol concentrations. Particuology. 11(1): 34–40, doi: 10.1016/j.partic.2012.04.005, 2013.

4. For the title of Table 1, "seasonal mean" is not accurate. I think, the maximum PBLH, as well as the minimum PBLH, is not the seasonal mean. Maybe "Statistics of the CALIOP-derived PBLH in different seasons" is more accurate. "Standard deviation PBLH" should be "Standard deviation of PBLH". Moreover, the authors should tell the readers how to determine/calculate the values in the table. Is the maximum/minimum PBLH determined as the maximum/minimum value of one grid in the duration or as the average of the maximum/minimum values at every grid in China? Is the standard deviation calculated at every grid and then averaged in China or calculated directly using all the data?

Response：Per your suggestions, we clarified the issues pointed out by you and modified the caption of Table 1 as follows:
"Table 1. Statistics of the CALIOP-derived PBLH in different seasons during the period 2011 - 2014. The mean PBLHs for all the grids are firstly calculated in China, then the maximum and minimum values of PBLHs are determined by sorting all the mean values. Meanwhile, the mean and standard deviation values of PBLH are determined as the average of mean values at every grid in China."

5. Following above question, Fig. 8 shows that the CALIOP-derived PBLH ranges from 1.2 km to 2.4km. But the statistics in Table 1 show that the CALIOP-derived PBLH varies in a very large range. How many data are not considered in Fig. 8? The authors should specify this issue in the text or in the figure caption.
Response: Thanks for pointing this out. We attempt to clarify as follows:
In Table 1, all PBLHs derived from CALIOP at every grid across China during the period from 2011 to 2014, which exhibit large variation ranging from 0.15km to 6.13km. However, all the cases with PBLHs greater than 3km or less than 0.25km are viewed as unreliable, which are then removed for further analyses in Fig.8. We have to make sure that PBLHs be extracted simultaneously from both radiosonde and CALIOP observations, leading to less valid collocated data pairs. Moreover, the calculated averaged CALIOP-derived PBLH tends to become more concentrated due to the collocation scheme of the radiosonde measurements and CALIOP, as evidenced in Fig.8. As a consequence, in the caption of Fig. 8, we added the following sentence:
"Note that the statistic results are only limited to the samples with collocated CALIOP- and radiosonde-derived PBLHs."

6. The authors declare in the abstract "The CALIOP observations belonging to Scenario 2 were found to be better for comparison with radiosonde-derived PBLH, owing to smaller difference between them". Similar statements are found in the conclusion section. However, Fig. 7 shows that the mean difference for Scenario 3 is the smallest. What is the solid evidence for this conclusion?

Response: In order to find more solid evidence to support the argument, we added to the revised manuscript one new figure (Figure 8, i.e., Figure R2 here), which shows the calculated 5th, 25th, 50th, 75th and 95th percentile values of PBLHs derived from CALIOP and radiosonde for each scenario. As such, to get a comprehensive understanding of the differences existing among various scenarios, the following texts have been added to section 3.4:
"As indicated in Figure 8, Scenario 2 witnesses the least difference of 0.08km between the CALIOP- and radiosonde-median PBLH values in contrast to larger differences of 0.24km and 0.12km for Scenario 1 and Scenario 3, respectively. In addition, the PBLH differences in terms of 25th and 75th percentile values for Scenario 2 are much more indiscernible, as compared with those for other two scenarios. This implies that Scenario 2 gains more advantages over other two scenarios due to the smaller difference between CALIOP- and radiosonde-derived PBLHs."

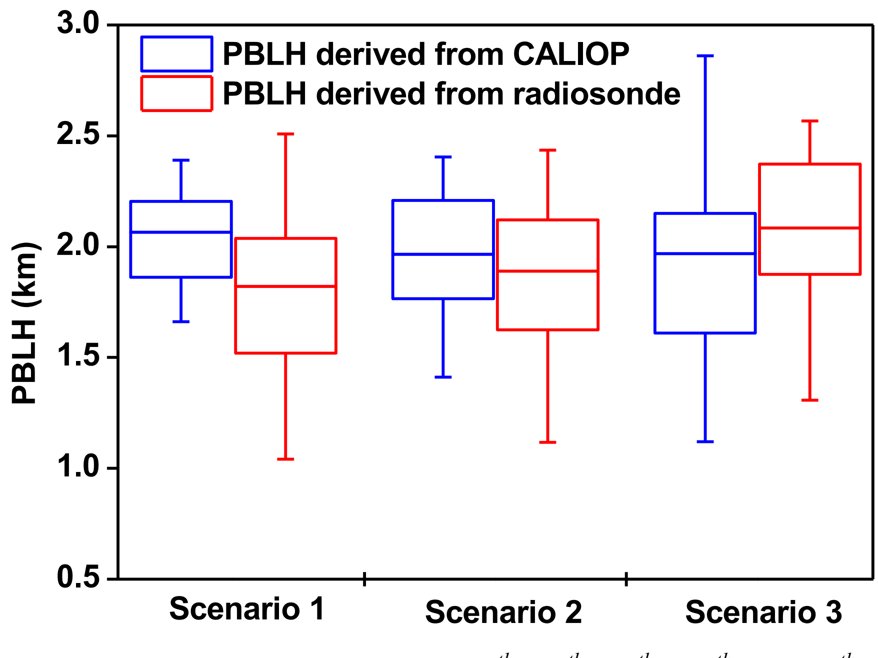

Fig. R2. Box-and-whisker plot showing the 5th, 25th, 50th, 75th and 95th percentile values of PBLH derived from CALIOP (in blue) and radiosonde (in red) for each scenario. Note that only 1400 BJT radiosonde are used to make comparison with afternoon CALIOP-derived PBLHs.

Technical Corrections

(1) The grammatical errors should be corrected (Just some are listed here. The author should thoroughly check for simple typos and grammatical errors). For example,
Page 2 line 1, “for comparison with” should be “in comparison with”.
Page 2 line 2, “at early summer afternoon” should be “in early summer afternoon”.
Page 3 line 20, “the fact the number” should be “the fact that the number”.
Page 4 line 22, “are” should be “is”.
Page 6 line 9, “this methods” should be “this method”.
Page 8 line 7, “in combination with and” should be “in combination with”.
Response: Except for the typos as you pointed out here, other grammatical errors have been corrected in this revision.

(2) Fig. 2, at the top of this figure the times “05:33:17” and “05:47:14” should be the local times “13:33:17” and “13:47:14”.
Response：Per your kind suggestions, the time at the top of Fig.2 has been changed to the local times, i.e., “13:33:17 (BJT)” and “13:47:14 (BJT)”.

(3) Fig. 7, the value of mean difference between the CALIOP-and radiosonde-derived PBLHs in each panel (0.17km, 0.22km, 0.17km and 0.15km respectively). But the figure shows that the difference for a single site is either positive or negative (denoted by different colours). How to calculate the mean value, directly or by the absolute values? I guess by absolute values. Therefore the absolute value sign should be added to ΔPBLH.
Response：We appreciate you pointing it out. You are right, the difference of PBLH was supposed to denote absolute value. Therefore, it has been changed to “$|\Delta PBLH|$” *in Fig. 7.*