Authors' Response to Referees' Comments

Anonymous Reviewer #2:

Comments on "Planetary boundary layer height from CALIOP compared to radiosonde over China"

The planetary boundary layer height (PBLH) is an important parameter for the weather and climate study, as well as atmospheric pollution study. This study tries to obtain global PBLH based on CALIPSO satellite observations, and carried out an intercomparison study with those from radiosondes and lidars here. The results suggest that they agree reasonably well in China regions. This is a valuable contribution to the science community to better understand the potential applicability of CALIPSO observations to obtain PBLH. However, this paper does need some improvement as detailed below, particularly regarding to the English writing. I would recommend the manuscript for publication in ACP, pending minor revisions.

Response: We are quite grateful to referee #2 for his/her positive comments on our work, which are quite constructive and helpful. All these comments and concerns raised by the referee 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.

Main Comments

1. The English writing strongly need improve. The paper descriptions could be more concise and accurate.

Response: Per your kind suggestions, we have improved the English writing, both grammatically and scientifically. Meanwhile, the descriptions have been revised to be as concise and accurate as possible in this revised manuscript.

2. One key role of this study as the author expressed is "The PBLH retrieval from CALIOP is expected to complement the ground-based site measurement due to its large spatial coverage". However, I think the pass of CALIPSO satellite over a specific location is limited. May you please provide more information about the CALIPSO passed regions?

Response: We agree with the reviewer that the pass of CALIPSO satellite over a specific location is temporally limited (especially in the capability of charactering diurnal variation of PBL). As shown in Figure 1, during one CALIPSO revisit cycle (16 days), there are about 42 ground tracks in China for the daytime ascending overpasses (1330 LT). And the neighboring ground tracks of CALIPSO are in the intervals of approximately 100-150 km, depending on latitudes. To make the

description more accurate, in the introduction section, we added "From the climatological point of view" just before "the PBLH retrieval from CALIOP is expected to complement the ground-based site measurement due to its large spatial coverage."

3. Section 2.1, I would like to know the uncertainties in the PBLHs obtained from radiosondes, which is very important since the authors are using them to evaluate those from CALIOP.

Response: The uncertainties associated with PBLH obtained from radiosonde come from (1) the estimation methods of PBLH, which are generally referred to structural uncertainty (Seidel et al., 2010). To our knowledge, the method (Sawyer and Li, 2013) we used here is one of the most advanced algorithms, in which prior knowledge of instrument properties and atmospheric conditions has been adequately taken into account; (2) the extreme adverse weather, which is also an important influential factor. For instance, the PBL as deep convective cloud occurs will collapse, leading to an extremely large value; (3) the failed launch of weather balloon. All of these uncertainties have been reflected in this revision.

Reference:

Seidel, D.J., Ao, C.O., Li, K.: Estimating climatological planetary boundary layer heights from radiosonde observations: Comparison of methods and uncertainty analysis. J. Geophys. Res. -Atmos. 115, 2010.

4. Section 2.2, what is the uncertainties of PBLHs from lidars, and what are the extra uncertainties caused by the selection of compare region size?

Response：In our points of view, the uncertainties of PBLHs from lidars largely come from the contamination caused by boundary layer cloud, along with the heavy haze which always leads to strong signal attenuation.

Moreover, the temporal window utilized to take averages centered at the observation time of ground-based lidar may be a factor influencing the PBLH uncertainty. To just name a few, the thorough analysis by Hennemuth and Lammert (2006) indicated that 10-min window leads to an average bias of 150 m as compared with 1-h window. All of these uncertainties have been discussed in detail and reflected in the last paragraph in section 2.2 of this revised manuscript.

To make the intercomparison more robust, a circle with a radius of 75 km centered at ground site was chosen to obtain averaged PBLH from CALIOP. As such, at least 100 samples around each radiosonde site can be used for the estimation of PBLH from CALIOP, given the 5km resolution along CALIPSO track.

Reference:

Hennemuth B, Lammert A. Determination of the atmospheric boundary layer height from radiosonde and lidar backscatter [J]. Boundary-Layer Meteorology, 2006, 120(1): 181-200.

5. Section 3.1, this is a comparison. If you would like to say 'evaluation", you need assume the accuracy of ground-based lidar-derived PBLH with at least clear uncertainty information.

Response：Per your kind suggestion, "evaluation" has been changed to "comparison".

6. Section 3.2, I would suggest you add the climatology of PBLH from the radiosonde profiles over China and compare this with your results from CALIPSO observations. This could let us know how reliable of your CALIPSO-derived PBLHs.

Response：Per your suggestion, the climatology of PBLH from the radiosonde profiles over China was added, as shown in Fig. R3 (i.e., Figure S2 in the supplementary material). Note that only the radiosonde-derived PBLH climatology at 1400 BJT in summertime is and should be used for comparison with CALIOP-derived PBLHs. In order to let the readers better know the reliability of CALIOP-derived PBLHs, the following description was added in the first paragraph of section 3.4:

"In terms of the spatial differences of PBLHs, both CALIOP retrievals (Figure 4b) and radiosonde observations (Figure S2) show that large PBLH values tend to occur at Tibetan Plateau, southwestern China, and northern China in early summer afternoon. This is likely indicative of good agreement between CALIOP- and radiosonde-derived PBLH retrievals"

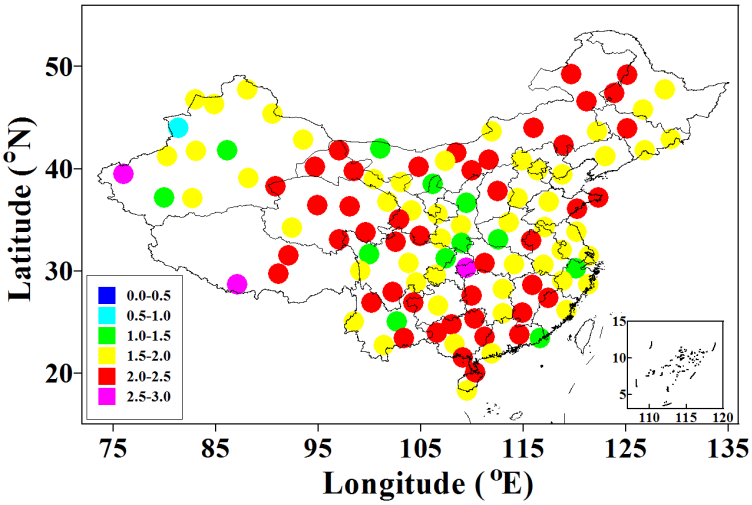

Fig. R3. Spatial distribution of climatological PBLHs derived from radiosonde at 1400 BJT in summer (June-July-August, JJA) during the period from 2011 to 2014.

Specific Comments:

Page1

（1） Line 12: The description could be more concise: the accurate estimation of planetary boundary layer height (PBLH) .... The PBLH retrieved from ..."

Response：Amended as suggested.

（2） Line 17: ground-based and satellite-based or ground-based and spaceborne.

Response：Amended as suggested.

（3） Line 17-18, for r=0.59 or 0.65, could we say "good agreement"?

Response：The sentence has been revised to "Comparison between PBLHs from ground- and satellite-based lidars leads to a correlation coefficient of 0.59 in Beijing and 0.65 in Jinhua, respectively."

（4） Line 19, ‘during 2011 to 2014’ -> ‘for the period from 2011 to 2014’

Response：Amended as suggested.

（5） Line 19, lower values

Response：Amended as suggested.

（6） What is the uncertainty for PBLH from radiosonde observations? What are the factors that could result in the differences in PBLH between satellite-and ground-based observations, and their contributions?

Response：Please see our response to main comment #3.

Page2

（7） Line 17, how do you arrange the order of references?

Response：We rearranged the order of references to chronological order by year of publication, which shows as follows: ‘‘(Medeiros et al., 2005; Hong et al., 2006; Zhang et al., 2007; Hu et al., 2010).”

（8） Line 18-20, the sentence have grammar error with 2 verbs.

Response： The sentence you pointed out has been revised as follows:

“The depth (or height) of PBL, which determines the vertical extent of turbulent mixing and convection activity within it, is a key length…”

Page 3

(9) line 1-3, why is it required 4-8 times for IOP experiment?

Response：Generally speaking, 4-8 times are required during IOP experiment to better capture the diurnal variation in the thermodynamic and dynamic conditions of atmosphere.

(10) line 4, how accurate of the PBL height is it for the measurements from radiosondes?

Response：Please see our response to question 3 for more detail.

(12) line 12-13, what do you mean with (Amiridis et al.) in these lines? Reference?

Response：It means reference. Therefore, we added a reference“(Seibert, 2000)” here.

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(13) line 13-15, what do you mean for this sentence: “large seasonal and diurnal variations in PBLHs were observed between the different methods applied to radiosonde, ground-based lidar, CALIOP observations over one site in South Africa”

Response：It has been changed to ‘‘large seasonal and diurnal variations in PBLHs were observed, most likely due to the different methods utilized to…”

(14) what do you mean for “large scale land-based observations”?

Response：We clarified it by changing it to “large scale ground-based radiosonde observations” in this revision.

(15) how reliable for the ground-based lidar observation of PBLH?

Response：Please see the response to main comment # 5 for more details.

Page 5

(16) line 14, times -> time

Response：Amended as suggested.

(17) line 15, why call the summer as flood season? It might be wet season, but not good as flood season?

Response: "flood season" has been changed to "wet season".

(18) line 16, what do you mean for "severe weather forecasting"?

Response: The sentence has been changed to "CMA required the soundings to be launched three to four times a day in summer (the wet season), i.e., 0200 BJT, 0800 BJT, 1400 BJT, and 2000 BJT to seamless monitor the vertical structure of atmosphere, and thus to better serve the high-impact weather forecasting."

(19) line 16-19, 'owe to ..., ... therefore..."?

Response: "therefore" was removed .

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(20) line 9, What are you comparing to regarding "a good agreement"?

Response: We rewrote the sentence as follows:

"By combining the methods of wavelet covariance and iterative curve-fitting (Steyn et al., 2009), 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 adequately considered."

(21)line 9, 'this methods of ... was ...'?

Response:"methods" has been changed to "method".

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(22) line 6, 'the algorithm in Zhang et al. (2015) are applied on ..."-> "the algorithm developed by Zhang et al. (2015) are applied to ..."

Response: Amended as suggested.

(23) line 7, what kind of profiles are you talking about? lidar profiles?

Response: We are referring to CALIOP profiles.

(24) line 8-9, why do you choose the area with radius of 75 km?

Response: See our response to main comment #3, please.

(25) line 10-13, what are the data volume fraction for these cases?

Response: Overall, the data volume fraction is roughly 87.7 %. To better describe the ground-based lidar data, we added Figure R4 (i.e., Figure S1 in the supplementary material). The related description was added to the end of section 2.2.

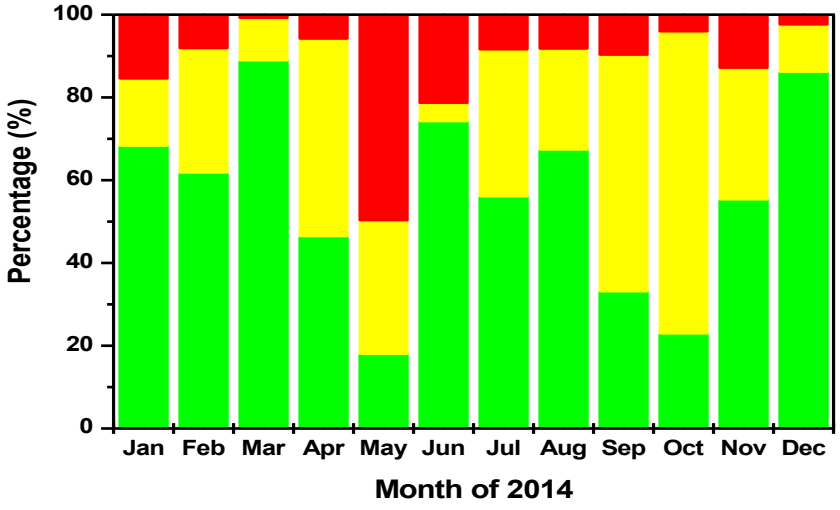

Fig. R4. Statistics showing the fractional volumes (in percent) of lidar measurement at Beijing during the whole year of 2014 stratified by no observation (in red), without PBLH retrievals due to weather conditions (in yellow), and with PBLH retrievals (in green).

(26) line 17-19, please correct the sentences, such as "It measures attenuated backscatter coefficients at resolutions of 1/3 km in the horizontal and
30 m in the vertical at the visible wavelength …"

Response：The sentences have been changed to "It measures attenuated backscatter coefficients at a resolution of 1/3 km in the horizontal at the visible wavelength (532 nm) and near-infrared wavelength (1064 nm), and its vertical resolution varies with altitude (h): 30m from ground up to h = 8.2 km, 60m from h = 8.2 km to 20.2 km, and 180m from h = 20.2 km to 30.1 km (Winker et al.,2009; Huang et al.,2015)"

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(27) line 7, " in combination with and …"?

Response：It has been changed to "in combination with.." .

(28) line 8-9, "This is because that …", You do not need to explain since you have said for "cloud screening"

Response：The redundant sentence you pointed out has been removed according to your kind suggestion.

(29) line 9-11, please indicate the advantage of your choosing method.

Response：Just following "..be inferred (McGrath-Spangler and Denning, 2012, 2013)." The following sentence was added: "However, either maximum variance algorithm or Haar wavelet technique has its weakness due to the strong dependence on the chosen strategy in the threshold values."

(30) line 11, there are two periods.

Response：One redundant period was removed.

(30) line 9-16, please tell readers the uncertainties or the uncertainty-influential factors for this determination method.

Response：We added the sentence as follows: "However, either maximum variance algorithm or Haar wavelet technique has its weakness due to the strong dependence on the chosen strategy in the threshold values."

(31) line 16-19, this is redundant since you have mentioned the 75 km earlier. Also, why do you select 75 km, not 50 or 25 km?

Response：These redundant sentences have been removed, and the following paragraph was added to the end of 2nd paragraph in section 2.2:

"Due to the neighboring ground tracks of CALIPSO at approximately 100-150 km longitudinal interval over China, a 75km-radius circle centered at each ground-based lidar site has been determined for its spatial matchup with CALIOP, so has the matchup of radiosonde site with CALIOP."

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(32) line 1, what do you mean "valid" here? For the overpasses, are there invalid ones? I do not understand.

Response："valid" means without cloud. Therefore, we modified the sentence to "The CALIPSO measurements were retained for PBLH retrievals at grid points where the number of valid (i.e., without cloud)…"

(33) line 4, How do you determine if the BL is convective or not?

Response：Our method utilized in PBLH retrieval (see our response to general comment #1 by reviewer #1 for details) does not rely on whether the BL is convective or not, and thus the sentence was deleted in this revision.

(34) line 5-10, you just gave one case to show the good agreement between two algorithms (even17 profiles averaged within a 5 km region). This is not enough to conclude that "the combined algorithms are reliable".

Response: The sentence of "indicating that the combined algorithms is reliable " was deleted in this revision.

(35) line 10, 'is' ->'are'

Response：Amended as suggested.

(36) line 13,are you sure your comparison study is "a first attempt"?

Response：We deleted "a first attempt" and revised the sentence to "In order to make the intercomparison more reliable between CALIOP- and radiosonde-derived PBLHs…".

(37) line 15-16, how do you exclude the cases with cloud cover? In other words, how do you get the cloud coverage?

Response：The cases were manually determined whether they were contaminated or not, based on the meteorological data from the neighboring weather station.

(38)line 17, "shows that"? I believe it should be just "shows"

Response：You are right, and thus "that" was deleted as suggested.

(39) line 17-21, for so limited data samples, how reliable are the comparison results?

Response：We rewrote these sentences as below:

"Due to the samples being still limited, we cannot be quite sure to argue that the CALIOP-derived PBLHs are reliable enough. Further evaluation studies are warranted in the future as long as more ground-based lidar observations are available. However, the correlation coefficients obtained here are similar to those reported at SACOL site of northwestern China (e.g., Liu et al., 2015)."

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(40) line 1-2, the correlation coefficients are low, why do you say 'show a good agreement'?

Response："which shows a good agreement" was deleted.

(41) line 11-13, the variability in winter (0.4 km) is larger than that in summer (0.31 km), why do you say the lowest PBLH variability occurs in winter?

Response：Per your suggestion, the "variability" has been removed, and the sentence has been changed to "the lowest PBLH values occur in winter".

(42) line 13, "were occurred" -> "occur'

Response：Amended as suggested.

(43) line 14-15, please modify the description to make it more concise.

Response：We modified the sentence as follows:

"…when the development of PBL is typically suppressed due to the less solar radiation received at the surface. In contrast, the more intense solar radiation reaching the surface in summer favors the development of PBL (Stull et al., 1988)."

(44) line 19, 'was' -> 'were'

Response：Amended as suggested.

(45) line 21, 'may be suppressed by aerosol radiative effects and aerosol-wind interactions(Xia et al., 2007; Yang et al., 2016)'

Yang, X., C. Zhao, J. Guo, Y. Wang, 2016, JGR: intensification of air pollution associated with its feedback with surface solar radiation and winds in Beijing，

Response：Amended as suggested.

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(46) line 2, 'had been' -> "have been"

Response：Amended as suggested.

(47)line 5-7, this information has been described two times earlier. I would suggest a more detailed description for only one time.

Response：We can not agree with the reviewer any more, so we deleted it in the first paragraph of section 3.3, and more detailed description concerning the matchup scheme between radiosonde and CALIOP was added in section 2.3.

(48)line 7-9, this also seems redundant.

Response：It has been deleted as suggested.

(49) line 14, delete "On the other hand,"

Response：Deleted.

(50)line 16, 'can be' -> 'are'

Response：Amended as suggested.

Page 12

(51) line 8, what do you mean for "basically"?

Response："basically" has been revised to "mostly".

(52) line 11-12, could you give me a little more explanation? I do not understand the logic here.

Response：We have revised the sentences as follows:

"..The more northward the radiosonde sites, the greater number of the CALIPSO overpasses over the same circle of 75 km radius. Therefore, the distinct discrepancy in geographic distributions of radiosonde sites belonging to Scenarios 1 and 3 are most likely due to the latitude differences…"

(53) line 16-17, "the PBLHs at all the 113 radiosonde sites have been successfully derived" and "so have the CALIOP-derived PBLHs" seem the same meaning to me.

Response：We have revised the sentence to "Using the algorithms as detailed in Section 2, the PBLHs at all the 113 radiosonde sites have been successfully derived from radiosonde and CALIOP."

(54) line 18-20, there is no verb in this sentence. Also, I do not understand what difference are you talking about? Do you mean "the difference of PBLH derived from CALIOP and from radiosonde"?

Response：You are right, and thus we revised the sentence to: "..the differences of PBLHs at every radiosonde sites (Figure 1) from CALIOP measurements at 1330 LT minus those from radiosonde observations at 1400 BJT in the summertime (June-July-August) during the period of 2011-2014 are calculated…"

Page 13

(55) line 1-2, I believe you are talking that PBLH exhibit negative values, not sites exhibit negative values. Please correct the description.

Response：Per your kind suggestion, we changed the sentence to "As shown in Figure 7(a), the PBLH differences over most of the radiosonde sites .."

(56) line 7-10, I believe the two sentences are expressing the same meanings, please delete one.

Response：Per your kind suggestion, we deleted "Note that we cannot totally rule out other factors that may also contribute to the east-west gradient."

(57) line 12-15, please modify it to make it concise.

Response: It has been shortened as "…Overall, the radiosonde-derived PBLHs tend to be overestimate compared with CALIOP-derived PBLHs due to the majority of radiosonde sites…"

(58) line 19, occurrence frequency for what?

Response：Occurrence frequency for the number of radiosonde sites

Page 15 (59) line 8, 'are' -> 'is'

Response：Amended as suggested.