We would like to thank the reviewers for their valuable comments and suggestions. We have considered all comments carefully which helped us significantly to improve our manuscript. Following the reviewers' comments and suggestions, we revised the manuscript. Our responses to the reviewers' comments are listed below in blue fonts and the changes in manuscript are listed in *blue italic fonts*.

Anonymous Referee #3

Received and published: 28 April 2019

The manuscript aims to investigate the relationship between BLH and air pollution in different ABL categories. The ABLH is defined based on both a micro-pulse lidar (DDL) and a coherent Doppler wind lidar (CDWL) through wavelet covariance transform method and variance analysis of the vertical velocity. It is well written and the analysis is careful. However, there are some aspects for improvement:

Thanks for your careful and thoughtful comments. We revised the manuscript according to your suggestions.

1. Only the relationship between PM2.5 and BLH before and after one precipitation process is analyzed. The manuscript only presents the phenomena, so what accounts for this difference, what role of the precipitation process, it is unclear;

The precipitation event above the ground may be responsible for the sudden increase of aerosol due to wet growth of smaller aerosols. The precipitation may lead to this difference in the early hours after the precipitation. *Geiß et al.*, 2017 investigated the relashionship between BLH and PM_{10}. They found that the pollution sources, meteorological conditions and BLH retrieval details should be considered. In addition, the cloud effect should also be considered. Thus a complex process which is unknown accounts for this difference. More observations in under different conditions and modeling study would be helpful to improve our knowledge on this complex topic.

Changes:

Page 8, line 23-28. "*The relationships between BLH and PM2.5 are changed after precipitation. Recently, Geiß et al. (2017) investigated correlations between BLH and concentrations of pollutants (PM_{10}, O_3, NO_x). They found that the correlations of BLH with PM_{10} were quite different for different sites without showing a clear pattern. In addition, the reflection and absorption of the incoming solar radiation by the clouds on 2 June 2018 could also affect the diffusion of aerosols. Therefore, BLH with different retrieval methods, pollutant sources and meteorological conditions should be considered in air quality prediction models*."

Page 9, line 23-24. "*The reasons for the differences in the relationships between BLH and $PM_{2.5}$ may result from both cloud effect and pollutant sources not just the precipitation*."

Page 9, line 26-27. "*To probe the mechanism of the BLH-$PM_{2.5}$ relations under different conditions, such as before and after the precipitation, not only such observations, but also model simulation are needed in further studies.*"

2. ABL may not belong to different categories before and after the precipitation, in fact, according to the Figure 3(a), the growing process of the CBL after the precipitation is very similar to that before the precipitation;

Yes, the growing processes of the CBL before and after the precipitation are similar. In Sect.

4.3, we mentioned that "*In general, these results show good responses of $PM_{2.5}$ to aerosol derived BLH (BLH_{RCS}) evolution with larger R^2 and stronger correlation than turbulence derived BLH (BLH_{VAR}) both before and after precipitation*." The different ABL categories in this manuscript mean that aerosol derived BLH (static, i.e., BLH_{RCS} and BLH_{CNR}) and turbulence derived BLH (dynamical, i.e., BLH_{VAR}). We are very sorry for this confusing expression and modified it in the revised manuscript.

Changes: Page 8, line 16-18. "*In general, these results show good responses of $PM_{2.5}$ to aerosol derived BLH (BLH_{RCS}) evolution with larger R^2 and stronger correlation than turbulence derived BLH (BLH_{VAR}) both before and after precipitation*."

3. From your manuscript, anti-correlation relationship between PM2.5 and BLH is found whether before or after a precipitation. The difference is that the relativity weakened after a precipitation. It seems that precipitation plays an important role. That is, the author paid more attention to different weather conditions instead of "different ABL categories ".

Thanks for this comment. As answered to comment 2, the different ABL categories are ABL retrieved from aerosol signal and turbulence, respectively. We have discussed the different relationships between $PM_{2.5}$ and BLH under different ABL categories (BLH_{RCS} and BLH_{VAR}) in Sect.4.3 and Table 2. We apologize for this confusing expression in the manuscript.

Changes:

Page 2, line 16-18. "*However, the relationship analysis of $PM_{2.5}$ and BLH in different ABL categories, i.e., aerosol derived (static) BLH and turbulence derived (dynamical) BLH, is still rare*."

Page 8, line 16-18. "*In general, these results show good responses of $PM_{2.5}$ to aerosol derived BLH (BLH_{RCS}) evolution with larger R^2 and stronger correlation than turbulence derived BLH (BLH_{VAR}) both before and after precipitation*."

4. The core content of the manuscripts is the "Relationship Analysis of PM2.5 and BLH", from the abstract, only the sentence "Negative correlation between BLH and PM2.5 is analyzed before and after a precipitation." is related to your title. And such conclusion is very common, lower concentration of PM always corresponds to higher BLH if there is no new emission source. The abstract does not show the purpose and innovation point of the study explicitly. Besides, only one paragraph describes the relationship of PM2.5 and BLH in the text? The abstract and the contents of the manuscripts should be improved.

Thanks for your comment. We revised the title as "Relationship Analysis of $PM_{2.5}$ and BLH using an Aerosol and Turbulence Detection Lidar". The relationship analysis is based on this innovative hybrid lidar. The advantages of this hybrid lidar is introduced in responses to minor comment 4 and 6. Then, the BLH retrieval method and retrieved BLH results should be evaluated. Finally, the relationship analysis can be performed. Thus, all of these are related to the title, not only one paragraph. In previous work, the correlation could be negative, but also positive (*Geiß et al.*, 2017). So comparing the correlation under different conditions and places in the world is desired to improve our understanding of this complex topic: relashionship between PM and BLH. The relashionship analysis before and after precipitation in this study may be helpful to this complex topic. We also revised the abstract and the contents according to your suggestions.

Changes:

Page 1, line 1-2. "*Relationship Analysis of $PM_{2.5}$ and BLH using an Aerosol and Turbulence*

Detection Lidar"

Page 1, line 18-20. "*Correlation between different BLH and $PM_{2.5}$ is strongly negative before a precipitation event and become much weaker after the precipitation. Different relations between $PM_{2.5}$ and BLH may result from different BLH retrieval methods, pollutant sources and meteorological conditions*."

Page 8, line 23-28. "*The relationships between BLH and PM2.5 are changed after precipitation. Recently, Geiß et al. (2017) investigated correlations between BLH and concentrations of pollutants (PM_{10}, O_3, NO_x). They found that the correlations of BLH with PM_{10} were quite different for different sites without showing a clear pattern. In addition, the reflection and absorption of the incoming solar radiation by the clouds on 2 June 2018 could also affect the diffusion of aerosols. Therefore, BLH with different retrieval methods, pollutant sources and meteorological conditions should be considered in air quality prediction models*."

Page 9, line 23-24. "*The reasons for the differences in the relationships between BLH and $PM_{2.5}$ may result from both cloud effect and pollutant sources not just the precipitation*."

Page 9, line 26-27. "*To probe the mechanism of the BLH-$PM_{2.5}$ relations under different conditions, such as before and after the precipitation, not only such observations, but also model simulation are needed in further studies.*"

Some minor revisions are as follows:

1. For line 3 on page 2, "The boundary layer height (BLH) is the height of the top layer of ABL", the description makes no sense, please improve.

Deleted.

2. For line 9 on page 2: Explain "ABL categories" here.

Thanks for this comment. The ABL categories are explained in the revised manuscript. "*different ABL categories, i.e., aerosol derived (static) BLH and turbulence derived (dynamical) BLH*"

Changes: Page 2, line 16-18. "*However, the relationship analysis of $PM_{2.5}$ and BLH in different ABL categories, i.e., aerosol derived (static) BLH and turbulence derived (dynamical) BLH, is still rare*."

3. For line 18 on page 2, "Among these instruments, lidar provides sufficient spatial and temporal resolution, long detection range and high accuracy to determine the BLH……", the description should be improved, lidar system provides backscattering signal with sufficient spatial and temporal resolution……

Corrected as suggested.

Changes: Page 2, line 16-18. "*Among these instruments, lidar system provides backscattering signal with sufficient spatial and temporal resolution, long detection range and high accuracy to determine the BLH.*"

4. For Lines 20-27 on page 2: Here, please highlight the advantages of two lidars.

Thanks for this suggestion. We added some advantages of these two lidars.

Changes:

Page 2, line 25-26. "*Recently, a micro-pulse direct detection lidar (DDL) based on up-*

conversion technology was developed to make continuous measurements of aerosol in troposphere (Xia et al., 2015)"

Page 2, line 27-32. "*Different from traditional micro-pulse lidars operated at or near 532 nm (He et al., 2008; Li et al., 2017b; Sawyer and Li, 2013), these two lidars are operated at 1.5 μm, which are eye-safe and can be made with all-fiber components. The 1.5 μm laser shows the highest maximum permissible exposure in the wavelength range from 0.3 to 10 μm (Xia et al., 2015). The invisible infrared eye-safe laser makes these two lidars can work in a densely populated city horizontally. The all-fiber structure makes these lidars robust, immune to external environment changes such as vibration and temperature.*"

5. For lines 22-24 on page 2, "in middle atmosphere via Rayleigh scattering……, in mesosphere and lower thermosphere via fluorescence backscatter……." The manuscripts focused on ABL, it may be unnecessary to mention the detection principle in middle atmosphere and in mesosphere and lower thermosphere.

Deleted as suggested.

6. For lines 25-26 on page 2, "Recently, a micro-pulse direct detection lidar (DDL) was developed to make continuous measurements of aerosol in troposphere….." In fact, the micro-pulse lidar (MPL) has been widely used to detect ABLH, there are several studies (He et al., 2008; Sawyer and Li 2013; Li et al., 2017), not recently, maybe you can describe the advantage of the MPL here, such as detecting with eye-safe laser, small field-of-view removing multiple-layer scattering concerns…… As well as for description about Doppler wind lidar later.

He Q, Li C, Mao J, et al. Analysis of aerosol vertical distribution and variability in Hong Kong [J]. Journal of Geophysical Research Atmospheres, 2008, 113(D14):-.

Sawyer, V.; Li, Z.J.A.E.; Detection, variations and intercomparison of the planetary boundary layer depth from radiosonde, lidar and infrared spectrometer. 2013, 79 (11), 518-528.

Li, H.; Yang, Y.; Hu, X.M.; Huang, Z.; Wang, G.; Zhang, B.J.A.; Application of Convective condensation Level Limiter in Convective Boundary Layer Height Retrieval Based on Lidar Data. 2017, 8 (4), 79

Thanks for this suggestion. The micro-pulse direct detection lidar (DDL) is "*based on up-conversion technology*". "*Different from traditional micro-pulse lidars operated at or near 532 nm (He et al., 2008; Li et al., 2017b; Sawyer and Li, 2013), these two lidars are operated at 1.5 μm, which are eye-safe and can be made with all-fiber components. The 1.5 μm laser shows the highest maximum permissible exposure in the wavelength range from 0.3 to 10 μm (Xia et al., 2015). The invisible infrared eye-safe laser makes these two lidars can work in a densely populated city horizontally. The all-fiber structure makes these lidars robust, immune to external environment changes such as vibration and temperature.*" Then the two lidars are integrated into one lidar system. "*In this work, a hybrid lidar integrating both systems are developed for simultaneous measurements of aerosol and vertical wind.*" The advantages of this hybrid lidar has been described in Sect. 2.1. "*Two lidar systems use only one set of laser source, optical collimator and control system. The unique optical telescope guarantees that the measured signal in both systems are from the same backscattering volume, and the radial wind profile and aerosol concentration are measured simultaneously.*" We also showed the advantages of this hybrid lidar in the abstract and conclusions in the revised manuscript.

Changes:

Page 1, line 12-13. "*This hybrid lidar is operated at 1.5 μm which is eye-safe and is made of all-fiber components*."

Page 2, line 25-26. "*Recently, a micro-pulse direct detection lidar (DDL) based on up-conversion technology was developed to make continuous measurements of aerosol in troposphere (Xia et al., 2015)*"

Page 2, line 27-32. "*Different from traditional micro-pulse lidars operated at or near 532 nm (He et al., 2008; Li et al., 2017b; Sawyer and Li, 2013), these two lidars are operated at 1.5 μm, which are eye-safe and can be made with all-fiber components. The 1.5 μm laser shows the highest maximum permissible exposure in the wavelength range from 0.3 to 10 μm (Xia et al., 2015). The invisible infrared eye-safe laser makes these two lidars can work in a densely populated city horizontally. The all-fiber structure makes these lidars robust, immune to external environment changes such as vibration and temperature*."

Page 9, line 8-11. "*The DDL incorporated a fiber laser at 1.5 μm and an up-conversion detector. This design of lidar makes it more eye-safe than traditional laser of 355, 532 and 1064 nm. All-fiber configuration is realized to guarantee the high optical coupling efficiency and robust stability. Two lidar systems use only one set of laser source, optical collimator and control system*."

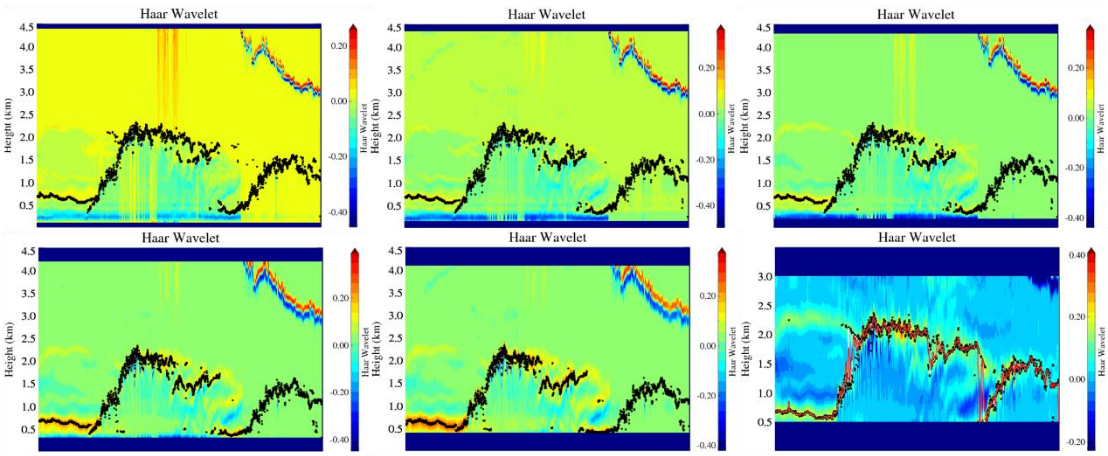

Figure R1. WCT method with different values of dilation for RCS. The values of dilation are 100 m, 150 m and 200 m for upper panels, 300 m, 400 m and 500 m for bottom panels, from left to right. The colored contours indicate the WCT results. The black dotted lines indicate retrieved BLH.

7. For lines 15-16 on page 4, "Considering different vertical spatial resolutions, a dilation of 150 m and 250 m is applied for RCS and CNR, respectively". The selection of an appropriate dilation is the key for WCT method. So why "150 m" and "250 m" are selected? Should be explained.

Thanks for this suggestion. We fully agree with your point of view "The selection of an appropriate dilation is the key for WCT method". Too large or too small dilation is not appropriate. We have tested different values of dilation as shown in Fig. R1, even height-dependent dilation that selected by previous studies for WCT method. At least for this 45 hour observations from 1 June to 2 June in Hefei, 150 m is one of the most appropriate values of dilation for RCS. The 250 m for CNR is similar. In fact, the optimum value is equal to the depth of the transition zone (Brooks, 2003). The depth of transition zone varies in different places and seasons. A further study of transition zone depth is desirable by multi instruments with longer enough observations.

Changes: Page 4, line 21-22. "*Considering different vertical spatial resolutions and having* *tested multi values of dilation, a dilation of 150 m and 250 m is applied for RCS and CNR, respectively for this 45-hour observations.*"

8. For line 16 on page 4, "Compared with gradient method, HWCT method has greater adjustability and robustness". In fact, as extended technique of gradient method, several studies (Brooks, 2003; Mao et al., 2013; Dang et al., 2019) have indicated the WCT method is also easily interference by multiple aerosol layers or cloud layer. So how the paper ideals with the interference of the cloud layers on ABLH determination in Figure 3(a)-(b)? No doubt, the signal gradient at the cloud boundary is strongest than at the ABL top on 2 June 2018, the HWCT may capture the cloud top rather than the true height of lower stable ABL.

Brooks, I.M.J.J.o.A.; Technology, O.; Finding Boundary Layer Top: Application of Wavelet covariance Transform to Lidar Backscatter Profiles. 2003, 20 (8), 1092—1105.

Mao, F.; Wei, G.; Song, S.; Zhu, Z.; Determination of the boundary layer top from lidar backscatter profiles using a Haar wavelet method over Wuhan, China. Optics Laser Technology 2013, 49 (7), 343-349.

Dang, R.; Yang, Y.; Li, H.; Hu, X.-M.; Wang, Z.; Huang, Z.; Zhou, T.; Zhang, T.; Atmosphere Boundary Layer Height (ABLH) Determination under Multiple-Layer Conditions Using Micro-Pulse Lidar. remote sensing 2019, 11 (263).

Thanks for this comment. For the cloud layer and aerosol layer higher than 2.5 km as shown in Fig. 3, we can easily remove the interference of such cloud layers above ABL by setting a top-limit of the WCT method in this manuscript similar to Dang et al., 2019. For the multiple aerosol layers in the ABL, an appropriate dilation is useful and robust as shown in Fig. R1. For the scattered stratocumulus that exist in the capping layer as shown in Fig. 3a and 3b, the difference between cloud top and BLH are relatively small. In addition, the duration time of stratocumulus is also short in the field of view of the lidar that can be easily removed by a longer temporal resolution. Thus the influence of scattered stratocumulus is negligible. For the continuous thick low level cloud not shown in this observation, the BLH cannot be retrieved. Thus, the interference of the cloud layers and multiple aerosol layers are negligible at least in this manuscript. We added some description of the cloud in Sect. 3 in the revised manuscript.

Changes: Page 5, line 1-6. "*It should be noted that cloud layer could affect the BLH results. A top-limit is set to the HWCT method for higher clouds. For the scattered stratocumulus that may exist in the capping layer, the differences between cloud top and BLH are relatively small. In addition, the duration time of stratocumulus is also short in the field of view of the lidar. Thus the influence of scattered stratocumulus is negligible. The low level cloud in the ABL can be identified by the paired minimum* $W_f(a,b)$ *and maximum* $W_f(a,b)$ *occurs at heights close to each other. The BLH cannot be retrieved under this condition.*"

9. For line 17 on page 4, "In order to reduce the interference from unexpected turbulence and noise", what is unexpected turbulence? Is the "turbulence" is ambiguous here? Similarly, line 25 on page 4.

Thanks for this comment. We removed "turbulence" here in line 17. But in line 25, the unexpected turbulence means turbulence occurs in the free atmosphere where no turbulence is considered to exists.

Changes:

Page 4, line 24 – page 5, line 1. "*In order to reduce the interference from unexpected noise, the signal is averaged to a temporal resolution of 1 min in BLH determination.*"

Page 5, line 13-14. "*A median algorithm is used to mitigate the interference and fluctuation from unexpected turbulence and noise in the free atmosphere*"

10. For lines 19-20 on page 4, "As an example, the measured RCS and CNR after one-minute average (after overlap correction and background noise deduction) at 1 June 2018, 10:40 am is shown in Fig. 2a", Figure 2 shows an example in clear sky situation, profiles in cloudy situations on 2 June 2008 is suggested.

Thanks for this suggestion. As answered to minor comment 8, the interference of the clouds is removed by setting a top-limit of 2.5 km in this manuscript. Besides, to propose a robust BLH retrieval method under complex conditions is beyond the scope of current manuscript, but such work is desirable with more observations in future.

Changes:

Page 5, line 2. "*A top-limit is set to the HWCT method for higher clouds.*"

Page 7, line 15. "*A top-limit of 2.5 km of BLH is applied during the BLH retrieval*."

11. For line 22 on page 4, "…which represented the turbulence kinetic energy", the "represented" should change to "represents".

Corrected as suggested.

Changes: Page 5, line 10-11. "*The BLH can also be determined from the variance of vertical velocity* σ_w^2*, which represents the vertical component of the turbulence kinetic energy*."

12. For line 24 on page 4, "In this study, the threshold is set to be 0.06 m2s-2", how the threshold is defined?

Similar to that of dilation, we have tested different values of threshold for this observation. The variance of vertical velocity with 5 min temporal resolution is shown in Fig. R2. A threshold between 0.04 m^2s^{-2} and 0.15 m^2s^{-2} may be appropriate. As shown in Fig. 2c, 0.06 m^2s^{-2} is one of the most appropriate threshold during this observation. A smaller value may be difficult to identify free atmosphere while a larger value may be difficult to distinguish CBL with several lower variances,

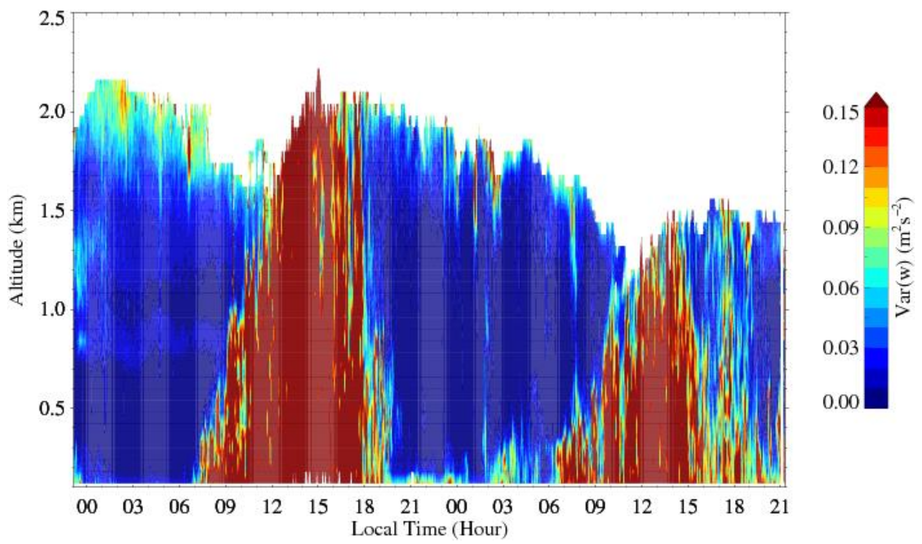

Figure R2. Variance of vertical velocity with 5 min temporal resolution.

such as the profiles shown in Fig. 2c. It should also be noted that the threshold may varies with different places and seasons.

Changes: Page 5, line 12-13. "*In this study, the threshold is set to be 0.06* m^2s^{-2} *which is suitable as shown in Fig. 2c*."

13. For line 4 on page 5, "BLH from reanalysis data is always used in boundary layer climatology", please improve the description.

We modified this sentence as follows: "*Reanalysis data is always used in climatological and regional analysis of BLH (Collaud Coen et al., 2014; Guo et al., 2016; Seidel et al., 2012)*."

Changes: Page 5, line 18-19. "*Reanalysis data is always used in climatological and regional analysis of BLH (Collaud Coen et al., 2014; Guo et al., 2016; Seidel et al., 2012).*"

14. For lines 7-8 on page 5, "The hourly BLH from high resolution realization sub-daily deterministic forecasts of ERA5 is used here", is the ABLH defined from ERA used to estimate the results from lidar? The purpose should be stated. In addition, should "realisation" be changed to "realization"?

Yes, the hourly BLH from high resolution realisation sub-daily deterministic forecasts of ERA5 is used to cross-check the BLH retrieved from lidar since there is no sounding data in Hefei. The use of "high resolution realization" can be seen from ECMWF website at https://confluence.ecmwf.int/display/CKB/ERA5+data+documentation, the first sentence of third paragraph in the Introduction, "The ERA5 dataset contains one (31 km) high resolution realisation (HRES) and a reduced resolution ten member ensemble (EDA)".

Changes: Page 5, line 22-23. "*The hourly BLH from high resolution realisation sub-daily deterministic forecasts of ERA5 is used to cross-check the BLH retrieved from lidar since there is no sounding data in Hefei.*"

15. For line 18 on page 5, "…… indicated the BLH derived from……", "indicated" should be change to "indicate".

Corrected as suggested.

Changes: Page 6, line 4-5. "*The black dotted line in each panel indicate the BLH derived from RCS, CNR and vertical wind, called as* BLH_{RCS}, BLH_{CNR} *and* BLH_{VAR} *in this study*."

16. For lines 17-19 on page 5, the description could be rewritten as "The black dotted line in each panel indicate the BLH derived from RCS, CNR and vertical wind, called as BLHRCS, BLHCNR and BLHVAR in the study".

Corrected as suggested.

Changes: Page 6, line 4-5. "*The black dotted line in each panel indicate the BLH derived from RCS, CNR and vertical wind, called as* BLH_{RCS}, BLH_{CNR} *and* BLH_{VAR} *in this study*."

17. For Line 24 on page 5: From the author, stratocumulus exists above the ABL; It can be seen clearly from Fig. 3(b) that signals between CBL top and cloud are relatively small, and the BLHs derived by aerosol method are cloud heights. Here, the authors should notice the influence of cloud in BLH retrieving based on lidar.

Thanks for this suggestion. As answered to minor comment 8, the influence of scattered stratocumulus exist in the capping layer with short duration time is negligible in this manuscript. The low level cloud is not exits during this observation. The low level cloud in the ABL can be identified by the paired minimum $W_f(a,b)$ and maximum $W_f(a,b)$ occurs at heights close to each other. The BLH cannot be retrieved under this condition.

Changes: Page 5, line 1-6. "*It should be noted that cloud layer could affect the BLH results. A top-limit is set to the HWCT method for higher clouds. For the scattered stratocumulus that may exist in the capping layer, the differences between cloud top and BLH are relatively small. In addition, the duration time of stratocumulus is also short in the field of view of the lidar. Thus the influence of scattered stratocumulus is negligible. The low level cloud in the ABL can be identified by the paired minimum $W_f(a,b)$ and maximum $W_f(a,b)$ occurs at heights close to each other. The BLH cannot be retrieved under this condition.*"

18. For line 28 on page 5, "The results observed in RCS can be also found in CNR", what is the results? The description is unclear.

We modified this description in revised manuscript. "*The phenomena that observed in RCS described above can be also found in CNR*."

Changes: Page 6, line 16-17. "*The phenomena that observed in RCS described above can be also found in CNR*."

19. For section 4.1, only the observations of aerosol concentration, the resulted ABLH and meteorological parameters are described, so how do they interact with each other? How does the BLH respond to the meteorological condition?

This is a good point. However, it's a complex question that beyond the scope of this manuscript. This paper focuses on the relationship between $PM_{2.5}$ and BLH based on a hybrid lidar in this manuscript. In fact, the meteorological parameters described here are intended to explain the evolution of PM, not the interaction with ABL. These parameters are essential for the study of correlations between BLH and PM concentrations (*Geiß et al.*, 2017). Nevertheless, it seems that there is a strong positive correlation between BLH and temperature. The maximum BLH is lower on 2 June 2018 than that on 1 June 2018, so does the maximum temperature. But this correlation may be due to the cloud-ABL interaction as discussed in Sect. 4.4. A recently accepted work on GRL may be helpful to this question (*Guo et al*., 2019). The influence of meteorology on the BLH has been investigated using long-term (1979-2016) radiosonde data in this work. More observational and modeling study are needed in future work.

20. For line 25 on page 6, "in Fig. 3, the BLH results are well retrieved, indicating that the HWCT and variance methods are appropriate for BLH determination……" The HWT and variance analysis may be interfered by the RL and cloud layer, how does this study ideal with the interference of them? Similar to comment 8.

For the HWCT method, we have answered how to deal with cloud layers in response to minor comment 8. An appropriate value of dilation of HWCT may be enough to deal with interference of RL as shown in Fig. R1, and so does an appropriate threshold of variance method as shown in Fig. R2. For the variance method, there is not any interference of cloud layer above the ABL. The low-level cloud that may interfere the results of variance method is not occurred during this observation.

Changes: Page 5, line 1-6. "*It should be noted that cloud layer could affect the BLH results. A* *top-limit is set to the HWCT method for higher clouds. For the scattered stratocumulus that may exist in the capping layer, the differences between cloud top and BLH are relatively small. In addition, the duration time of stratocumulus is also short in the field of view of the lidar. Thus the influence of scattered stratocumulus is negligible. The low level cloud in the ABL can be identified by the paired minimum* $W_f(a,b)$ *and maximum* $W_f(a,b)$ *occurs at heights close to each other. The BLH cannot be retrieved under this condition.*"

21. For line 29 on page 6, "In turbulence derived CBL, all three BLH results from lidar measurements are comparable when the ABL is fully mixed", please improve the description.

We modified this sentence as follows: "*All three retrieved BLH from lidar measurements are comparable when the ABL is fully mixed*."

Changes: Page 7, line 18-19. "*All three retrieved BLH from lidar measurements are comparable when the ABL is fully mixed*."

22. For line 31 on page 6, "a criteria is proposed to classify the ABL as CBL and RL/SBL by the values of BLHVAR and BLHRCS in this study……in the morning, when BLHVAR meets the BLHRCS, the type of ABL changes from RL/SBL into CBL. In the Afternoon, when BLHVAR departs from BLHRCS, the ABL turns into RL/SBL again……" When BLHVAR firstly meets or departs from BLHRCS? How to classify if there are several moments that BLHVAR meets or departs from BLHRCS?

Here we defined $\Delta = BLH_{RCS} - BLH_{VAR}$. There is a hypothesis that BLH_{RCS} (RL) is higher than BLH_{VAR} (SBL) at midnight. This hypothesis is true in most cases. In the morning, the BLH_{VAR} grows with temperature increases. The meet (depart) is defined as when the sign of Δ become negative (positive) for the first (last) time after (before) midnight. If the sign of Δ never changes during the whole day and night, a specified value is used. The meet (depart) is defined as when the value of Δ is less than (greater than) the specified value for the first (last) time after (before) midnight. It should be noted that the specified value varies with different places and seasons. We added more description in the revised manuscript.

Changes: Page 7, line 21-26. "*A parameter is defined as* $\Delta = BLH_{RCS} - BLH_{VAR}$. *The sign of* Δ *is positive at nighttime in most cases. In the evening, a SBL is capped by a RL as shown in Fig. 5a. In the morning, when* BLH_{VAR} *meets the value of* BLH_{RCS}*, i.e., the sign of* Δ *become negative or the value of* Δ *is less than a specified value for the first time after midnight, the type of ABL changes from RL/SBL into CBL. In the Afternoon, when* BLH_{VAR} *departs from* BLH_{RCS}*, i.e., the sign of* Δ *become positive or the value of* Δ *is greater than a specified value for the last time before midnight, the ABL turns into RL/SBL again.*"

23. For section 4.3, only the "relationship between the BLH and PM2.5" before and after a precipitation case is analyzed. It is not enough to illustrate the title of the manuscripts. In addition, before precipitation, it is clear that the PM shows a contrary tendency with the ABLH. After precipitation, although the ABLH is lower than on previous day maybe caused by cloud or others, the growing process of CBL is similar to that before precipitation, however, there is no obvious tendency of PM2.5. Therefore, what caused the difference of relationship between PM2.5 and ABLH is the PM2.5 distribution. What should be considered is the factor contributing to the difference of PM before and after precipitation, what's role of the precipitation process?

Besides the precipitation, the relationship between BLH and $PM_{2.5}$ is also analyzed with different BLH retrieval methods as shown in Fig. 5d~5e and Table2. A good response of $PM_{2.5}$ to aerosol derived BLH evolution with larger R^2 and stronger correlation than turbulence derived BLH both before and after the precipitation. The correlation between BLH and $PM_{2.5}$ becomes much weaker after the precipitation. The wet growth of existing small particles caused by the precipitation process may be responsible in the early hours. Recently, Geiß et al. (2017) investigated correlations between BLH and concentrations of pollutants (PM_{10}, O_3, NO_x). They found that the correlations of BLH with PM10 were quite different for different sites without showing a clear pattern. The pollution sources, meteorological conditions and details of BLH retrievals should be considered (*Geiß et al.*, 2017). More observational and modeling study are need to solve this question in future work. We added some discussions in the revised manuscript.

Changes:

Page 8, line 23-28. "*The relationships between BLH and PM2.5 are changed after precipitation. Recently, Geiß et al. (2017) investigated correlations between BLH and concentrations of pollutants (PM_{10}, O_3, NO_x). They found that the correlations of BLH with PM_{10} were quite different for different sites without showing a clear pattern. In addition, the reflection and absorption of the incoming solar radiation by the clouds on 2 June 2018 could also affect the diffusion of aerosols. Therefore, BLH with different retrieval methods, pollutant sources and meteorological conditions should be considered in air quality prediction models*."

Page 9, line 23-24. "*The reasons for the differences in the relationships between BLH and $PM_{2.5}$ may result from both cloud effect and pollutant sources not just the precipitation*."

Page 9, line 26-27. "*To probe the mechanism of the BLH-$PM_{2.5}$ relations under different conditions, such as before and after the precipitation, not only such observations, but also model simulation are needed in further studies.*"

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