

Reply to Anonymous Referee #1:

We appreciate the reviewer's comments on the manuscript. All comments are highly valuable and helpful for us to improve our manuscript. We have studied them carefully and have addressed them in the revised manuscript (red marked) which includes additional investigations. Below are point-by-point responses to the referee's comments.

Comments from the editors and reviewers:

General comments:

This manuscript analyses long-term measurements of mixed layer height (MLH) over Beijing. Authors describe and evaluate the techniques, derive climatological diurnal variation, and presents an application towards the estimation of fine particulate matter. Several comments and suggestions are offered for authors to consider while revising the manuscript for ACP.

Major points:

1. Introduction section should provide more background, based on studies comparing mixed layer measurements, not limited to LIDAR but also from RADAR and other instruments. Some discussion has been made on the importance of MLH in context of air pollution mixing and dispersion, which should be corroborated with relevant recent references (e.g. Singh et al., 2016; Mues et al., 2017).

A1: Thank you to mention the question from this perspective. The measurement of RADAR, microwave radiometer, ceilometer is added in the revised manuscript. "Singh et al.(2016) investigate the evolution of the Local Boundary Layer in the central Himalayan region, using a radar wind profiler detecting wind components based on signal to-noise ratio profile. Collaud et al. (2014) compared the MLH measurement of microwave radiometer from atmospheric temperature profile with other measurement in Swiss plateau. Mues et al. (2017) used the ceilometer to retrieve the MLH based on aerosol backscatter signal in the Kathmandu Valley." "Recent studies compared remote sensing measurements (lidar, radar wind profiler, microwave radiometer) with radiosonde (RS) (Milroy et al., 2012; Sawyer and Li, 2013; Cimini et al., 2013; Tang et al, 2016; Singh et al., 2016; Mues et al., 2017; Su et al, 2019)".The relevant recent references (Singh et al., 2016; Mues et al., 2017) is added when talk about air pollution mixing and dispersion in the first paragraph.

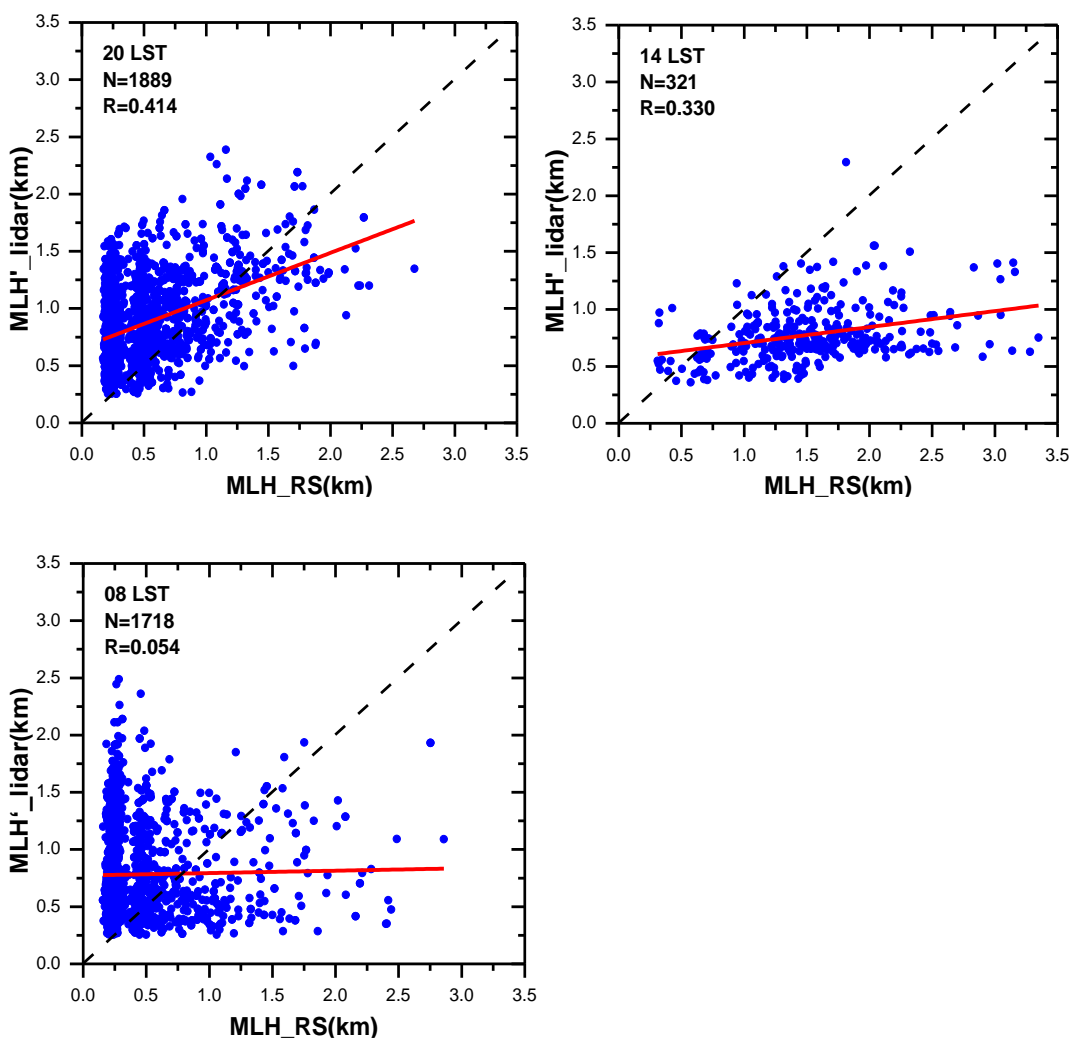
2. Stronger correlations between LIDAR and Radiosonde are seen during afternoon but such correlations are absent in morning and evening. Besides poor correlation, values of MLH also do not match with radiosonde in morning and evening. There should be more deeper analysis and discussions on these aspects with references to previous studies.

A2: It is necessary. Discussions is added as "The poor agreement between MLH (MLH') from lidar and MLH_RS is also reported in the study of Su et al. (2019), in which shows that the correlation of PBLH measurement between lidar and radiosonde is 0.14 at 0630 LST. The significant scatter in the morning and evening is associated with complicated structure of boundary layer, as

indicated by the existence of stable boundary layer and residual layer (Su et al., 2019; Tang et al., 2016). In this study, more than 35% measurement of SBL height is not within the scope of the lidar detection. Additionally, under stable conditions, it is difficult to estimate the MHL from lidar data in some cases, due to the weak vertical gradients in the aerosol content. In the evening and early morning, problems arise from finding a sufficiently clear change in the backscatter profile at the top of the SBL, within the previously well-mixed layer (Russell et al., 1974; Seibert et al., 2000).”

3. The correlation analysis between MLH' and radiosonde should be shown for all three times in the supplement.

A3: It is added as Fig. S4 in the supplementary.



4. Section 3.1 describes mostly the variations as retrieved with limited new insights into boundary layer evolution. Additionally, several general statements are made e.g. “MLH' sometime agree well with SBL”. Remove general statements and provide more specific discussions based on analysis.

A4: General statements is removed from Section 3.1, and add some description of boundary layer evolution, as well as some specific discussions based on analysis, see the revised manuscript.

5. Figure 8 shows significant reduction in MLH after sunrise, particularly during summer (l.245). This should be elaborated. How do the horizontal winds change during this time of minimum MLH? Have any other studies reported such variability in Beijing or elsewhere?

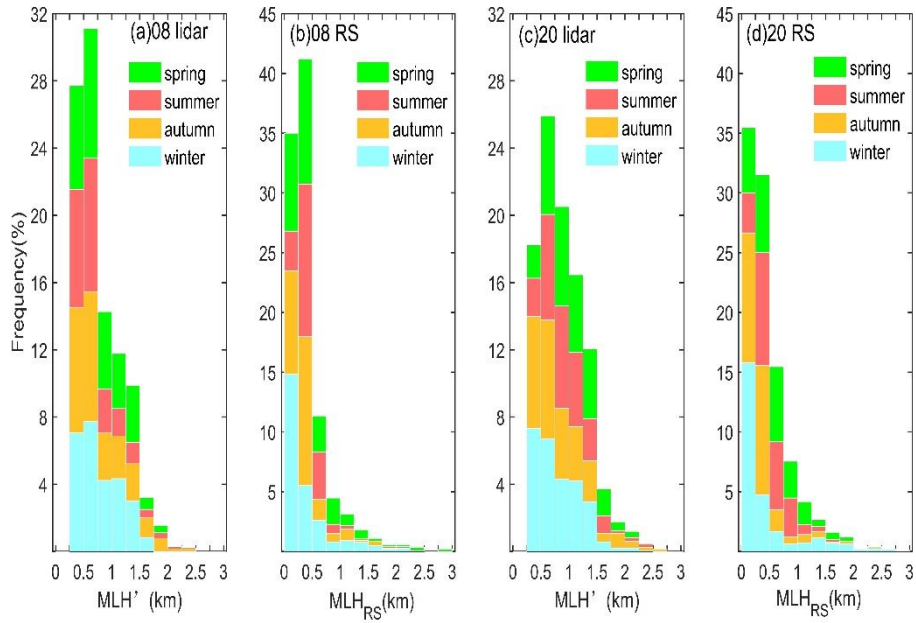
A5: Deep analysis is added, as well as the study in Beijing of Tang et al. (2016). "It should be noted that summer exists the biggest amplitude of diurnal variation, with the deepest valley (0.93 km) increasing to the peak value of 1.51 km. Tang et al. (2016) indicate that the lower MLH value for summer nights and early mornings is contributed to the effect of the mountain plain wind. Beijing is located in the North China Plain, with Taihang Mountain in the west and Yanshan Mountain in the north. When the local mountain breeze from the northeast in the summer night superimposes the surface cooling, leading to the increase the thickness of the inversion layer, the height of the mixed layer gradually decreases. After sunrise, with the drive of thermal turbulence, the residual layer height observed by lidar is gradually replaced by a convective boundary layer height, with MLH increasing rapidly, and after 12:00 LT, the plain wind from the south-westerly direction gradually dominates."

6. Interannual variation – It seems that some of the years have data limited to particular season (s). it will be appropriate to compare the years which have consistency in the seasonal coverage. Otherwise better to analyze a particular season among different years. In any case it is not clear what new is learnt by this analyses. There should be supporting analyses of temperature /winds and /or aerosol changes to explain observed inter-annual variations.

A6: Except for the MLH data from lidar of 2013 mainly existing in winter and spring, the measurement of 2014-2018 are all annual continued observations, covering all the seasons. From 2014 to 2018, the magnitude of diurnal cycle of MLH increase year by year, indicating the volume available for the dispersion of pollutants extend, which is beneficial to the mitigation of surface pollution. Correlation of MLH and wind speed, relative humidity, temperature and AOD are calculated. The observed inter-annual variations can be explained by the aerosol change, the detail please see the manuscript. The statistic of interannual variation of the average, maximum and minimum of MLH, as well as CBL, is presented in the revised manuscript.

7. There are several variables defined MLH, MLH', MLH_RS etc. Try to use these variables-consistently. For example in discussions MLH_RS is used but in Fig S3 -axis title -it is written as MLH.

A7: Thank you for mentioning this question. It is easy to be confused. In the revised manuscript, "MLH_L" indicates the biggest local maximum from lidar, and "MLH_L'" indicates the first local maximum from lidar, and "MLH_{RS}" presents MLH from radiosonde. All the content of the manuscript and figure has been revised.



8. Correlations are very weak $r = 0.01$ between radiosonde and lidar at 8LST (Fig S4) and data has significant scatter. Add some inter-comparison studies from literature to elaborate on this.

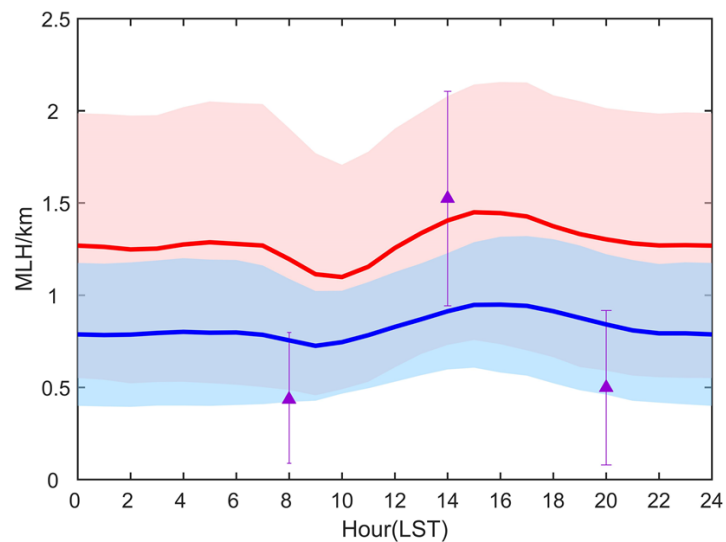
A8: As far as we can see, this comment is similar as comment 2. Please infer the author comment of comment 2.

9. Computation of PM2.5 should be part of the main manuscript, instead of supplementary material.

A9: Computation of PM2.5 is transferred from supplementary to the main manuscript.

10. Fig 7: show variability in RS data too.

A10: The variability is added as standard deviation in Fig. 7 below.



Minor changes

11. Manuscript needs careful proofreading for language as various places. e.g. l.69: change consistent” to “consistency” l.107: “MHL” to “MLH” l.118: check the sentence: “..where was located”, probably it should be “which was located” l.195: change “collapse” to “collapsed” and “develop” to “developed” l.203: “shown” to “shows”

A11: All the cacography mentioned is corrected, as well as other spelling errors.