Authors' Response to Referees' Comments

Anonymous Reviewer #2

This study utilizes four-year sounding measurements, surface PM measurements and reanalysis data to examine the influence of the synoptic patterns on the planetary boundary layer (PBL) structure and air pollution in Beijing. As Beijing has been experiencing extremely severe particulate pollution in the past few years, this study shed light on the contribution of the regional scale dynamics to the haze formation in a quantitative way. Using a synoptic pattern classification method, three patterns are identified to be closely related with heavy pollution condition in Beijing and the underlying dynamical processes are revealed in details. The cloud influence on PBL is also assessed. Overall, the manuscript is well written and I recommend publishing this study on ACP after some minor questions below can be addressed by the authors.

We thank reviewer #2 for his/her positive comments on our manuscript. In response to his/her comments, we have made relevant revisions to the manuscript. Listed below are our responses and the corresponding changes made to the manuscript according to suggestions given by the reviewer. Each comment (in black) is listed, followed by our responses (in blue).

1. Page 3, Line 9-19. I am kind of surprised that the contribution from the automobile exhaust to the Beijing air pollution was not even mentioned. Some associated references can be added here (Zhang et al., 2015, Chem. Rev.; Peng et al., 2016, PNAS)

Per your kind suggestions, the literatures concerning the contribution from automobile exhaust were added as below:

"*The major sources of aerosol in Beijing include traffic emission, power plant, industry, domestic emission, and agricultural activities (R. Zhang et al., 2015; Liu et al., 2016; Peng et al., 2016).*"

2. Page 4, Line 19. Please be specific on how the sea-breeze affects PBL and if it alleviates or deteriorates air pollution.

The impacts of sea-breeze on PBL structure and air pollution were added on Page 4 in the revised manuscript, as shown below.

"The diurnal variation of land-breeze and sea-breeze provides a mechanism for the pollutants in the Beijing-Tianjin-Hebei region to be recirculated and accumulated. In the evening and early morning, the presence of land-breeze (offshore wind) could bring the pollutants emitted from coastal regions to Bohai sea, and then in the afternoon, the development of sea-breeze (onshore wind) could bring these pollutants back to coastal regions, leading to exacerbated pollution. With the sea-breeze penetrates further inland, the pollutants emitted from coastal regions could be transported to the downstream regions."

3. Page 10, Line 11. I don't understand how come R is low as -0.37 but p-value is less than 0.01. What significance test is performed here?

The Pearson correlation coefficient (R) measures the linear relationship between two dataset. The closer to 1 the more 'confident' we are of a positive linear correlation and the closer to -1 the more 'confident' we are of a negative linear correlation.

The confidence in a correlation is formally determined not just by the correlation coefficient but also by the number of pairs in your data. If there are very few pairs then R needs to be very close to 1 or -1 for it to be deemed 'statistically significant', but if there are many pairs then a R closer to 0 can still considered 'highly significant' (Fenton and Neil., 2012). The critical values of R could be found at following website (Table B.7): onlinelibrary.wiley.com/doi/10.1002/9781118342978.app2/pdf

One of the standard methods to measure the 'significance' is the p-value, which is a number between 0 and 1 representing the probability that the data would have arisen if the null hypothesis (i.e., the slope of the regression line is zero) were true. In this study, there are 282 pairs of data whose correlation coefficient is -0.37, and the p-value is less than 0.01. This means the chance that we would have seen these data

pairs were unrelated is less than 1%.

In this study, the p-value was calculated based on the student's t-distribution (Weathington et al., 2012), which was added in the caption of Figure 4.

4. Section 3.2. Does a haze event have to be tied to a synoptic pattern? How about a 'no wind' condition? It seems not belonging to none of the seven synoptic patterns listed there, but it did occur during some severe haze event.

Yes, every haze event develops under a specific synoptic condition, even for those haze episodes under "no wind" condition. Table S1 (in the Supplementary Materials) shows the synoptic type for each day of time period (2011 to 2014) investigated. A large body of literatures (e.g., Chen et al., 2008; Wei et al., 2011; Zhang et al., 2012) has demonstrated that a synoptic pattern is an important factor modulating the day-to-day variation of air quality. Also, the near-surface calm wind situations are often linked to a certain synoptic forcing (Kim Oanh and Leelasakultum, 2011; Ye et al., 2016), although the impacts of synoptic pattern on calm wind situations may be relatively weak, which still cannot be ignored.

5. Fig. 13. The schematic diagram is very interesting, but the mechanism only works for daytime. The pollution is typically even worse during the nighttime. It will be interesting to have some discussion about the possible PBL-synoptic pattern interactions during the nighttime.

We totally agree with the reviewer, the nocturnal boundary layer (NBL) structures/processes also play an important role in modulating the air pollution. During a diurnal cycle, the relatively high nighttime concentration of pollutants is primarily induced by the drop of BLH after sunset and the variation of emission. Besides, the daytime PBL processes also partition the pollutants within NBL and those retained in the residual layer aloft. Therefore, the following discussion has been added in the Conclusions.

"*Although this study focuses on the daytime PBL structure, the nocturnal PBL also significantly affects the air quality at hourly to diurnal scales through the*

intermittent turbulence, which also cannot be ignored. The structure of nocturnal PBL is primarily determined by (stull, 1988; Salmond and Mckendry, 2005). The nocturnal PBL may range from fully turbulent to intermittently turbulent or even non-turbulent at a variety of heights, temporal scales and spatial locations, which was largely induced by complex interactions between the static stability of the atmosphere and those processes (i.e. wind shear from synoptic patterns, terrain induced flows, low-level jets) that govern mechanical generation of turbulence. This makes it very difficult for the observation of large-scale atmospheric advection, investigation of the PBL-synoptic pattern interaction, transport pathways and dispersion of pollutants in the NBL, particular in regions of complex terrain such as Beijing. To fully understand the impacts of PBL on air quality in Beijing, more attention should be paid to the nocturnal PBL in the future."

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