Dear Editor and Anonymous Referees,

Thanks for your thoughtful review of the manuscript. We read the reviewer's comments carefully, and have responded and taken all of the reviewers' comments into consideration and revised the manuscript accordingly. All the changes have been highlighted in the revised manuscript. My detailed responses, including a point-by-point response to the review's comments, are as follows:

For Referee #1:

"Comments to the Author:

The precise cause of the explosive growth of $PM_{2.5}$ levels during heavy aerosol pollution episodes in China is an interesting topic. The study utilized hourly $PM_{2.5}$ monitoring data and vertical meteorological data to characterize typical explosive growth of $PM_{2.5}$ during different stages of heavy pollution episodes occurred in Beijing since 2013, and attempted to quantify the effect of meteorological factors on such growth. The topic is certainly suitable for ACP, the methods are appropriate, and the analysis and the results are generally reasonable. This paper can be considered for publication after the following issues are addressed".

Response: We appreciate the referee for the valuable and constructive reviews of our manuscript. We carefully revise the manuscript based on the following comments.

General comments:

1) **"One of my concerns with this paper is that the title is appropriate. What is the exact meaning of "feedback effects"? Do they represent the effects of worsening meteorological conditions on pollutant accumulation, or the feedbacks of cumulative pollutants on worsening meteorological conditions? Also, it seems that the "feedback effects" only occurred during the cumulative explosive growth processes, right? I think "feedback effects" is somewhat misleading and thus unsuitable. Thus I would suggest the author to consider**

another title. ”

Response: Thanks for the valuable comment. We wanted to focus on the feedback effect of worsening meteorological conditions on $PM_{2.5}$ cumulative explosive growth, so we have changed the title to 'Feedback effects of boundary-layer meteorological factors on cumulative explosive growth of $PM_{2.5}$ during winter heavy pollution episodes in Beijing from 2013 to 2016'.(L1-4, P1)

2) **"Another concern is that it would benefit if the paper can be more quantitative as a whole. There are many places when the author stated a conclusion, but did not back it up sufficiently with a number. For example in Line 237-238, Sect. 3.2.2, "the mass concentrations of soluble organic aerosols, sulfate, nitrate, and ammonium rapidly increase with RH (Figure S1)"**

Response: Thanks for the constructive comment. We try our best to describe some issues with less qualitative descriptions, and provide more number values to support them.

3) **"The methods look a bit simple. First, what is the representative of the air quality monitoring data and vertical meteorological data used in this study? It should be noted that these data have different spatial and temporal resolution. Can they represent the urban conditions in Beijing? Also, the atmospheric vertical observations are twice daily at 0800 h and 2000 h. Are they sufficient to capture the rapid changes during the explosive growth stages? It would be nice if the readers could see a brief discussion of the representative. For example, a figure displaying the locations of the observation stations is helpful. Second, even though references are given for the PLAM index, it would be easier for readers' understanding if more information given in this manuscript"**

Response: In fact, we use all state-controlled stations to represent the averaged $PM_{2.5}$

concentration in Beijing municipal city. We have mentioned it in the "Method" section. As illustrated, $PM_{2.5}$ mass concentration and ground-level meteorological factors are hourly measured, the vertical profiles of the aerosol extinction coefficient are obtained every fifteen minutes, and vertical meteorological factors are measured using L-band radiosonde radar twice daily at 0800 h and 2000 h. The explosive growth usually begins in the afternoon and lasts for ten hours, so the vertical observations at 2000 h could capture the meteorological conditions during which the explosive growth appears. If we had obtained vertical observations with higher spatio-temporal resolution, we would have definitely illustrated more clearly the change of meteorological conditions during the explosive growth of $PM_{2.5}$. Such fine observations are exactly what we desire, but beyond the reach. More descriptions and calculation of PLAM are also added in the details to the "Method". (L91-93; L102-113, P5-6)

Specific comments:

1) **"Line 201-203: A more formal citation to the model results should be used, rather than "personal communication with Dr. Hong Wang". Some model details should be added in the methods, perhaps."**

Response: This is a manuscript that is being prepared, so it's using personal communications. We have added the same author's similar reference on ACP 2015 to support this point. (L212-213, P9)

2) **Line 247 and Line 436: The in-text citation and the reference for "Y. Liu et al., 2008" is in the wrong format.**

Response: We have corrected the citation and reference. (L257, P11; L397-399, P16)

3) **Line 260: "100 to 50" - units should be added.**

Response: Added (L269, P11)

4) **"Line 299-301: Why the PLAM index can be used to approximately quantify the atmospheric feedback on the growth? Can they fully represent those meteorological causes of the cumulative explosive growth mentioned in this study?"**

Response: The cumulative explosive growth is caused by stable stratification characterized by weak winds, near-surface anomalous inversion, and moisture accumulation. The enhanced atmospheric stability and additional accumulation of moisture could be quantified by PLAM index, because PLAM is an index diagnosed based on conventional meteorological factors, having linear relation between it and $PM_{2.5}$ mass concentration. Its core elements are "regional air mass stability" and "condensation rate of water vapor on aerosol", just reflecting the key characteristics of the meteorological conditions in the cumulative explosive growth stage.

5) **"Figure 7: (1) Are the plots just for the cumulative explosive growth processes? But it seems that in February 2014 (b) there is no cumulative explosive growth process, only the convergent explosive growth process? (2) What's the temporal resolution of the PLAM index and PM2.5 concentrations? Hourly or 12 hours?"**

Response: (1) The cumulative explosive growth and the convergent explosive growth processes have been discussed separately. The squared correlation coefficients between hourly PLAM and $PM_{2.5}$ in 2013, 2015, and 2016 are 0.71, 0.69, and 0.71 respectively, exceeding the 0.05 significance level. The mean value of four coefficients is over 0.70, which suggests the noted feedback of worsening meteorological conditions on PM explains over 70% in cumulative explosive growth of $PM_{2.5}$. In addition, the squared correlation coefficients between PLAM and $PM_{2.5}$ in 2014 is 0.76, which indicates enhanced regional atmospheric stability facilitate convergent explosive growth of $PM_{2.5}$. (L318-323, P13-14) (2) The used PLAM index and $PM_{2.5}$ concentration are measured hourly, which has been added in this section. (L318, P14)

For Referee #2:

"General Comments:

Based on the observational dataset of 12 wintertime heavy haze events in Beijing and its surroundings over 2013-2016, this manuscript explored the feedback effects of boundary-layer factors on explosive growth of PM2.5 during the different stages, including transport, cumulative and convergent explosive growth, presenting some interesting results about meteorological feedback on PM explosive growth during heavy haze pollution, which could improve our understanding on air quality change and fall within the scope of ACP. "

Response: Thank you for the positive comments on our manuscript.

I suggest the minor revisions before it is published as follows:

Specific comments:

"Airflow from the south of Beijing can transports not only water vapor and pollutants, and also warm air mass to Beijing. Considering the maximum transport layer at ca. 500 m, the southerly wind transport could also contribute warm air to the development of temperature inversion. Please discuss this potential contribution to anomalous inversion and $PM_{2.5}$ accumulation during TS and CS."

Response: The warm airflow transported by southerly winds would definitely facilitate temperature increase in Beijing, might serve to weak inversion during TSs, and also creates the requisite thermal conditions to some degree for the formation of anomalous inversion. However, in the TS stage, southerly winds which transports warm airflow are more striking during the TSs than the CSs, and we did not observe the anomalous inversion. On the contrary, in the CS stage, the anomalous inversion occurred under calm air, which indicates the contribution of southerly warm airflow is not direct and dominant in the development of anomalous inversion. The anomalous inversion in the CSs is more likely caused by surface radiative cooling under weak winds.

1) **"Lines 167- 168: the statement: "with the Tai-hang Mountains and the Yan Mountains limiting the invasion of northerly cold air and leading northeast movement of southerly winds" is unreasonable for the boundary-layer analysis in heavy haze events in Beijing. I suggest change it with "with the Tai-hang Mountains and the Yan Mountains strengthening the southwest wind belt and leading the convergence of pollutant transport in Beijing"**

Response: Thanks for it. Revised (L175-176, P8)

2) **"Lines 152-153: Please check English grammar."**

Response: Checked. (L163-164, P8)

3) **"Line 185: Please modify " The ground exceeds long-wave radiation"**

Response: Thanks for this. We have changed 'exceeds' to 'emits'. (L194, P9)

4) **"Lines 314-315: please delete one repeated "different stages"**

Response: Deleted. (L326, P14)