Authors' Response to Referee #1

RC1: The current paper is focused on the air pollution by $PM_{2.5}$ at the Beijing-Tianjin-Hebei region in China. The subject merits to be investigated due to the noticeable impact on the affected population. The period investigated is around January 2017, although only three days are selected. Measurements are considered together with modelling analysis. Observations are provided by the National Environmental Monitoring Center, 149 stations, and the Hebei Meteorological service, 210 stations. Moreover, two kind of modelling calculations are used, one of them with the aerosol-radiation interaction, and the second calculation without this interaction. The synoptic pattern is presented at varied pressure surfaces, and vertical cross-sections with the airflow and concentration are also shown. Although the subject and procedure are suitable for a publication, some restrictions of this research indicate that this paper could be accepted in a journal with low impact, but not in Atmospheric Chemistry and Physics.

AC1: We sincerely thank Pérez for taking time to carefully read through the manuscript, constructive comments and suggestions, which greatly improved the substance of our study. Our manuscript is revised according to all your valuable comments, and the changes are highlighted in red in the revised manuscript. To achieve the publication standards of Atmospheric Chemistry and Physics, we made Major Revision to this manuscript (summarized one-by-one as follows):

(1) We revised the description of the importance and necessity for this study in the introduction and added relevant references (Lines 42–43, 53–54, 69–73).

(2) The analysis of the average results for the three pollution periods was added in the revised manuscript (Lines 190–191, 208–219, 311–325) and the Supplement (Fig. S1–S3) besides the three haze days, and extended the first pollution period from January 5–7 to January 1–7 (Lines 167–172).

(3) The analysis for January 25 with higher $PM_{2.5}$ concentrations was introduced to replace the results for January 24 (Lines 224–225, 240–242, 260–264, 284–286, 298–302, 335–338, 355–357).

(4) The information of emission was added (Lines 37–41, 105–106, 116).

(5) Some statistical parameters, Table 1, and related instructions for $PM_{2.5}$ evaluation were added (Lines 117–119, 157–164, 184).

Other minor revisions:

(1) The names of mountain ranges and sea were introduced in Fig. 1a.

(2) The format and spelling errors throughout the full text including references were checked and corrected.

(3) All the figures involving elements of January 24 have been replaced with those of January 25.

(4) The conclusion and the abstract have been revised according to the changes in the text.

Aerosol-radiation interaction (ARI) not only play an important role in the regulation of the global climate system, but may also lead to complex feedbacks on regional or local scales (Ramanathan et al., 2001; Shindell and Faluvegi, 2009). In recent years, researchers achieved many results around ARI in revealing the formation of heavy air pollution in China, mainly including the interactions between ARI, the planetary boundary layer (PBL), and long-range transport (Gao et al., 2015; Ding et al., 2016; Li et al., 2017; Wang et al., 2015, 2018; Huang et al., 2018, 2020), and these works have been published in Atmospheric Chemistry and Physics and other high-impact journals. However, these works rarely focus on the link between ARI and local circulation driven by typical topography. For the Beijing-Tianjin-Hebei (BTH) region, the mountainous topography is an important factor contributing to its persistent severe air pollution (Chen et al., 2009; Liu et al., 2009; Miao et al., 2015; Zhang et al., 2018). Based on the above studies, this paper further discussed the interaction between ARI and local circulation driven by mountainous topography, and found that their superimposed effects may be the most important reason for the extreme haze events in critical polluted region. We believe that this study of ARI on local circulation is an effective complement to the ARI studies on multiple scales and it is as important as the results from global to regional scales mentioned above. This research contributes to a more comprehensive and accurate understanding of the causes of heavy pollution.

RC2: The main inconvenience lies on the extremely low number of situations where the study is made, only three days, 6th, 17th, and 24th. Although the analysis is detailed, the readers should know if these days are representative enough for the pollution days at this site. Moreover, the readers should know if these conditions could be reproduced at different sites.

AC2: In addition to the three pollution days, we added the average condition of all three pollution periods in January 2017 to investigate the general link between local circulation, ARI, and haze pollution. The average result was highly consistent with the findings of the three days (Lines 311–325 in the revised manuscript), which shows that our analysis is representative in this region. Moreover, to make this paper structure more logical, we also added descriptions of the average weather situation for the three pollution periods in the text (Lines 208–219) and the Supplement (Fig. S1-S3). Nevertheless, average result failed to reflect more characteristics about the local circulation under different haze days, such as the widespread westerly winds along the west-east cross-section on January 17 and the widespread southerly winds along the north-south cross-section on January 25, suggesting that the long-term average result may weaken the features on local scale. Therefore, a detailed analysis of individual day in indispensable. It should be noted that according to the definition of heavy pollution (the daily mean PM_{25} concentration larger than 150 $\mu g\ m^{-3}$) issued by the Ministry of Environmental Protection of China, we replaced the analysis on January 24 with the results on January 25 in the full text. But the good news is the strengthening of the local circulation by ARI is more pronounced due to the higher $PM_{2.5}$ concentrations on the 25th than on the 24th. This result again proves that our findings are representative.

We understand that readers should know more conditions at different sites. However, the observed

vertical data is very scarce and there are only three weather sounding stations (Beijing, Tangshan, and Xingtai) in our study area. Moreover, we focused on the central and southern plains of Beijing-Tianjin-Hebei associated with the local circulation and heavy pollution, rather than on specific sites. The evaluation of the vertical potential temperature at the only three sounding sites showed a well reproduction of atmospheric vertical structure by the model, which provided a reasonable prerequisite for the subsequent local circulation analysis.

RC3: Since the pollution levels are affected by factors such as the emissions and the meteorological variables, some information about the patterns of both factors could be useful to focus the pollution problem at the site.

AC3: Yes. Anthropogenic emissions and meteorological conditions are two key factors affecting pollutants. We have added some description of the impact of emissions on the heavy pollution (Lines 37–41) and information on the emission inventory used in the model (Lines 105–106, 116) in the revised manuscript. Numerous previous studies have shown that heavy winter pollution in northern China is often caused by a combination of high emissions and unfavorable meteorological conditions. However, for short period, emissions in a region do not normally change much, and the regional or local meteorological conditions may dominate pollution levels (Wang et al., 2018; Zheng et al., 2015; Zhong et al., 2017). Moreover, pollutant emissions are quite complex and obtaining accurate hour-by-hour pollutant emission data is very difficult. The emission inventory used in our model is the monthly average result and we used it for both sets of experiments.

RC4: Figure 2 presents the concentration evolution. The authors should comment the reason to discard the first days of the month when the concentrations are even higher than those selected for the analysis.

RC4: We have extended the first pollution period from January 5–7 to January 1–7, covering the days with high $PM_{2.5}$ concentrations at the beginning of the month. The reason to discard the first days of the month was that we did not consider it to be a complete continuous rise in pollution. However, this reason was not sufficient since the pollution levels on the first four days (January 1–4) were comparable to those on the last three days (January 5–7) of the period, so we revised it based on the referee's comments. The revisions can be seen in Lines 167–172 in the revised manuscript.

RC5: Some statistics to contrast the measured and calculated concentrations should be introduced. If the correlation is made with the Pearson correlation coefficient, the authors should consider that a good value of this estimator could not indicate a good agreement between measured and calculated values. A better statistic for this calculation could be the index of agreement.

AC5: We thank the referee's suggestion. More statistical parameters including the mean bias (MB), the mean fractional bias (MFB), the mean fractional error (MFE), and the root mean square error (RMSE) were introduced (Lines 117–119) to make the evaluation on $PM_{2.5}$ concentration more comprehensive. As list in Table 1, the statistics showed that, compared to the results without ARI (the EXP case), the

model considering ARI (the CTL case) showed better agreements with the observations, with reduced MB (from -40.2 to -16.4 $\mu g\ m^{-3}$), reduced MFB (from -34.2% to -15.7%), reduced MFE (from 37.6% to 28.5%), reduced RMSE (from 57.0 to 45.3 $\mu g\ m^{-3}$) and increased r (from 0.71 to 0.74). We added Table 1 and the related description (Lines 157–164) in the revised manuscript.

Table 1. Model evaluation for $PM_{2.5}$ in BTH during January 2017.

	r	MB $\mu g\ m^{-3}$	RMSE $\mu g\ m^{-3}$	MFB %	MFE %
CTL	0.74	-16.4	45.3	-15.7	28.5
EXP	0.71	-40.2	57.0	-34.2	37.6

Minor remarks.

RC1: The names of mountain ranges and sea should be introduced in Fig. 1a (indicated in the text, l. 51), not in Fig. 1b.

AC1: We have corrected this error in Fig. 1a of the revised manuscript.

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