Authors' Response to Referee #2

General comments:

The authors of the manuscript entitled: "Superimposed effects of typical local circulations driven by mountainous topography and aerosol-radiation interaction on heavy haze in the Beijing-Tianjin-Hebei central and southern plains in winter", try to investigate the link between aerosol, local vertical circulation, and heavy haze pollution in the Beijing-Tianjin-Hebei plain in winter, by implementing the atmospheric chemistry model GRAPES_Meso5.1/CUACE in January 2017. In my opinion this is an interesting manuscript suitable for Atmospheric Chemistry and Physics journal, however some important issues need to be addressed before it can be further considered for possible publication.

AC: We sincerely thank the referee for taking time to carefully read through the manuscript, recognition of our work, and insightful comments and suggestions, which greatly improved the substance of the study. Our manuscript is revised according to all the comments from the referee. All changes are highlighted in red in the revised manuscript. Our point-by-point responses to all the comments are provided below. We sincerely hope the corrections will meet with approval.

Specific comments:

RC1: Lines 20-21: This phrase is not clear. Please revise.

AC1: We corrected this phrase (Lines 20–22) as well as similar expressions throughout the text in the revised manuscript.

RC2: Line 33: Please define $PM_{2.5}$ based on their diameter.

AC2: We rewrote this sentence based on the diameter of $PM_{2.5}$ in Lines 34–35 in the revised manuscript.

RC3: Line 43: The expression "high concentration aerosols" is not clear. Please revise.

AC3: This sentence was corrected in revised manuscript (Lines 47–48).

RC4: Line 89: Why was this time period selected? This must be explained.

AC4: We appreciate the referee's comment. During the period from December 2016 to February 2017, the Beijing-Tianjin-Hebei (BTH) region suffered from several heavy pollution episodes, of which January 2017 was the most representative month with persistent and heavy pollution levels. Therefore, we selected this month to investigate the link between aerosol, local vertical circulation, and heavy haze pollution. We have added this explanation in Lines 74–75 in the revised manuscript.

RC5: Figure 1: The abbreviation OBS is not defined in the legend. Please revise.

AC5: The description of OBS has been added in the caption in Figure 1 in the revised manuscript.

RC6: Line 127: Please define the type of these correlation coefficients.

AC6: We added the description of the correlation coefficient (r) in Section 2.3 in the revised manuscript.

RC7: Lines 128-129: The difference of the correlation coefficients (0.03) between the two numerical scenarios (CTL and EXP) is really low to support this statement. Please revise.

AC7: Yes. The difference of the r values between CTL and EXP is very small, and this metric alone does not fully indicate that the simulations agree with observations. Therefore, we introduced multiple metrics including the mean bias (MB), the root mean square error (RMSE), the mean fractional bias (MFB), and the mean fractional error (MFE) besides r to evaluate the model performance (Lines 117–119). The statistical results showed that CTL with ARI is closer to the observations compared to EXP, with higher r (from 0.71 to 0.74), smaller MB (from -40.2 to -16.4 $\mu g\ m^{-3}$), and smaller RMSE (from 57.0 to 45.3 $\mu g\ m^{-3}$). Besides, both MFB and MFE showed substantial reductions, from -34.2 $\mu g\ m^{-3}$ and 37.6 $\mu g\ m^{-3}$ to -15.7 $\mu g\ m^{-3}$ and 28.5 $\mu g\ m^{-3}$, respectively. According to model performance goals for $PM_{2.5}$ proposed by Morris (2005), both CTL and EXP achieved an average level (MFB $\leq \pm 60\%$ and MFE $\leq 75\%$), while CTL exceeded a good level (MFB $\leq \pm 30\%$ and MFE $\leq 50\%$) and was very closed to an excellent level (MFB $\leq \pm 15\%$ and MFE $\leq 35\%$). We have revised the original phrases according to the above contents in the revised manuscript (Lines 157–164) and added Table 1 to make the comparison between CTL and EXP more intuitive.

RC8: Lines 131-134: The justification for the selection of the three studied pollution periods (January 5–7, 16–18, and 23–26) is not adequate. Other extreme pollution periods are also indicated in Figure 2. In addition, the selection of January 6, 17, and 24 as the representatives of the three pollution periods is also not adequately justified. This is an important issue because biased results can be implied. Please include more convincing explanations. Moreover, in my opinion the authors should expand the implementation of their method in other time periods besides January 2017 to enhance their manuscript.

AC8: 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. In addition, more convincing explanations were introduced for the selection of the three days. These revisions can be found in Lines 165–178 in the revised manuscript. 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 supported the findings of this study.

To expand the implementation of our method and make the conclusion more representative, we added the average condition of all three pollution periods (January 1–7, 16–18, and 23–26) in January 2017. The average result was highly consistent with the findings of the three days (Lines 311–325), which shows that our analysis is representative in this region. Due to the limitation of space and structure, we did not add other time periods besides January 2017 to this manuscript. However, we still thank the referee's valuable suggestions, and we will continue to explore this issue in the future work, and carry out statistics and comparative analysis of the interaction between aerosols and local circulation in

different seasons and years.

RC9: Figure 4: The quality of these images is very low and has to be improved. In addition, some elements are not defined the legend. More specifically: a) which images correspond at 500 hPa and which at 700 hPa? b) the red square indicates the BTH region?

AC9: We have improved the resolution of all figures including Figure 4. Moreover, the description of Figure 4 has been supplemented in the revised manuscript according to the referee's comments.

RC10: Figure 5: A red square is also needed here to indicate the BTH region. Please add it.

AC10: The red square has been added to Figure 5 in the revised manuscript.

RC11: Lines 231-232: This sentence is incomplete

AC11: This sentence was corrected in the revised manuscript (Lines 311–312).

RC12: Lines 238-242: This section is not clear especially for January 24. Please revise.

AC12: We have modified this section in the revised manuscript (Lines 334–340).

RC13: Line 248: The enhancement of northerly winds in the lower level on January 24 is not clear in Figure 9c. Please revise.

AC13: This section was revised in Line 346 in the revised manuscript as we replaced the original analysis of January 24 with January 25.

RC14: Line 253: A reference to Figure 10 (b, e) would be useful here

AC14: We added this in the revised manuscript (Line 351).

RC15: Figure 9: (g–i) is missing from the legend. Please include it.

AC15: (g–i) was added in the Figure 10 in the revised manuscript (Line 369).

References:

Morris, R. E., McNally, D. E., Tesche, T. W., Tonnesen, G., Boylan, J. W., and Brewer, P.: Preliminary Evaluation of the Community Multiscale Air Quality Model for 2002 over the Southeastern United States, J. Air Waste Manage. Assoc., 55(11), 1694–1708, https://doi.org/10.1080/10473289.2005.10464765, 2005.