

## **Response to the Comments of Referee #1**

### **Lidar vertical observation network and data assimilation reveal key processes driving the 3-D dynamic evolution of PM<sub>2.5</sub> concentrations over the North China Plain**

Yan Xiang, Tianshu Zhang, Chaoqun Ma, Lihui Lv, Jianguo Liu, Wenqing Liu, and Yafang Cheng

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. Below we address the reviewers' comments, with the reviewer comments in black, and our response in blue. We have revised the manuscript accordingly, and mentioned the line number of the tracked revision.

#### **Anonymous Referee #1:**

##### **Summary and general comments:**

This manuscript reports the evolution characteristics of PM<sub>2.5</sub> concentration in different dimensions (surface-layer, vertical-distribution and three-dimensional) under four different phases (an early phase, a transport phase, an accumulation phase, and a removal phase) of heavy pollution process in North China Plain. The authors used data from an observation network consisting of 13 aerosol lidars and more than 1000 ground observation stations, combined with a data assimilation technique, to conduct a comprehensive analysis of an extreme heavy aerosol pollution over the North China Plain from November–December 2017. Meanwhile, the regional transport of PM<sub>2.5</sub> over different transport channels was quantified, including PM<sub>2.5</sub> concentration, transport flux and transport flux intensity. Moreover, the authors also captured the regional transport of air pollutants stretching over 1000 km, proving the necessity and importance of the joint prevention and control of regional air pollution.

These results could significantly improve our understanding on the key processes driving the 3-D dynamic evolution of PM<sub>2.5</sub> concentrations. The scope of this manuscript is well suited to ACP, and the data obtained by the authors are valuable. The data set is meaningful to further verify or constrain the representation of aerosols in air quality model and satellite remote sensing. This paper is very well-written and should be considered for publication after addressing my comments below.

**Thank you very much for your encouraging comments.**

### **List of minor comments:**

1. Page 4, Line 10: The map information shown in Fig. 1a and Fig. 1b is too duplicate with that shown in Fig. 1c and Fig. 1d respectively. It is suggested to delete Fig. 1c and Fig. 1d or put them in the supporting material.

**Thanks for the suggestions; we have moved figures 1c and 1d into the supporting material. Please see line 12 on page 4 in the revised manuscript and Figure S1.**

2. Page 5, Line 5: The time resolution of 3-10 minutes refers to the time resolution of the original data or the smoothed data. If it is original, please describe clearly; if it is smooth, please give a detailed smoothing method in the manuscript.

**Yes, the time resolution here refers to the original data, that is, the interval time of each profile. We have added a clear description to the revised manuscript. See line 21 on page 4.**

3. Page 5, Line 6: The semicolon should be changed to a comma.

**Corrected, please see line 22 on page 4 in the revised manuscript.**

4. Page 5, Line 17: Please provide the WRF Chem version used in the manuscript.

**Thanks. We have provided the version information of WRF-Chem (version 3.8.1) in the revised manuscript. Please see line 9 on page 5 in the revised manuscript.**

5. Page 6, Line 26: A space needs to be added between 1 and km to be consistent with other contents of the manuscript.

**Corrected, please see line 18 on page 6 in the revised manuscript.**

6. Page 9, Line 7: Xintai should be Xingtai.

**Thanks. They were changed, please see line 3 on page 9 in the revised manuscript.**

7. Page 12, Line 5: What is the meaning of white color in j, k and l of Figure 6? Does it mean that the current moment is missing data? Or is it deleted due to low SNR? Please add a clear description to the manuscript.

**Yes, the reason for the white color in Figure 6 is that these lidars were not working normally at the current time, resulting in the missing of data. We have added an explanation to the revised manuscript. Please see line 11 on page 12.**

8. Page 16, Line 4: Why choose 1.5 km to calculate the total amount of PM<sub>5</sub> transportation. Why not 1 km or 2 km, 3 km? Please give reasons. Is it based on the height of the atmospheric boundary layer? Or is it due to the 1.5 km explained in line 9 on page 15?

**Thanks for the suggestion. Most aerosol pollutants were centralized near the surface, while a part of particles can also be transported to the height of 1–3 km from the ground (Figure 6). Therefore, this work focuses on the horizontal transport of PM<sub>2.5</sub> within a height of 3 km (Figure 7 & 8 & 9).**

**In addition, the vertical profiles of PM<sub>2.5</sub> cross-sections on different transport channels reveal that the pollutant transport mainly occurs within 1.5 km (Figure 8), which is also mainly the height of the boundary layer (Figure 7). Therefore, the PM<sub>2.5</sub> transport flux intensity (TFI) was calculated up to a height of 1.5 km**

**We have added the details in the revised version; please see lines 3-6 on page 16.**