Responses to interactive comments

Journal: Atmospheric Chemistry and Physics

Manuscript ID: acp-2020-953

Title: "Changes in source contributions of particulate matter during COVID-19 pandemic in the Yangtze River Delta, China"

Dear Referee #1,

We appreciate your comments to help improve the manuscript. We tried our best to address your comments and detailed responses and related changes are shown below. Our response is in blue and the modifications in the manuscript are in red.

Comments: This paper applied the modified CMAQ model to investigate the source contribution of $PM_{2.5}$ in the nationwide lockdown due to the COVID-19 in the Yangtze River Delta region in China. By setting case 2 with reduced emission as input during the target period, the changes of source sectors of $PM_{2.5}$ were investigated, as well as the contribution of regional transport. The results showed how the contribution of location sources and regional transport changed in response to the local emission reduction and regional reduction, which are helpful to understand how regional emission reduction, quarantine measures, for example, impact the local $PM_{2.5}$ pollution and how to formula reduction policy for a more effective air quality improvement.

Response: Thanks for the recognition of our study. Below is the response to each specific comment.

Comments: One of my confusions is the application of non-reactive tracer to scale the contribution of the specific source of primary $PM_{2.5}$ (PPM). 0.001% was given as the ratio of the emission rate of tracers to the total PPM emission rates. Maybe I missed some key points, but I am wondering that:

1. Does the emission rate of each tracer account for 0.001% of the source emission rate? Or do the emission rates of all the tracers added up together account for 0.001% of the emission rates of all the sources?

Response: The emission rate of each tracer in each grid cell is set as 0.001% of primary $PM_{2.5}$ (PPM) emission rate from the source sector it represents. This makes sure that these tracers are small enough to not influence physical and chemical processes in the CMAQ model (Hu et al., 2015;Guo et al., 2017).

2. Was the scaling factor 10^5 applied for each of the sources? How the authors addressed the discrepancy between multiple sources in terms of the relative emission rate of tracers?

Response:

Yes, the tracers were set as 0.001% of the source it represents, a factor of 10^5 should be used to covert to the actual contribution from that source. Tracers represent different sources and have different values. Each source has its own tracer and is converted back to represent its contribution after model simulation. For instance, if the emission rate of PPM from source 1 is 1 g s^{-1}, the emission rate of the tracer $ATCR_1$ will be set to 1×10^{-5} g s^{-1}. Similarly, if the emission rate of PPM from source 2 is 2 g s^{-1}, the emission rate of the tracer $ATCR_2$ will be set to 2×10^{-5} g s^{-1} (Guo et al., 2017;Hu et al., 2015). To make it clearer, the calculation formula was added into manuscript and shown below.

Changes in manuscript:

Methodology (Lines 72-75 in the revision): "as shown in equation (1):

$$ATCR_i = 10^{-5} * PPM_i \quad (1)$$

where $ATCR_i$ represents emission rate of the tracer from the *i*th emission source or region with PPM emission rate of PPM_i, and 10^{-5} is the scaling factor.".

3. Was 0.001% a rounded assumption? If the real numbers were 0.0005% and 0.001%, both of which can be rounded to 0.001%, the scaling factors may differ by a factor of 2. I am confused so please explain.

Response:

The scaling factor is an exact number, which is 0.001% for all types.

Comments: Another concern is about the importance of revealing the change of relative contributions of regions due to the quarantine measures and its significance for future policymaking. In the discussion about the changes of regional contribution to local $PM_{2.5}$ concentration, the authors stated that the transportations of emissions were likely due to the north wind (or a key factor). If meteorology was the main reason for the change of relative contribution, what is the information the government can use when

establishing the policy and adjusting the control measures? A greater reduction of emission in the regions that will contribute more to the YRD region? Please clarify the significance.

Response:

Thanks for your comments. Wind is the reason for transport of pollutants from one location to another, and north wind causes transport from Shandong and Ha-BTH to north YRD in the study period. However, this does not mean it is the main reason for the changes of relative contribution. Wind transports pollution no matter the emissions are reduced or not, but it transports different amounts of pollutants from one region (the origin) to another (the target) when the emissions from the origin region change. The different amounts of pollutants in the target region have changed relative importance. Whether it is more or less important depends on the changes of emissions from other regions.

Although this study shows the changes are important, more studies are needed to quantify the contributions from one region to another for longer period to be directly used for policy makers. This study highlights the importance of joint efforts from different regions.

We added more explanation in the manuscript to avoid misunderstanding.

Changes in manuscript:

Results and discussion (Lines 206-207 in the revision): "Consequently, the government should strengthen regional joint preventions in addition to local emission reductions.".

Comments: Below are several minor comments about the spelling, grammar, and others. Edits have been highlighted.

1. Line 35. "***In*** the Yangtze River Delta (YRD), one of the largest economic centers, ….". Missing *in*.

Response:

The sentence was modified as suggested.

Changes in manuscript:

Introduction (Line 35 in the revision): "In the Yangtze River Delta (YRD), one of the largest economic centers, …".

2. Line 40. Typo. "$PM_{2.5}$ is a ***complex*** mixture of …, and its source apportionment ***is*** based on quantifying the contribution of different sources to all the components.

Response:

Mistakes were revised and shown below.

Changes in manuscript:

Introduction (Line 40 in the revision): "$PM_{2.5}$ is a complex mixture of primary PM components (PPM) and secondary formed components, …".

3. Line 45. "… that local emissions ***accounted*** for the highest fraction of PPM…"

Response:

Changed as suggested.

Changes in manuscript:

Introduction (Line 47 in the revision): "… local emissions accounted for the highest fraction of PPM …".

4. Line 47. "…, and ***the*** remaining contributions ***were*** from industrial and residential sector…"

Response:

We revised the sentence.

Changes in manuscript:

Introduction (Line 49 in the revision): "… and the remaining contributions were from industrial and residential sectors in Shanghai.".

5. Line 51. "…to support the ***formulation*** of further reduction policy."

Response:

Revised as below.

Changes in manuscript:

Introduction (Line 53 in the revision): "… is needed to support the formulation of further reduction policy.".

6. Line 53. "…anthropogenic activities ***since*** January 2020."

Response:

Revised accordingly.

Changes in manuscript:

Introduction (Line 55 in the revision): "… to limit anthropogenic activities since January 2020.".

7. Line 58. ", and ***the conclusions reported in the mentioned literature*** cannot be used to…"

Response:

The sentence was revised.

Changes in manuscript:

Introduction (Line 60 in the revision): "… and the conclusions reported in the mentioned literature cannot be used to design control strategies.".

8. Line 68. "was modified ***with*** additional non-reactive tracers…"

Response:

Revised as below.

Changes in manuscript:

Methodology (Line 70 in the revision): "… was modified with additional non-reactive tracers …".

9. Line 72. "Details ***were*** discussed in Hu et al. (2015)"

Response:

We revised the sentence.

Changes in manuscript:

Methodology (Line 77 in the revision): "Details were discussed in Hu et al. (2015).".

10. Line 103. "The model performance of meteorological parameters ***including*** temperature at 2 m…"

Response:

Revised accordingly.

Changes in manuscript:

Results and discussion (Lines 109-110 in the revision): "The model performance of meteorological parameters including temperature at 2 m above …".

11. Line 105. Commas should be used instead of semicolons in this sentence.

Response:

Changed as suggested.

Changes in manuscript:

Results and discussion (Lines 111-112 in the revision): "The statistical values of mean prediction (PRE), mean observation (OBS), mean bias (MB), gross error (GE), and root mean square error (RMSE) …".

12. Line 107. "***T2 predicted by the WRF model were slightly higher*** than the observations…"

Response:

Sentence was modified and shown below.

Changes in manuscript:

Results and discussion (Line 113 in the revision): "T2 predicted by the WRF model were slightly higher than observations in the two periods.".

13. Line 144. "More ***significant*** decreases were found…"

Response:

Revised as suggested.

Changes in manuscript:

Results and discussion (Lines 151-152 in the revision): "More significant decreases were found in …".

14. Line 148. "…mainly due to ***a greater reduction of*** SO2 from industries…"

Response:

Revised accordingly.

Changes in manuscript:

Results and discussion (Lines 154-155 in the revision): "… mainly due to a greater reduction of SO_2 from …".

15. Line 155-157. Sentences stated that the reduction of secondary components was greater than that of primary components, which indicated the important role of atmospheric reactions and meteorological

conditions. I don't see any meteorological impact was mentioned in this paragraph so please explain why the meteorological condition was important in the discussion here.

Response:

We are grateful for your comment. We are sorry for being not clear here. In this sentence, we intended to express that the reduction difference between secondary components and primary components was influenced by atmospheric reactions. Since, these processes were based on same meteorological conditions, there is no need to consider the impact of meteorological conditions here. We deleted the words meteorological conditions in the sentence.

Changes in manuscript:

Results and discussion (Lines 162-164 in the revision): "Secondary components (SIA + SOA) dropped more significantly than primary components, especially for nitrate (35-45%) due to the severe decrease of NO_x from transportation. This also indicated that atmospheric reactions were important during the pandemic period.".

16. Line 162-163. It might better to summary the main conclusion of this section in the last few sentences and state that the analysis provides a solid basis for the later source contribution analysis. The current statement sounds like the $PM_{2.5}$ component analysis is useless for the establishment of regional emission control policies.

Response:

Thanks for your suggestion. The conclusion was added in the last of the section and shown below.

Changes in manuscript:

Results and discussion (Lines 169-171 in the revision): "With the impact of the lockdown, the $PM_{2.5}$ concentrations decreased significantly in the YRD region, mainly due to the reduction in the concentration of PPM and SIA. The results provided a solid basis for conducting the source appointment of the $PM_{2.5}$ components. And the next section showed the source appointment and regional transport of $PM_{2.5}$.".

17. Line 193. "…were the same in both cases ***but*** Case 2 had lower…"

Response:

Thanks for the comment. Revised as below.

Changes in manuscript:

Results and discussion (Line 201 in the revision): "… were the same in both cases but Case 2 had lower …".

18. Line 199-200. My understanding about the regional transport of $PM_{2.5}$ is mainly due to meteorology as stated in Line 196 and Line 224. So please explain why the limitation of commercial activities and traffics suppressed the dispersion of $PM_{2.5}$.

Response:

We appreciate the comment. As the reviewer stated, the transport of $PM_{2.5}$ was directly influenced by meteorology, but the transported concentration was also indirectly influenced by the local emission rate. Compare to Case 1 (business as usual), the transported concentration of $PM_{2.5}$ in Case 2 (lockdown) was lower under the same meteorology as shown in Figure 6 in the manuscript. This was because that the local emission rate of $PM_{2.5}$ in Case 2 was lower than that in Case 1. The lockdown measures limited the activities of commercial and traffic, which resulted in a significant decrease in $PM_{2.5}$. It also indirectly suppressed the dispersion of $PM_{2.5}$. To avoid unnecessary confusion, we added the word "indirectly" in this sentence to express more clearly and as shown below.

Changes in manuscript:

Results and discussion (Lines 208-209 in the revision): "The limitation of commercial activities and traffic caused by the pandemic lockdown significantly decreased the emission of $PM_{2.5}$ and indirectly suppressed its dispersion.".

Reference

Guo, H., Kota, S. H., Sahu, S. K., Hu, J., Ying, Q., Gao, A., and Zhang, H.: Source apportionment of PM2.5 in North India using source-oriented air quality models, Environ Pollut, 231, 426-436, 10.1016/j.envpol.2017.08.016, 2017.

Hu, J., Wu, L., Zheng, B., Zhang, Q., He, K., Chang, Q., Li, X., Yang, F., Ying, Q., and Zhang, H.: Source contributions and regional transport of primary particulate matter in China, Environ Pollut, 207, 31-42, 10.1016/j.envpol.2015.08.037, 2015.