

March 9, 2016

Dear Editor,

We have received the comments from the two reviewers of the manuscript. Below are our responses and the revisions that we have made in the manuscript.

Thank you for your efforts on this manuscript. We look forward to hearing from you.

Best Regards,

Guohui Li

## Reply to Anonymous Referee #2

We thank the reviewer for the careful reading of our manuscript and helpful comments. We have revised the manuscript following the suggestion, as described below.

### Major Comments:

1) This study provides a WRF-CHEM analysis of ozone and PM<sub>2.5</sub> pollution in Xi'an, China over a short time period of 3-days. If this type of urban study focusing on just 3 days were conducted for an urban area in the US or Europe it would not have a level of significance that would warrant publication in ACP. But because this study focuses on China, the fastest growing emissions region on the planet with enormous implications for tropospheric chemistry and trace gas budgets, the study is appropriate for ACP. Therefore my main recommendation to the authors is to devote less space to describing the details of the model/measurement comparison, and spend more time discussing or emphasizing the results that have implications for future atmospheric chemistry research: comparison of Xi'an ozone and PM<sub>2.5</sub> to other region in China, the difficulties of controlling PM<sub>2.5</sub> which then boosts ozone production, describing the full seasonal cycle of ozone at Xi'an. Specifically, the abstract and conclusions are quite long and can be shortened by reducing the model/measurement comparison which is adequately covered in the main text.

We have compared the summertime O<sub>3</sub> and PM<sub>2.5</sub> concentrations in Xi'an to those in the main cities of BTH, YRD, and PRD, and included a paragraph on Page 8: *“Table 2 shows the comparison of summertime O<sub>3</sub> and PM<sub>2.5</sub> concentrations (averaged in the afternoon) in Xi'an to the main cities of BTH, YRD, and PRD in China during 2013. The O<sub>3</sub> and PM<sub>2.5</sub> concentrations in cities of BTH are much higher than those in Xi'an, showing the heavy air pollution in BTH. Due to the impact of frequent precipitation in South China, the PM<sub>2.5</sub> concentrations in the cities of YRD and PRD are lower than those in Xi'an, but the O<sub>3</sub> concentrations in Shanghai and Hangzhou are still higher than those in Xi'an. Generally, the air quality in Xi'an is better than that in the cities of BTH, but worse than that in Guangzhou of PRD.”*

Table 2 Summertime O<sub>3</sub> and PM<sub>2.5</sub> concentrations (averaged in the afternoon) in the main cities of Guanzhong basin, BTH, YRD, and PRD in China during 2013.

Region	City	O <sub>3</sub> (μg m <sup>-3</sup> )	PM <sub>2.5</sub> (μg m <sup>-3</sup> )
Guanzhong	Xi'an	104.6	48.5
	Beijing	133.9	74.7
	Tianjin	116.9	78.1
BTH	Shijiazhuang	140.4	86.6
	Shanghai	122.9	47.1
YRD	Hangzhou	110.5	35.0
	Nanjing	96.6	41.2
PRD	Guangzhou	94.9	29.4

We have included a paragraph to discuss the difficulties of controlling PM<sub>2.5</sub> which then boosts ozone production on Page 22: *“Since the release of “Atmospheric Pollution Prevention and Control Action Plan” in 2013 ([http://www.gov.cn/zwggk/2013-09/12/content\\_2486773.htm](http://www.gov.cn/zwggk/2013-09/12/content_2486773.htm)), the stringent PM<sub>2.5</sub> control strategy has been implemented in China. The summertime PM<sub>2.5</sub> concentration in the afternoon in Xi’an has decreased from 48.5 μg m<sup>-3</sup> in 2013 to 38.8 μg m<sup>-3</sup> in 2014; however, the O<sub>3</sub> concentration has increased from 104.6 μg m<sup>-3</sup> in 2013 to 114.7 μg m<sup>-3</sup> in 2014. The same trend is also found in the cities of BTH: the PM<sub>2.5</sub> concentration has decreased from 71.5 μg m<sup>-3</sup> in 2013 to 57.4 μg m<sup>-3</sup> in 2014, while the O<sub>3</sub> concentration has increased from 125.8 μg m<sup>-3</sup> in 2013 to 139.1 μg m<sup>-3</sup> in 2014. Therefore, the decrease of the PM<sub>2.5</sub> level might enhance O<sub>3</sub> production, which is consistent with the results in the present study.”*

We have added a paragraph to describe the full seasonal cycle of ozone at Xi’an on Pages 7-8: *“Figure 4 further presents the monthly minimum, 5<sup>th</sup> percentile, median, 95<sup>th</sup> percentile, and maximum observations of near-surface O<sub>3</sub> concentrations in the afternoon averaged over 13 sites in Xi’an during the period from April 2013 to March 2014. The seasonal cycle of O<sub>3</sub> levels in Xi’an shows high summertime O<sub>3</sub> concentrations, which is consistent with that in North China Plain (Cooper et al., 2014). In the study of Cooper et al. (2014), the midday O<sub>3</sub> mixing ratio in North China Plain peaks in June and then decreases in July and August due to the southerly monsoon flow. However, during the summer of 2013, the median O<sub>3</sub> concentration in the afternoon in Xi’an increases progressively from about 90 μg m<sup>-3</sup> in June to 120 μg m<sup>-3</sup> in August, with the maximum increasing from about 170 μg m<sup>-3</sup> in June to 210 μg m<sup>-3</sup> in August, which is possibly caused by the inland location of Xi’an with less monsoon precipitation during summertime.”*

We have shortened the abstract on Page 1 and conclusions on Page 20 as suggested.

2) Greater context of the Xi’an region and ozone observations needs to be given in relation to China, the US and Europe. Please expand Figure 1 by showing a map of all China and the location of Xi’an so the reader can understand that this city is far from the urban areas of Beijing and Shanghai. It would also be very helpful if you can show the seasonal cycle of ozone in Xi’an by plotting the monthly median, 5th percentile and 95th percentile for daytime observations. Then the reader can understand how the ozone observations in this study fall in relation to typical conditions. For example, in the North China Plain ozone peaks in June and then decreases in July and August due to the southerly monsoon flow. Does the same pattern occur at Xi’an? Are the high ozone values in August in Xi’an less than the values in June? Also the reader will then be able to compare Xi’an to the regionally representative sites in northern China, the USA and Europe as shown in the recent review paper:

Cooper et al. (2014), Global distribution and trends of tropospheric ozone: An observation-based review, *Elementa: Science of the Anthropocene*, 2, 000029, doi: 10.12952/journal.elementa.000029

See their Figure 10 <http://www.elementascience.org/articles/29>

We have updated Figure 1 on Page 35 to clearly show the relative situations of Xi’an, Beijing, and Shanghai in China. We have included a paragraph to describe the seasonal cycle of O<sub>3</sub> in

Xi'an on Pages 7-8: "Figure 4 further presents the monthly minimum, 5<sup>th</sup> percentile, median, 95<sup>th</sup> percentile, and maximum observations of near-surface O<sub>3</sub> concentrations in the afternoon averaged over 13 sites in Xi'an during the period from April 2013 to March 2014. The seasonal cycle of O<sub>3</sub> levels in Xi'an shows high summertime O<sub>3</sub> concentrations, which is consistent with that in North China Plain (Cooper et al., 2014). In the study of Cooper et al. (2014), the midday O<sub>3</sub> mixing ratio in North China Plain peaks in June and then decreases in July and August due to the southerly monsoon flow. However, during the summer of 2013, the median O<sub>3</sub> concentration in the afternoon in Xi'an increases progressively from about 90 μg m<sup>-3</sup> in June to 120 μg m<sup>-3</sup> in August, with the maximum increasing from about 170 μg m<sup>-3</sup> in June to 210 μg m<sup>-3</sup> in August, which is possibly caused by the inland location of Xi'an with less monsoon precipitation during summertime."

3) No description is provided of the methods used to make the observations of ozone, NO<sub>2</sub> and PM<sub>2.5</sub>. Instruments? Institutions? Were the data checked for quality and reliability?

We have added a paragraph to describe the methods used to make the observations of O<sub>3</sub>, NO<sub>2</sub>, and PM<sub>2.5</sub> on Page 6: "The real-time hourly measurements of O<sub>3</sub>, NO<sub>2</sub>, and PM<sub>2.5</sub> used in this study are released by China MEP and can be accessed from the website <http://106.37.208.233:20035/>. The historical profile of the observed ambient pollutants can be accessed at <http://www.aqistudy.cn/>. The O<sub>3</sub>, NO<sub>2</sub>, and PM<sub>2.5</sub> concentrations are measured by using Model 49i Ozone Analyzer, Model 42i (NO-NO<sub>2</sub>-NO<sub>x</sub>) Analyzer, and Model 5030 SHARP Monitor from Thermo Fisher Scientific, USA, respectively. All the instruments are maintained and routinely calibrated by China MEP to assure data quality."

4) According to the ACP data policy, the underlying chemical observations used in the analysis should be publicly available, as described here:

Statement on the availability of underlying data: [http://www.atmospheric-chemistry-and-physics.net/about/data\\_policy.html#data\\_availability](http://www.atmospheric-chemistry-and-physics.net/about/data_policy.html#data_availability) "Authors are required to provide a statement on how their underlying research data can be accessed. This must be placed as the section "Data availability" at the end of the manuscript before the acknowledgements."

This paper contains no data availability statement and the authors need to provide one. I am bringing this up because there is great interest within the atmospheric chemistry community regarding the quantity of ozone produced in East Asia as well as the ozone produced by East Asian emissions once the pollutants have been exported from the continent. With ozone pollution decreasing in North America and Europe, East Asia is the main driving force behind any increase in tropospheric ozone. By having access to the ozone and ozone precursor observations described in this paper the scientific community can further its understanding of the global tropospheric ozone budget. It would be a great service to the community if the authors of this paper can make available the ozone and precursor data for at least a full year, rather than just the 3 days described in the paper. The authors can provide a further valuable service to the research community by uploading the hourly ozone

observations to the database of IGAC's Tropospheric Ozone Assessment Report (TOAR): <http://www.igacproject.org/TOAR>. One of the goals of TOAR is to calculate ozone metrics at thousands of surface sites around the world relevant for research on ozone's impact on human health, vegetation and climate change. With so little data publicly available from East Asia, the data in this paper would be of great benefit to TOAR.

We have included "Data availability" on Page 23: "*Data availability: The real-time O<sub>3</sub>, NO<sub>2</sub> and PM<sub>2.5</sub> are accessible for the public on the website <http://106.37.208.233:20035/>. One can also access the historic profile of observed ambient pollutants through visiting <http://www.aqistudy.cn/>.*"

5) The standard of English in the manuscript needs to be greatly improved. The paper has too many grammatical and word-choice errors for me to correct and I recommend that the authors either find a colleague with excellent English skills to edit the grammar line-by-line, or employ the assistance of an ACP journal copy-editor.

We have revised the manuscript carefully and corrected the errors as suggested. In addition, our co-author Dr. Luisa T. Molina, has edited the grammar carefully.

#### **Minor Comments:**

1) Abstract, page 30564 line 27 I'm not sure what you mean by "manifest changes of the emission inventory". Manifest means obvious, is that what you mean to say? Also, is it the inventory of the emissions that has changed, or the actual emissions that have changed? The inventory is the documentation of the emissions, and from what I can infer from your paper, the inventory is out of date because the actual emissions have changed faster than the inventory can be updated. I think what you mean to say is Further studies need to be performed for O<sub>3</sub> control strategies considering the rapid changes in emissions that are not reflected in the available emission inventories, and uncertainties of meteorological field simulations.

We agree with the reviewer's comments that the inventory is out of date because the actual emissions have changed faster than the inventory can be updated. We have updated sentence on Page 1 as suggested: "*Further investigation on O<sub>3</sub> control strategies will need to be performed, taken into consideration the rapid changes in anthropogenic emissions that are not reflected in the current emission inventories, and the uncertainties in the meteorological field simulations.*"

2) Page 30582, lines 9-11 I don't understand what this sentence is trying to convey due to poor sentence structure. I think the word "whether" is used incorrectly. "The industry emissions contribute the most to the O<sub>3</sub> concentrations in Xi'an and surrounding areas, but whether individual anthropogenic emissions or biogenic emissions do not play a dominant

role in the O<sub>3</sub> formation. ”

We have corrected the sentence on Page 21: *“The industrial emissions contribute the most to the O<sub>3</sub> concentrations in Xi’an and surrounding areas, but neither individual anthropogenic emission nor biogenic emissions play a dominant role in the O<sub>3</sub> formation.”*

3) Page 30583 lines 11-13 Please provide a reference for the claim that O<sub>3</sub> is now the major summertime pollutant in the Beijing region.

We have rewritten the sentence and included a paragraph on Page 22: *“The summertime PM<sub>2.5</sub> concentration in the afternoon in Xi’an has decreased from 48.5 μg m<sup>-3</sup> in 2013 to 38.8 μg m<sup>-3</sup> in 2014; however, the O<sub>3</sub> concentration has increased from 104.6 μg m<sup>-3</sup> in 2013 to 114.7 μg m<sup>-3</sup> in 2014. The same trend is also found in the cities of BTH: the PM<sub>2.5</sub> concentration has decreased from 71.5 μg m<sup>-3</sup> in 2013 to 57.4 μg m<sup>-3</sup> in 2014, while the O<sub>3</sub> concentration has increased from 125.8 μg m<sup>-3</sup> in 2013 to 139.1 μg m<sup>-3</sup> in 2014.”*

4) Table 2: What are the sources of the ozone and PM<sub>2.5</sub> data from all of these cities?

We have added a paragraph to introduce the sources of the O<sub>3</sub> and PM<sub>2.5</sub> data on Page 6: *“The real-time hourly measurements of O<sub>3</sub>, NO<sub>2</sub>, and PM<sub>2.5</sub> used in this study are released by China MEP and can be accessed from the website <http://106.37.208.233:20035/>. The historical profile of the observed ambient pollutants can be accessed at <http://www.aqistudy.cn/>.”*

5) Figure 6 and 7 and 10: The squares indicating observed values are too small and need to be larger.

The squares have been updated as suggested.

### Reply to Anonymous Referee #3

We thank the reviewer for the careful reading of the manuscript and helpful comments. We have revised the manuscript following the suggestion, as described below.

#### General comments:

Air pollution has been a serious problem in China in recent decades. While most of the previous studies have focused on the three major polluted regions with dense population – the Beijing-Tianjin-Hebei region, the Yangtze Delta region, and the Pearl River Delta region (as cited in the manuscript), there are many other cities which have also been experiencing heavy air pollution but with limited studies so far. Being the largest city in northwestern China, Xi'an is such an example. This study employed the WRF-CHEM model to investigate the ozone formation in Xi'an and surrounding areas during a heavy air pollution episode in August 2013. Simulated meteorological fields and near-surface ozone and PM<sub>2.5</sub> concentrations showed reasonable agreement with measurements. Sensitivity studies were performed to evaluate the impact of aerosols and changes in anthropogenic and natural emissions on the surface ozone concentrations. Based on the simulation results, the authors concluded that ozone formation in Xi'an and surrounding areas varied from NO<sub>x</sub> to VOC-sensitive regimes, constituting a dilemma for ozone control strategies. Although the conclusions are unsurprising, this study is comprehensive and presents some new data/results that are beneficial for future air quality studies in China. Therefore, I think the topic covered in this study is appropriate for ACP. However, the English needs to be improved a little bit before publication and more efforts are needed to highlight the significance and application of the results.

#### Specific comments:

1. This study focused on a three-day simulation episode in August 2013, which is too short to be representative of the prevalent meteorological conditions. It would be helpful if the authors could show time series of observational temperature, relative humidity, and other variables for a longer period (for example, June, July, and August) to see whether the meteorological conditions of the simulation period is adequately representative over the study area.

We have added a paragraph to show time series of the observational temperature, relative humidity, wind speed and direction at Xianyang meteorological station during the summertime of 2013 on Page 7: “*Figures 3a-d show the temporal variations of the temperature, relative humidity, wind speed and direction at Xianyang meteorological station (Figure 1c) during the summer of 2013. In general, the Guanzhong basin is hot and humid in the summer, with an average temperature of 26.7°C and relative humidity of 67.2% recorded at the Xianyang station. The winds are not strong in the basin; the average wind speed is around 3 m s<sup>-1</sup> at the Xianyang station. During the simulation period, the observed average temperature, relative humidity, and wind speed at Xianyang station are 27.9°C, 63.4%, and 3.4 m s<sup>-1</sup>, respectively, representing typical summertime meteorological conditions.*”

2. It is also recommended to show longer period of observed ozone and PM<sub>2.5</sub> concentrations in Xi'an and surrounding areas, not only to justify the choice of the short simulation period, but also provide useful realistic observations for future studies.

We have added a paragraph to show longer period of observed O<sub>3</sub> and PM<sub>2.5</sub> concentrations in Xi'an and surrounding areas on Pages 7-8: *“The profiles of summertime hourly O<sub>3</sub> and PM<sub>2.5</sub> concentrations averaged over 13 sites in Xi'an are also shown in Figures 3e and 3f, respectively, to provide an overview of the air quality in the summer of 2013. The observed average PM<sub>2.5</sub> and peak O<sub>3</sub> concentrations frequently exceed 75 and 160 μg m<sup>-3</sup>, respectively, showing bad air quality in Xi'an. The simulation period corresponds to a heavy pollution episode with fairly high O<sub>3</sub> and PM<sub>2.5</sub> concentrations, which often occurs during summertime. Figure 4 further presents the monthly minimum, 5<sup>th</sup> percentile, median, 95<sup>th</sup> percentile, and maximum observations of near-surface O<sub>3</sub> concentrations in the afternoon averaged over 13 sites in Xi'an during the period from April 2013 to March 2014. The seasonal cycle of O<sub>3</sub> levels in Xi'an shows high summertime O<sub>3</sub> concentrations, which is consistent with that in North China Plain (Cooper et al., 2014). In the study of Cooper et al. (2014), the midday O<sub>3</sub> mixing ratio in North China Plain peaks in June and then decreases in July and August due to the southerly monsoon flow. However, during the summer of 2013, the median O<sub>3</sub> concentration in the afternoon in Xi'an increases progressively from about 90 μg m<sup>-3</sup> in June to 120 μg m<sup>-3</sup> in August, with the maximum increasing from about 170 μg m<sup>-3</sup> in June to 210 μg m<sup>-3</sup> in August, which is possibly caused by the inland location of Xi'an with less monsoon precipitation during summertime.”*

3. In Section 3.1.1, the authors tried to explain the possible causes for the biases of simulated wind speeds and wind directions. It would be more convincing if any evidence could be found from previous studies with similar comparisons.

We have included two previous studies on the biases of simulated wind speeds and directions in the WRF model on Page 9: *“(Chen et al., 2011; Lee et al., 2011)”*.

4. It would be helpful if the authors could briefly introduce the air quality standards in China as many readers might not be familiar with them.

We have added a paragraph and a table to provide a brief introduction of the air quality standard in China on Page 7: *“The Chinese air quality standard released in 2012 is categorized into six levels based on the observed hourly and daily pollutants concentrations. During summertime, O<sub>3</sub> and PM<sub>2.5</sub> are the major atmospheric pollutants. A brief summary of the air quality standard based on the hourly O<sub>3</sub> and PM<sub>2.5</sub> concentrations is presented in Table 1.”*



Table 1 Air quality standards, individual air quality indices (IAQI) and their corresponding hourly O<sub>3</sub> and PM<sub>2.5</sub> concentration limits

Air quality standards	IAQI	Hourly O <sub>3</sub> concentration ( $\mu\text{g m}^{-3}$ )	Hourly PM <sub>2.5</sub> concentration ( $\mu\text{g m}^{-3}$ )
Excellent	50	160	35
Good	100	200	75
Lightly polluted	150	300	115
Moderately polluted	200	400	150
Heavily polluted	300	800	250
Severely polluted	300 <sup>+</sup>	800 <sup>+</sup>	250 <sup>+</sup>

5. It would be helpful to show a map of biogenic emissions (similar to Figure 2b) so that the readers can have a sense of the relative magnitudes of biogenic VOC emissions versus anthropogenic emissions.

We have added the map of biogenic emission in Figure 2 on Page 36 along with anthropogenic emissions.

6. The paper would be more influential if the authors could stress more on the PM<sub>2.5</sub> and ozone concentrations in north China (Page 30582, line 16 to Page 30583 line 13). For example, the authors could discuss more about the similarities and differences of the ozone formation regimes in Xi'an versus other mega-cities in north China. Does the dilemma of O<sub>3</sub> control strategy also exist in other cities?

We have added a paragraph to discuss the similarities and differences of the ozone formation regimes in Xi'an versus other mega-cities in north China on Page 21: “*Studies in North China show that the BTH area is under a VOC-sensitive regime (Wang et al., 2006; Tang et al., 2012). Xue et al. (2014) also reports that O<sub>3</sub> production is VOC-limited in both Shanghai and Guangzhou, but NO<sub>x</sub>-limited in Lanzhou.*”

We have compared the summertime O<sub>3</sub> and PM<sub>2.5</sub> concentrations in Xi'an to those in the main cities of BTH, YRD, and PRD, and included a paragraph on Page 8: “*Table 2 shows the comparison of summertime O<sub>3</sub> and PM<sub>2.5</sub> concentrations (averaged in the afternoon) in Xi'an to the main cities of BTH, YRD, and PRD in China during 2013. The O<sub>3</sub> and PM<sub>2.5</sub> concentrations in cities of BTH are much higher than those in Xi'an, showing the heavy air pollution in BTH. Due to the impact of frequent precipitation in South China, the PM<sub>2.5</sub> concentrations in the cities of YRD and PRD are lower than those in Xi'an, but the O<sub>3</sub> concentrations in Shanghai and Hangzhou are still higher than those in Xi'an. Generally, the air quality in Xi'an is better than that in the cities of BTH, but worse than that in Guangzhou of PRD.*”

Table 2 Summertime O<sub>3</sub> and PM<sub>2.5</sub> concentrations (averaged in the afternoon) in the main cities of Guanzhong basin, BTH, YRD, and PRD in China during 2013.

Region	City	O <sub>3</sub> (μg m <sup>-3</sup> )	PM <sub>2.5</sub> (μg m <sup>-3</sup> )
Guanzhong	Xi'an	104.6	48.5
BTH	Beijing	133.9	74.7
	Tianjin	116.9	78.1
	Shijiazhuang	140.4	86.6
YRD	Shanghai	122.9	47.1
	Hangzhou	110.5	35.0
	Nanjing	96.6	41.2
PRD	Guangzhou	94.9	29.4

We have also included a paragraph to discuss the possible dilemma of O<sub>3</sub> control strategy on Page 22: “*Since the release of “Atmospheric Pollution Prevention and Control Action Plan” in 2013 ([http://www.gov.cn/zwqk/2013-09/12/content\\_2486773.htm](http://www.gov.cn/zwqk/2013-09/12/content_2486773.htm)), the stringent PM<sub>2.5</sub> control strategy has been implemented in China. The summertime PM<sub>2.5</sub> concentration in the afternoon in Xi'an has decreased from 48.5 μg m<sup>-3</sup> in 2013 to 38.8 μg m<sup>-3</sup> in 2014; however, the O<sub>3</sub> concentration has increased from 104.6 μg m<sup>-3</sup> in 2013 to 114.7 μg m<sup>-3</sup> in 2014. The same trend is also found in the cities of BTH: the PM<sub>2.5</sub> concentration has decreased from 71.5 μg m<sup>-3</sup> in 2013 to 57.4 μg m<sup>-3</sup> in 2014, while the O<sub>3</sub> concentration has increased from 125.8 μg m<sup>-3</sup> in 2013 to 139.1 μg m<sup>-3</sup> in 2014. Therefore, the decrease of the PM<sub>2.5</sub> level might enhance O<sub>3</sub> production, which is consistent with the results in the present study.*”

#### Technical corrections:

1. Page 30564, line 18 Please spell out VOC.

We have spelled out the abbreviation VOC on Page 1: “*VOC (Volatile Organic Compounds)-sensitive*”.

2. Page 30570 line 12 and Page 30581 line 1 The RMSE of surface temperature is 1.0 °C while in Table 1 it is 1.1 °C.

We have updated the RMSE of surface temperature on Page 9 according to the table (Table 3 now): “*1.1 °C*”.

3. Page 30572 line 6 “the plume formed in the urban region of Xi'an is pushed to the north of Xi'an and surrounding areas in the afternoon...”, which seems to be inconsistent with Figure 6f. As shown by Figure 6f, the convergence zone is located in the south of Xi'an and surrounding areas.

We have corrected the sentence on Pages 10-11: *“On August 24, the plume formed in the urban region of Xi’an was pushed to the south of Xi’an and surrounding areas in the afternoon and the simulated O<sub>3</sub> concentrations were less than 200 μg m<sup>-3</sup> in the urban area of Xi’an, generally consistent with the observations.”*

4. Page 30583, line 20 Please specify the base year.

We have specified the base year (2010) on Page 22: *“since the base year (2010)”*.

5. There are some grammatical errors throughout the manuscript and I suggest the authors go through the manuscript carefully. Here are some examples. 1). Page 30566, line 18 “at the nine districts” -> “in the nine districts”. 2). Page 30570, line 1 “results in” -> “results from” 3). Page 30574, line 10 “closed” -> “close” 4). Page 30576, line 14-16 The sentence “which is determined ... in the presence of sunlight” sounds a little weird. 5). Page 30582, line 10 “whether” is not used correctly. Line 17 “having experiencing” -> “experiencing”. 6). Page 30583, line 1 Delete “within”?

We have corrected the grammatical errors in Comments (1), (2), (3), (5), and (6) on Pages 3, 8, 13, 21, and 22, respectively. The sentence in Comment (4) is revised on Page 15: *“O<sub>3</sub> formation in the atmosphere is a complicated photochemical process, which is determined by its precursors from various sources and transformation in the presence of sunlight.”* And the sentence in Comment (5) is revised on Page 21: *“...but neither individual anthropogenic emission nor biogenic emissions play a dominant role in the O<sub>3</sub> formation ...”*

6. There are some places in the manuscript that need appropriate references. For example, page 30574, line 11 after “. . .under humid conditions”. Page 30583, line 10 “With the implementation of stringent air quality standards for PM<sub>2.5</sub> in China since 2014 (need ref.), O<sub>3</sub> has been frequently reported to be the major pollutant during summertime in the Beijing-Tianjin-Hebei area with the decrease of the PM<sub>2.5</sub> level (need ref.), which is consistent with the results in the present study.”

We have added a reference after “. . .under humid conditions” on Page 13: *“(Wang et al., 2014)”*.

We have updated the sentences and included measurements from China MEP on Page 22: *“Since the release of “Atmospheric Pollution Prevention and Control Action Plan” in 2013 ([http://www.gov.cn/zwgk/2013-09/12/content\\_2486773.htm](http://www.gov.cn/zwgk/2013-09/12/content_2486773.htm)), the stringent PM<sub>2.5</sub> control strategy has been implemented in China. The summertime PM<sub>2.5</sub> concentration in the afternoon in Xi’an has decreased from 48.5 μg m<sup>-3</sup> in 2013 to 38.8 μg m<sup>-3</sup> in 2014; however, the O<sub>3</sub> concentration has increased from 104.6 μg m<sup>-3</sup> in 2013 to 114.7 μg m<sup>-3</sup> in 2014. The same trend is also found in the cities of BTH: the PM<sub>2.5</sub> concentration has decreased from*

71.5  $\mu\text{g m}^{-3}$  in 2013 to 57.4  $\mu\text{g m}^{-3}$  in 2014, while the  $\text{O}_3$  concentration has increased from 125.8  $\mu\text{g m}^{-3}$  in 2013 to 139.1  $\mu\text{g m}^{-3}$  in 2014. Therefore, the decrease of the  $\text{PM}_{2.5}$  level might enhance  $\text{O}_3$  production, which is consistent with the results in the present study.”

## Tables and Figures:

1. Table 2 needs appropriate citation for the data presented.

The data source has been specified below the table (Table 4 at present): “*The original data are from China MEP.*” We have added a paragraph to describe the observations of  $\text{O}_3$ ,  $\text{NO}_2$ , and  $\text{PM}_{2.5}$  used in the study on Page 6: “*The real-time hourly measurements of  $\text{O}_3$ ,  $\text{NO}_2$ , and  $\text{PM}_{2.5}$  used in this study are released by China MEP and can be accessed from the website <http://106.37.208.233:20035/>. The historical profile of the observed ambient pollutants can be accessed at <http://www.aqistudy.cn/>. The  $\text{O}_3$ ,  $\text{NO}_2$ , and  $\text{PM}_{2.5}$  concentrations are measured by using Model 49i Ozone Analyzer, Model 42i ( $\text{NO}$ - $\text{NO}_2$ - $\text{NO}_x$ ) Analyzer, and Model 5030 SHARP Monitor from Thermo Fisher Scientific, USA, respectively. All the instruments are maintained and routinely calibrated by China MEP to assure data quality.*”

2. Figure 2. It is recommended to add “anthropogenic” before emissions in the title. Also please specify the meaning of the black lines in the plots.

We have modified the figure caption for Figure 2 and the meaning of the black lines in the plots has been specified in the figure caption on Page 29: “*Geographic distributions of anthropogenic emissions of (a) nitrogen oxide, (b) volatile organic compounds, and (c) biogenic isoprene emission in the simulation domain. The black lines present provincial boundaries in China.*”

3. Figure 9 “scattering plot” -> “scatter plot”.

We have corrected the figure caption (Figure 11 now) on Page 29: “*(a) scatter plot of measured daily aerosol constituents ...*”

4. Figure 13. There are no explanations for how Y-axis is defined. According to Page 30577, line 2 and line 10, the changes of  $J[\text{NO}_2]$  and  $\text{O}_3$  concentrations are defined as (SEN-REF), i.e. results from sensitivity simulation minus results from reference simulation. However, the changes of  $J[\text{NO}_2]$  and  $\text{O}_3$  concentrations in Figure 13 are both negative, which are calculated as (REF-SEN). This inconsistency caused confusion when I first read the text and looked at the figure.

We have changed the definition according to the figure (Figure 15 at present) on Pages 15-16: “*Aerosols significantly decrease  $J[\text{NO}_2]$  by 30-70% (defined as  $(\text{REF}-\text{SEN})/\text{SEN}$ )*” and “*in Xi’an and surrounding areas, the reduction in  $\text{O}_3$  concentration (defined as  $(\text{REF}-\text{SEN})$ )*”.

5. Figure 15 Please add the unit for plot (a) and (b) beside the legend. “a 50% reduction” is duplicated in the title.

We have added the unit in the figure (Figure 17 at present) and the duplication is removed on Page 30.