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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Impacts of emission reduction and meteorological conditions on air quality improvement during the 2014 Youth Olympic Games in Nanjing, China" *by* Qian Huang et al.

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Thank you very much for reviewing the manuscript and providing us the constructive comments and suggestions on our study. We have learned a lot from your advice and revised the manuscript, which we hope meet with approval. And point-by-point responses are listed as below:

Responses to the reviewer's comments:

General Comments:

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Discussion paper

Comment 1: This paper tried to evaluate the impacts of emission reduction and meteorological conditions on the air quality improvement during an air pollution control period-YOG of Nanjing. Accurate quantification of the influence of emission reduction and meteorological conditions is important to evaluate the air pollution control measures. This paper used both observation data and modeling results to address this issue. However, this manuscript has major writing and structure problem. The validation of model simulation and uncertainty analysis is essential and required but lack in the manuscript.

Response: Thank you for your comment. We have extended the model description part in Section 2.2, in this part, we explained that the dynamic parameterization in WRF as well as the physical and chemical schemes of CMAQ applied in this research were the same as those in the research of Shu et al. (Shu is a member of our research group) and were proven to have good simulation performance. So we no longer validate the model performance and uncertainty in this paper. The following table and figure (See uploaded Fig.1 and Fig.2) are the evaluation of WRF/CMAQ performance from Shu et al. (2016). The table presents the performance statistics, including the values of R, the NMB and the RMSE, which are all calculated for 2 m air temperature (T2), 2 m relative humidity (RH2), 10 m wind speed (Wspd10), 10 m wind direction (Wdir10), surface O3 concentrations and surface NO2 concentrations in Shanghai (SH), Nanjing (NJ) and Hangzhou (HZ), China. As indicated in the table, the simulated results of surface air temperature and relative humidity from WRF show good agreement with the observations. The highest correlation coefficient of T2 is found to be 0.91 at SH, followed by 0.84 at NJ and 0.80 at HZ (statistically significant at 95 % confident level). The corresponding correlation coefficients for RH2 are 0.85, 0.83 and 0.78, respectively. The values of RMSE for T2 at SH, NJ and HZ are 4.15, 2.91 and 3.09 âÚęC and those for RH2 are 19.3, 9.41 and 13.96 %, respectively. The simulation underestimates T2 and overestimates RH2 to some certain extent, however, they're reasonable and acceptable compared to some relevant studies. Besides, the table indicates that the simulation of Wspd10, Wdir10 , and concentrations of pollutants are also reliable.

The following figure shows the comparisons between the modeling results from CMAQ and the observed hourly concentrations of O3 in Shanghai, Nanjing and Hangzhou during 4-15 Aug. 2013. Obviously, the observations and the simulated results present reasonable agreement at each site, with the correlation coefficients of 0.81 to 0.83, NMB of −6 to 12.12 % and RMSE of 33.95 to 38.79 ppb. Moreover, the simulation also reproduces the diurnal variation of O3, which shows that the concentration reaches its maximum at around noontime and gradually decreases to its minimum after midnight.

Comment 2: The paper lacks in-depth discussions of the observation data and model results. Some conclusions are too arbitrary and lack sufficient evidence to back the interpretations of the results (see detail comments below).

Response: Thank you for your comment. This paper tries to apply model simulations to investigate the reason why observation pollutant concentration changes. We have studied your comment and added some discussion in-depth about the results in the revised manuscript.

Comment 3: The literature review in the introduction section needs improvement.

Response: Thank you for your comment. According to your detail comments, we have improved the introduction section in the revised manuscript.

Comment 4: The quality of English needs substantial improving. I believe that the paper needs substantial revisions before considering to be published at ACP.

Response: Thank you for your comment. The co-authors have helped to improve the English of the paper, and some sentences have been rewritten and reorganized.

Detail Comments

Comment 1: Line 22-26 This sentence here is not rigorous. What concentration? Hourly average? Daily average? From what data? Observation data at which site? You'd better give the standard deviations of the data.

Response: Thank you for your comment. We're sorry about the ambiguous expression. They're the hourly average observational concentrations. And they are the mean of the two representative sites in Nanjing. We have rewritten the sentences as follows: "During the YOG holding month (Aug., 2014), the hourly mean observational concentration of SO2, NO2, PM10, PM2.5, CO and O3 was 11.6 μg/m3, 34.0 μg/m3, 57.8 μg/m3, 39.4 μg/m3, 0.9 mg/m3, and 38.8 μg/m3, respectively, which were below China National Ambient Air Quality Standard." Besides, we have added some explanation in Section 3.1 Observed air quality during YOG (See Line 214-217, Page9). And the standard deviations of the data was given in Section 3.1.

Comment 2: The introduction section should be rewritten and reorganized. The references cited in the introduction section should be more targeted and well selected. Take Line 78-82 for example, the references cited here have nothing to do with the topic of the paper. Line 60-82, too many references are cited without summary and in-depth understanding.

Response: Thank you for your comment. The references cited in the introduction section are mainly discussing the impact of emission reduction or meteorology on air quality in social events, like Beijing Olympic Games, the 16th Asian Games in Guangzhou and the World Expo in Shanghai. And some discussed the air pollution characteristics in Yangtze River (where Nanjing locates). All of them have reference value to our research. Line 78-79 "Xu et al. (2013) concluded that PM2.5 was mainly emitted from anthropogenic sources other than biogenic sources." related to the impact of emission reduction, it indicated that cut down anthropogenic sources could decrease PM2.5 in the air. Line 79-80 "Dong et al. (2013) found that independent NOx emission reduction would strengthen O3 as a side effect in YRD." helped to explained the simulated increase of O3 in our research. Some introduction of references might be simple or not very important, we have modified them and added some references. The modified sentences are in Line 60-90.

Comment 3: Section 2.2, Fig.1 is hard to read. The authors stated that the 9 stations

were chosen for representing the whole Nanjing city. But all of the 9 stations located at the center part of the city. I doubt can they represent the whole city? Moreover, what is the purpose of these sites? For model validation? Please give the results of model validation.

Response: Thank you for your comment. There are only 9 state controlling air sampling sites in Nanjing as shown in this paper. They locate in different districts of Nanjing. And the density of population, traffic conditions and economics can differ a lot in different district, for example, the urban district Gulou District (where CCM station locates) and suburb district Xianlin District (where XL station loctes). In this condition, Nanjing Municipal Environmental Protection Bureau chooses the local 9 state controlling air sampling sites to represent the whole Nanjing city. In conformity with this, we chose the 9 state controlling air sampling sites to represent the whole Nanjing while analyzing model simulation impacts. Thus, they're not use for model validation. The details about model validation have been answered in the General Comment Response part (General Comments, Comment 1). Besides, we have added the reason why we choose the 9 sites in the revised manuscript (Line 151-155, Page6).

Comment 4: Section 2.3 The description here is quite ambiguous. Which year of the emission inventory is used for simulation? How do the authors make the emission inventory after reduction? How to determine the reduction ratio? Based on the control measures? Is there any hypothesis here? If there is hypothesis? What is the uncertainty? Please state the experimental process in detail.

Response: Thank you for your advice. We have added the detail about how the innermost domain emission inventories were set in Section 2.3 (Line 173-187) in the revised manuscript. The inventory before emission control was based on the local emission in 2012. According to the control measures offered by the local Environmental Protection Agency (EPA), we made the emission inventory under emission control. The emission control measures include all coal-combustion enterprises must use high-quality coals with low sulfur content less than 0.5% and ash content less than 13%, over 100 local

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petrochemical, chemical and steel enterprises were forced to cut or halt their production during Aug. 2014, and heavy pollution vehicles called “yellow label buses” were prohibited. And more details about emission control measures like the reduction ratios of some enterprises were in 2014 Youth Olympic Games Nanjing Environmental Air Quality Assurance and Emergency Response Program offered by the local EPA. So, there could still be some bias with the emission inventories used in model simulation.

Comment 5: Section 3.1 The title of this section is inconsistent with the content. Why CCM and XL station are chosen for study? Can they represent the whole study area of the modeling or Nanjing (same as detail comments NO.3)? The data analysis in this section should be more rigorous and more in-depth. Line 147-148 How to get the reduction percentage? Calculate from observation data or other ways? Line 154-156 Why the authors avoid discussion of NO2 at CCM and CO at XL? Line 157-158 The discussion here is inaccurate. The deviation of PM10 and PM2.5 is larger in 2014. Line 158-160 How to get this conclusion from the analysis above? Line 182-199 Similar problems as above. Line 190-191 The change percentage of NO2 listed here is 19.8 %, but in Table 4 is -19.8%, please check the correctness and consistency of your results. In line 193-194, the authors said that “the pollutant concentrations declined with emission control, but rebounded after releasing control”. How to explain the higher simulated concentrations of SO2 and CO during Aug. with strictly control measures? The authors listed too many tables in this section without in-depth analysis and solid discussions.

Response: Thank you for your comment. To avoid misunderstanding, we have changed the title as 3.1 Observed air quality during YOG. And the reason why we choose CCM and XL station for study has been added in Section 2.1 Data description (Line 109-123, Page 4). Both of the two stations are state controlling air sampling sites. The data quality assurance and quality control procedures for monitoring strictly follow the national standards (State Environmental Protection Administration of China, 2006). Caochangmen (CCM) Station (118.75° E, 32.06° N) locates in Gulou District, the city

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center of Nanjing. Gulou District is the center of economy, politics, culture and education in Nanjing. Here gathers many East China's high-end industrial and corporate headquarters. Besides, over 90% provincial authorities, more than 20 colleges and universities, and more than 120 research institutes situate in Gulou District. It's the most populated area in Nanjing, with lively commercial hub and heavy traffic. Thus, CCM station was chosen to represent the urban status of Nanjing. The other station is Xianlin (XL) Station (118.92° E, 32.11° N). XL station locates in Qixia District, the suburb of Nanjing. Compared to Gulou District, Qixia District is much more sparsely populated. And there is no traffic congestion problem in Qixia District. Thus, XL station was chosen to represent the suburban status of Nanjing. The reduction percentages were percentages of the emission sources, the details about the emission reduction were added in Section2.3 Emissions and simulation scenarios (Line 173-195). In the revised manuscript, to prevent misunderstanding, we no longer mention the emission reduction percentage in Section 3.1. In order to stressed the observational concentration of most species decreased in Aug. 2014, we didn't mentioned the slightly rise of NO2 at CCM and CO at XL. The slightly rise of NO2 and CO could be caused by traffic. To meet the traffic demand of numerous tourists, athletes, and freightage, there could be more traffic pollution and raised the level of NO2 and CO. Thanks for your correction. Line 157-158 (old manuscript) is inaccurate, the conclusion is not reasonable in Line 158-160 (old manuscript). we have corrected them (See Line 223-225, Page 9) as "Besides, the smaller standard deviation (std) of SO2, NO2, CO and O3 revealed that concentrations of these air pollutants varied more steadily in Aug. 2014. The drop of pollutant concentration could be caused mainly by meteorology conditions or emission reductions. And we will discuss the reason based on model simulations in Section 3.2 and Section 3.3.". Besides, we have corrected the problem in Line 182-199 (old manuscript), the details are in Line 262-269. Sorry about the error in Line 190-191 (old manuscript), the change percentage of NO2 should be -19.8% other than 19.8%, and we have corrected it. The discussion of this part has been rewritten (Line 249-269). According to Table 4 and Table 5, concentrations of most species decreased in Aug.

2014, but rebound in Sept. 2014. Besides, the simulated concentration of SO2 and CO during Aug. were not higher. The simulated SO2 dropped by 24.6% and the simulated CO dropped by 7.2% (See Section 3.3 Simulated impact of emission reduction, Line 338-340) .

Comment 6: Line 221-232, The authors should avoid ambiguous discussion. The word such as "lower temperature and weaker winds", "rather worse meteorological conditions" is quite obscure to readers. Line 227, The authors stated ". . .. . . which was consistent with the observations", could you give more detailed comparison results of model and observations? How about the accuracy of the simulated meteorological parameters? Fig. 6, What do "data1" and "data2" stand for?

Response: Thank you for your comment. We have rewritten this section (Section 3.2 Simulated impact of meteorological conditions Line 291-328). In the revised manuscript, the bias of meteorological parameters during the two simulated period were added to explain the different weather conditions. Details about the model performance please see the earlier response to General Comments, Comment 1. "data1" and "data2" means nothing, they should not show in the figure. We're sorry about the mistake, and have redrawn the figure.

Comment 7: How to explain the spatial distributions of the impact percentage? For CO and O3, the simulated concentrations of Exp.2 are lower than those of Exp.3, especially for the north part of Nanjing city.

Response: Thank you for your comment. "For CO and O3, the simulated concentrations of Exp.2 are lower than those of Exp.3" is incorrect. And O3 of Exp.2 was not higher in the north part of Nanjing (Fig.7). Statistically, as for the mean of the whole city and the mean of 9 sites, the simulated CO and O3 concentrations of Exp.2 are higher than those of Exp.3. As discussed in Line 302, CO and O3 were increased by 7.8% and 0.8% (the mean of 9 sites). The decrease of CO in the small section of northern Nanjing didn't bother our conclusion, we are more concern about the overall

impact.

Comment 8: Section 3.3, Line 247-248, the statement here is ambiguous. 9.2% and 38.1% is from model results or others? 9.2% to 38.1% is a fuzzy range. Line 249-250, what do you mean? What is the definition of short-lived chemical composition? Line 250-251 How to explain the uneven distribution of the impact percentage? Line 256-257 The reduction ratios here are compared to what period? The authors should give more exact time during the discussion.

Response: Thank you for your suggestion. We're sorry about the ambiguous expression. 9.2% and 38.1% is from emission inventories used for simulations before and after emission control. In the revised manuscript, we have added description about emission inventories in Section 2.3, so we no longer refer the cutting ratios of emission inventories in Section3.3. Line 249-251 (old manuscript) means the uneven distribution of impact percentage was related to the uneven distribution of emission sources and the uneven reduction of emission sources. Thus the large simulation variations (Exp.1 - Exp.2) occurred in the west of Nanjing corresponding to the downwind regions of heavy reduction districts was reasonable. Short-lived chemical composition refers to the chemical composition whose residence time in the atmosphere is short. Line 256-257 (old manuscript) The reduction ratios referred to the simulated pollutant concentrations before and after emission control in Aug. 2014 (the holding month of YOG). And the exact time was explained in Line 340.

Comment 9: Section 3.4 Why do you choose 16th Aug. to 28th Aug. not the whole month of Aug. as the study time here? Line 270-271 How can you make the conclusion here? From Fig. 9, it seems that the influence of meteorological conditions is more important for the air quality of Nanjing. Line 278-291 The authors focus on discussing difference of emission reduction influence at two sites. However, 0.9 %, 1.1 % etc. is quite small change. What is the result when considering the uncertainty of the model simulations? Line 299-308 The discussions here lack of evidence.

Response: Thank you for your comment. The old Fig.9 is the current Fig.10. The holding time of YOG is 16th Aug. to 28th Aug., to highlight the impact during the holding time, we choose 16th Aug. to 28th Aug.. As discussed in Section 3.2 Simulated impact of meteorological conditions, meteorological conditions in Aug. 2014 led to increases of pollutant levels compared to those under the conditions in Aug. 2013. However, the discussion of observational data in Section 3.1 showed that the observational pollutant concentrations were lower in Aug. 2014 compared to those in Aug. 2013. So, we could conclude that the weather conditions in Aug. 2014 were worse than those in Aug. 2013 and might raise the pollutant level, the observational drop of pollutant concentrations in Aug. 2014 compared to those of Aug. 2013 was mainly due to emission reduction. 0.9% and 1.1% (old manuscript) are simulated impact percentage of O3 at sites. Though they're small , they reflected that meteorology in Aug. 2014 could raise O3, and emission reduction could also raise O3 considered the reducing NO2 and the titration effect. And they still support our conclusion. The details about the simulation model performance are in the previous response (General Comments, Comment 1). Discussions in Line 299-308 (old manuscript) were according to the emission control measures as introduced in Section 2.3 Line 178-187.

Technical Comments

Comment 1: The authors should refer to "the guidelines for authors" of ACP to prepare the manuscript.

Response: Thank you for your comment. We have carefully read "the guidelines for authors" of ACP and revised the manuscript.

Comment 2: Abbreviations should be given for the first time. Such as "CST" etc.

Response: Thank you for your comment. Sorry about our carelessness. We have revised the manuscript (See Line 197, Page8 "The simulated period was from 27 Jul. to 1 Sept. (China standard time, CST)"). And "CST" means China standard time in this paper.

Comment 3: The date format need to be uniform.

Response: Thank you for your suggestion. We have revised the date format to be uniform.

Comment 4: Spaces must be included between number and unit.

Response: Thank you for your suggestion. We have checked and revised the manuscript.

Comment 5: Fig. 9 The legend makers “Met” and “Red” here are easy to lead misunderstanding. You’d better use “Met.” and “Red.”.

Response: Thank you for your suggestion. We have corrected them.

Comment 6: The reference format should be uniform. Too many references in Chinese are cited.

Response: Thank you for your suggestion. We have checked and correct the format. Besides, we have added some more references in English and cut some references in Chinese.

Comment 7: The English of this manuscript needs substantial improvement.

Response: Thank you for your comment. The co-authors have helped to improve the English of the manuscript and some sentences have been rewritten and reorganized.

Interactive comment on Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2017-114, 2017.

Table 3. Comparisons between the simulations and the observations at Shanghai, Nanjing and Hangzhou stations during 4–15 August 2013.

Site[a]	Vars[b]	Mean		R[e]	NMB[f]	RMSE[g]
		OBS[c]	SIM[d]			
SH	T_2 (°C)	33.27	31.38	0.91	−5.68 %	4.15
	RH_2 (%)	57.91	65.23	0.85	12.64 %	19.3
	$Wspd_{10}$ ($m\,s^{-1}$)	4.59	4.66	0.77	1.53 %	2.18
	$Wdir_{10}$ (°)	176.34	182.57	0.63	3.53 %	41.44
	O_3 (ppb)	87.77	82.5	0.81	−6.00 %	38.79
	NO_2 (ppb)	29.01	38.25	0.54	31.85 %	28.95
NJ	T_2 (°C)	32.95	30.98	0.84	−5.98 %	2.91
	RH_2 (%)	63.28	66.14	0.83	4.52 %	9.41
	$Wspd_{10}$ ($m\,s^{-1}$)	3.21	3.4	0.74	5.92 %	2.41
	$Wdir_{10}$ (°)	197.68	194.58	0.57	−1.57 %	71.19
	O_3 (ppb)	69.7	78.15	0.81	12.12 %	36.8
	NO_2 (ppb)	41.44	40.09	0.61	−3.26 %	22.4
HZ	T_2 (°C)	33.25	31.08	0.8	−6.53 %	3.09
	RH_2 (%)	52.76	61.39	0.78	16.36 %	13.96
	$Wspd_{10}$ ($m\,s^{-1}$)	3.04	3.32	0.75	9.21 %	2.39
	$Wdir_{10}$ (°)	186.45	186.2	0.58	−0.13 %	69.44
	O_3 (ppb)	76.57	84.51	0.83	10.37 %	33.95
	NO_2 (ppb)	31.06	27.21	0.66	−12.40 %	16.86

[a] Site indicates the city where the observation sites locate, including Shanghai (SH), Nanjing (NJ) and Hangzhou (HZ). [b] Vars indicates the variables under validation, including 2 m air temperature (T_2), 2 m relative humidity (RH_2), 10 m wind speed ($Wspd_{10}$), 10 m wind direction ($Wdir_{10}$), ozone (O_3) and nitrogen dioxide (NO_2). The words between the parentheses behind variables indicate the unit. [c] OBS indicates the observation data. [d] SIM indicates the simulation results from WRF/CMAQ. [e] R indicates the correlation coefficients, with statistically significant at 95 % confident level. [f] NMB indicates the normalized mean bias. [g] RMSE indicates the root-mean-square error.

Fig. 1. Table for General Comment 1, Table 1. model performance

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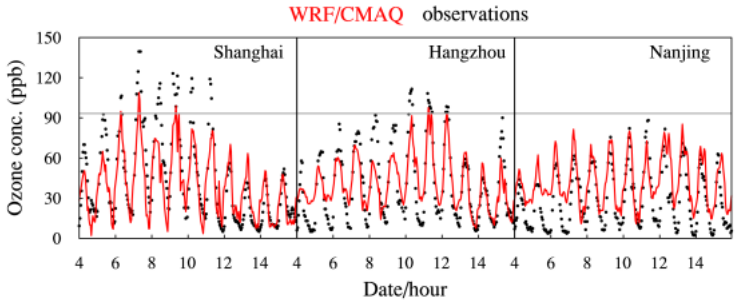

Figure 6. Hourly variations of the observed and the simulated O_3 concentrations in Shanghai, Nanjing and Hangzhou during 4 to 15 August 2013. The red solid lines show the modeling results, the black dot lines give the observations, and the solid gray lines represent the national standard for the hourly O_3 concentration, which is 200 $\mu g\, m^{-3}$.

Fig. 2. Figure for General Comment 1, Fig.2. model performance

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