Dear Referee,

Thank you very much for your constructive comments that help clarify some vague issues and improve the quality of our manuscript. The following are our responses to your specific comments:

1. **Clarification of why a city-level validation of the model performance was not conducted, and clarification of the reliability of the modelling results and the credibility of the conclusions of this study based on one representative traffic monitoring station for model evaluation**

Comment 1: The city-level validation of model performance and analysis of air quality improvement is missing.

Response 1: Thanks for your critical comment. It is true that we used only one air quality monitoring station (CGZ), which was located at the crossroad with high traffic flows and was well maintained as a traffic monitoring site representative of heavy traffic (Cao et al., 2002), for the model evaluation. Actually, there were two typical traffic-representative air quality monitoring stations set up and maintained by the Beijing Municipal Environmental Monitoring Centre (BMEMC), which was the administration for all monitoring stations. The BMEMC provided us with evaluation data from both of the typical traffic monitoring stations. Unfortunately, the data from Qianmen station, which was located at a high-traffic environment and was used for model evaluation purpose in previous studies (Song et al., 2006 and Wang et al., 2008b), were incomplete during the evaluation period, with about 70% of the data missing due to malfunction of the monitoring equipment. In contrast, data from the CGZ monitoring station were complete, and therefore were used for the model evaluation. With its particular location at a busy crossroad, CGZ station provided hourly sequential monitoring data, which reflected mainly the air quality impact of vehicular emissions, which was in accordance to the model predictions influenced mainly by local on-road vehicles, with a minor contribution from other well controlled sources like power plants and polluting industrial plants, construction sites and gas stations both in Beijing and the surrounding provinces during the Games (Wang et al., 2009). Thus, we believe that the CGZ monitoring data were suitable for comparison with model predictions for the model evaluation purpose. In addition, as construction sites were shut down, industrial production were restricted, and agricultural activities, particularly biomass burning in rural areas were strictly banned both in Beijing and other eight surrounding provinces (MEP, 2008), the major emissions in the UAB during the Games came from vehicles, and this emission characteristic during the Games was distinct from the usual situation with much more emissions from other sources, under which circumstances the previous studies (Song et al., 2006 and Wang et al., 2008b) were conducted, with additional rural and industrial monitoring stations added for the modelling evaluation. The particular characteristic of sources emissions during the Games convinced us that other air quality monitoring stations, particularly those usually adopted to reflect air quality impacts from industrial sources or rural emissions, were unnecessary or not suitable to select for the model evaluation in this study. Moreover, the major objective was not an intensive model evaluation using multi-monitoring stations, but was the assessment of air quality impacts and the effectiveness of the TRS policy during the Games, based on an evaluated urban air quality modelling system. This is why a city-level validation of the model performance was not conducted, and we believe that the evaluation based on the measurements from this representative traffic monitoring station was reliable and the overall modelling results and the conclusions were credible. Accordingly, we have added these clarifications in Lines 585-614, Pages 31-32 of the revised manuscript.

We would appreciate your respect for the fact that the daily average, diurnal, weekly and spatial variations of the concentrations of major air pollutants before, during and after the TRS policy took effect were analyzed and implications for air quality improvements in response to the TRS policy were discussed, in Sections 3.2.2 and 3.2.3 of the ACPD manuscript.

2. Clarification of the credible reduction effect of PM_{10} by the TRS policy

Comment 2: On-road vehicles are not recognized as the major contributor of PM emissions, but the results showed that the traffic restriction policies decreased the PM concentration to a surprisingly large extent. More clarification and analysis need to be addressed to identify the actual contribution of traffic policies from other air pollution control measures on power plant, industry and soon.

Response 2: Thanks for your critical comment. It is known that soil dust, coal or fossil fuel combustion, secondary aerosols (sulfate and nitrate) and biomass burning were recognized as the major sources for PM_{10} or $PM_{2.5}$ in Beijing (Zheng et al., 2005; Song et al., 2006; Wang et al., 2008a), and particularly, secondary sources, including secondary sulfate and secondary nitrate were identified as major PM_{10} sources in July (Xie et al., 2008). Nevertheless, other studies found that motor vehicles were also a major source of PM_{10} and could not be neglected (Okuda et al., 2004; Sun et al., 2004; Song et al., 2007; Zhang et al., 2007), accounting for about 20% or higher. These studies indeed provided substantial evidences on the sources of PM_{10} or $PM_{2.5}$ in the ambient air of Beijing in the past few years (2000-2006). However, the previous conclusions in relevant with the contribution to PM from vehicles can be very different from this study, due to a distinct characteristic of source emissions during the Games when a series of control measures were taken, such as fuel shift from coal to natural gas in residential and heat supply sectors, moving high-polluting industries like the Capital Steel out of Beijing, shutting down construction sites, phasing out leaded gasoline, upgrading gasoline quality to meet EURO 3 emission standards, promoting abatement and removal technologies for sulfur dioxide and particulate matter from industrial point sources, and greening of bare land by afforestation. Consequently, the green cover of Beijing, the green cover in mountainous area, and the green cover in urban area had reached 51.6%, 70.49% and 43% respectively, by the end of 2007. In particular, in the vicinity of Beijing and Tianjin, the average vegetation coverage was increased by 20% compared to that eight years ago. This substantial improvement in establishment of ecological barriers for prevention of dust storm strikes in Beijing was expected to decrease to a large extent the contribution of soil dust to PM_{10} concentrations during the Games, compared to the situation revealed by previous studies in the past years (Okuda et al., 2004; Sun et al., 2004; Zheng et al., 2005; Zhang et al., 2007; Wang et al., 2008a). Similarly, contribution to PM_{10} from fossil fuel combustion, another identified major source of PM_{10} pollution in Beijing by previous studies (Okuda et al., 2004; Sun et al., 2004; Song et al., 2007; Zhang et al., 2007; Wang et al., 2008a), was also expected to decrease to a great extent during the particular period. Furthermore, the massive reduction of primary emissions from industrial production, agricultural activities, vehicles, gas stations, construction activities due to the strict control measures was expected to decrease to a large extent the formation of secondary sulfate and nitrate, lowering the contribution of secondary sources to PM_{10}. With the strict control of emissions from soil dust, construction sites, industrial plants, coal combustion, gas stations, and rural biomass burning for the pre-, during- and post-TRS periods, the contributions of these sources to PM_{10} were expected to decrease significantly, with relatively more emissions coming from the remaining major source of on-road vehicles. Moreover, the PM_{10} or $PM_{2.5}$ samples used for the previous source apportionment studies in Beijing were collected with samplers located at the roofs of several sites, of which the height ranged from one story (about 5 metres) to five stories (about 25 metres) (Zheng et al., 2005; Song et al., 2007), and even to 40 metres high (Zhang et al., 2007). These PM measurements obtained on the roofs of buildings tended to be less influenced by on-road vehicles of which the exhaust tailpipes were usually below 0.3 meter. Besides, according to a previous study focusing on the vertical profile of PM near major roads, the PM_{10} concentrations decreased substantially on the top of a high-rise residential building compared to their ground-level values near roadways (Wu et al., 2002). Therefore, the PM measurements used in the previous source apportionment studies tended to underestimate the PM contribution from on-road vehicles, while on-road vehicles considered in this study had a more substantial impact on the PM_{10} concentrations, which were predicted at a much lower height of 1.5 metres. Thus, with the distinct characteristic of source emissions and the larger influence of on-road vehicles on predicted PM_{10} concentrations in this study than previous measurements, it was reasonable to have higher vehicular contribution to predicted PM_{10}, and the reduction of vehicular emissions due to the TRS policy, which was the major cause for emission reduction during the Games as control measures for sectors other than on-road vehicles remained the same and had little extra effect on emission reduction, resulted in a reasonably more notable effect on the reduction of PM_{10} concentration, than the previous source apportionment studies would expect. Accordingly, we have added these clarifications in Lines 76-88, Pages 4-5, in Lines 99-103, Page 5, in Lines 490-527, Pages 26-27, and in Lines 678-683, Page 36 of the revised manuscript.

Though control measures besides the TRS policy were also taken for industrial plants, construction sites, gas stations, biomass burning, and natural sources like dust to improve the air quality in the whole UAB, the aim of this study was not to conduct a complete evaluation of the effectiveness of each control measure on the improvement of air quality in the whole UAB, but to focus on the air quality impact of a particular traffic emission control policy and on the evaluation of the effectiveness of the TRS policy on mitigating air pollution. Furthermore, these control measures for sectors other than on-road vehicles remained the same and were constantly in effect for the pre-, during- and post-TRS periods, it was therefore reasonable to exclude a discussion about the contributions to air quality improvement during the Games from these air pollution control measures.

3. **Clarification of the objective of the current study, the role of receptors, and the reasons for ignorance of model evaluation using measurements away from the simulated roads**

Comment 3: The receptors could capture the air quality improvement on the roads, but not the whole modeling domain. The distribution of receptors is OK if the objective of the analysis is the road environment, but more comparison between the modeling results and air quality monitor data AWAY FROM THE ROADS are essential to evaluate the performance of the model in the whole domain.

Response 3: Thanks for your comment. We agree with your point of view that the located receptors only reflected the air quality in the areas near the simulated roads, rather than the air quality in the whole UAB. We located the receptors along the major roads distributed around the UAB, because the objective of the current study was to seize the valuable case study opportunity to evaluate the impact and effectiveness of a particular traffic control measure on mitigating air pollution based on the short-term air quality improvement near the roads, as indicated by the receptors. Besides, receptors located in different regions of the UAB were used to capture the air quality improvement in different parts of the UAB in response to the TRS policy. This was one of the reasons we did not make comparison between modelling results and measurements from air quality monitoring sites away from the roads. Besides, it was not the objective of this study to conduct an intensive model evaluation, and we did not intend to evaluate the air quality impact of the TRS policy by an overall assessment of the air quality improvement throughout the UAB, which benefited from all control measures including the TRS policy. As far as the primary objective of this study is concerned, the model evaluation based on measurements from CGZ was reliable due to the distinct characteristic of source emissions during the assessment period, and the modelling results and conclusions were therefore credible. Thus, we ignored the model evaluation using measurements away from the simulated roads. Accordingly, we have added these clarifications in Lines 117-123, Page 6, in Lines 207-209, Page 10, in Lines 211-213, Page 11, and in Lines 279-284, Pages 14-15 of the revised manuscript.

4. **Clarification of consideration on emissions from sources other than on-road vehicles and clarification of the reasons for not considering emissions from other roads**

Comment 4: According to the text, emissions from 2nd, 3rd and 4th RR and the LRs were considered in this work. But the authors didn’t tell how other emission sources are considered in the analysis, including on-road vehicle emissions from other roads and other emission sources such as power plants and industry, residential and biogenic emissions. These information are essential to the model the air quality in the whole domain.

Response 4: Thanks for your comment. As we have clarified in Response 2, a series of aggressive emission control measures were taken to improve the air quality during the Games. Consequently, there were few emissions remaining from power plants which had reduced their capacities and residential cooking that had a fuel shift from coal to natural gas or LPG. Nevertheless, to take into account the few emissions from industry, residential cooking, and rural and biogenic activities, we used the data from a rural monitoring station as the background contributions from these minor sources, to minimize the possible inaccuracy due to the lack of a complete emission inventory that was very difficult to compile accurately.

We did not consider the emissions from other minor roads, partly because emissions from these roads were relatively less than those monitored emissions from the major roads, and partly because emissions from the minor roads were difficult to quantify due to lack of the online continuous monitoring system for traffic flows. Besides, we have clarified in Response 3 that the objective of this study was to conduct the evaluation of the air quality impact and effectiveness of the TRS policy, by analyzing the variation in air quality near the simulated roads, which were reflected by the receptors, rather than analyze the air quality throughout the UAB, like the areas away from the monitored major roads. As the other Referee has commented, the dense network of monitored on-road traffic flows has helped towards the realistic representation of the species emission rates used as input in the modelling system, and we believe that the number of the considered road segments in the study was statistically adequate to assure the credibility of the results and the conclusions of this air quality impact assessment study.

Accordingly, we have added information on the consideration on emissions from sources other than on-road vehicles, as well as the clarification of the reasons for not considering emissions from other roads in Lines 269-294, Pages 14-15 in the revised manuscript, to clear the doubt about the inappropriateness of the input of emissions and the credibility of the results of the modelling work.

5. Clarification of the reasonable difference in predicted PM_{10} concentrations in this study, compared to the source apportionment results in previous studies

Comment 5: According to the context, neither the emissions for sources other than on-road vehicles, nor the policies to control them such as shutting down the industrial plants and stopping constructions, were considered in the modeling work. These information should be important in modeling the PM concentration as some previous paper indicated small contribution of PM emissions from on-road vehicle in Beijing. Thus the modeling concentrations of PM are expected to be much lower than the observation data if only on-road vehicle emissions are counted in, but it is not true from the results in this paper. The authors should make a comment on that.

Response 5: Thanks for your comment. Actually, we had in mind, but did not emphasize the control measures and policies for sources other than on-road vehicles in the current ACPD manuscript. To clarify the distinct characteristic of source emissions dominated by on-road vehicles during the particular period, we have added the information of control measures or policies for sources other than vehicles in Lines 76-88, Pages 4-5 of the revised manuscript. Also, we have clarified in Response 4 the reasons why we did not specifically consider the emissions from sources other than on-road vehicles, but instead adopted the data from a rural background monitoring station to compensate the expected minor emission contributions from those sources. As for the good correlation of predicted PM_{10} concentrations with the observations, instead of a much lower concentration level for predicted PM_{10} as would otherwise be expected based on some previous studies, we have clarified in Response 2 the evidences (primarily due to the distinct characteristic of source emissions dominated by on-road vehicles during the Games, larger impact on PM_{10} concentrations in this study than previous work due to the difference between sampling height and simulation height, and by using background measurements from a proper air quality monitoring station to take into account the impact of other minor sources) for the reasonably good predictions of PM_{10} concentrations compared to observations, which the previous source apportionment results would not expect.

References:

Cao, L., Tian, W.Z., Ni, B.F., Zhang, Y.M., and Wang, P.S.: Preliminary study of airborne particulate matter in a Beijing sampling station by instrumental neutron activation analysis, Atmos. Environ., 36 (12), 1951-1956, 2002.

Ministry of Environmental Protection of the People’s Republic of China: Disposition of banning of biomass burning for the air quality assurance during the Games, http://test.mep.gov.cn/ztbd/sjhjr/0865/lsay/200805/t20080529_123206.htm (in Chinese), 2008.

Okuda, T., Kato, J., Mori, J., Tenmoku, M., Suda, Y., Tanaka, S., He, K., Ma, Y., Yang, F., Yu, X., and Duan, F.: Daily concentrations of trace metals in aerosols in Beijing, China, determined by using inductively coupled plasma mass spectrometry equipped with laser ablation analysis, and source identification of aerosols, Sci. Total Environ., 330 (1-3), 145-158, 2004.

Song, Y., Tang, X.Y., Xie, S.D., Zhang, Y.H., Wei, Y.J., Zhang, M.S., Zeng, L.M., and Lu, S.H.: Source apportionment of PM2.5 in Beijing in 2004, J. Hazard. Mater., 146, 124-130, 2007.

Song, Y., Zhang, Y.H., Xie, S.D., Zeng, L.M., Zheng, M., Salmon, L.G., Shao, M., and Slanina, S.: Source apportionment of $PM_{2.5}$ in Beijing by positive matrix factorization, Atmos. Environ., 40 (8), 1526-1537, 2006.

Sun, Y.L., Zhuang, G.S., Wang, Y., Han, L.H., Guo, J.H., Dan, M., Zhang, W.J., Wang, Z.F. and Hao, Z.P.: The air-borne particulate pollution in Beijing-concentration, composition, distribution and sources, Atmos. Environ., 38 (35), 5991-6004, 2004.

Wang, H.L., Zhuang, Y.H., Wang, Y., Sun, Y.L., Yuan, H., Zhuang, G.S., and Hao, Z.P.: Long-term monitoring and source apportionment of $PM_{2.5}$/PM_{10} in Beijing, China, J. Environ. Sci. - China, 20, 1323-1327, 2008a.

Wang, L.T., Hao, J.M., He, K.B., Wang, S.X., Li, J.H., Zhang, Q., Streets, D.G., Fu, J.S., Jang, C.J., Takekawa, H., and Chatani, S.: A modeling study of coarse particulate matter pollution in Beijing: Regional source contributions and control implications for the 2008 Summer Olympics, J. Air. Waste. Manag. Assoc., 58 (8), 1057-1069, 2008b.

Wang, X., Westerdahl, D., Chen, L.C., Wu, Y., Hao, J.M., Pan, X.C., Guo, X.B., and Zhang, K.M.: Evaluating the air quality impacts of the 2008 Beijing Olympic Games: On-road emission factors and black carbon profiles, Atmos. Environ., 43 (30), 4535-4543, 2009.

Wu, Y., Hao, J.M., Fu, L.X., Wang, Z.S., Tang, U.: Vertical and horizontal profiles of airborne particulate matter near major roads in Macao, China. Atmos. Environ., 36 (31), 4907-4918, 2002.

Xie, S.D., Liu, Z., Chen, T., and Hua, L.: Spatiotemporal variations of ambient PM_{10} source contributions in Beijing in 2004 using positive matrix factorization, Atmos. Chem. Phys., 8, 2701-2716, 2008.

Zheng, M., Salmon, L.G., Schauer, J.J., Zeng, L.M., Kiang, C.S., Zhang, Y.H., and Cass, G.R.: Seasonal trends in $PM_{2.5}$ source contributions in Beijing, China, Atmos. Environ., 39 (22), 3967-3976, 2005.

Zhang, W., Guo, J.H., Sun, Y.L., Yuan, H., Zhuang, G.S., Zhuang, Y.H., and Hao, Z.P.: Source apportionment for urban PM_{10} and $PM_{2.5}$ in the Beijing area, Chinese Science Bulletin, 52 (5), 608-615, 2007.

Thank you very much for your valuable time spent reviewing our manuscript and for your helpful comments!

With best regards,

Hao Cai and Shaodong Xie
College of Environmental Science and Engineering,
Peking University,
Beijing, China

sdxie@pku.edu.cn