Dear Referee,

Thank you very much for your constructive comments and technical corrections that help clarify some vague issues and improve the quality of our manuscript. It seems that you have made your comments based on our originally submitted manuscript for publication consideration by ACPD. Substantial revisions have been made to the original manuscript based on Referee #2's previous indepth comments, to improve the clarity and the quality of this study by better explaining certain key aspects, before it was accepted by ACPD. In the revised manuscript as is currently subject to the Open Discussion, we have made clarifications of the choice of background and monitoring sites, provided additional information on the exact model set up and configuration, and made clarification of the previous assumption that the emission factors of PM_{10} from PC and LDV kept constant when average driving speed increased for the during-TRS period. Particularly, we have resimulated with background O_3 data from Shangdianzi (SDZ), a regional atmospheric background monitoring site established for northern China including Beijing, instead of the previously adopted O_3 data from the downwind DL site. Accordingly, the results and discussion involving with O_3 and NO_2, on which the new simulation had some (slightly worse for O_3 and slightly better for NO_2), though not substantial impact, had been revised, and no major changes were found compared to previous modelling results, with the previously drawn conclusions unaffected.

The following are our responses to your specific comments:

1 Clarifications of two main issues

(1) Clarification of the appropriateness of using one traffic monitoring station for the model evaluation

Comment: Section 3.1.1, page 16: One important disadvantage of the manuscript is the use of only one measuring station to conduct the evaluation of the model results. Scientifically, such a comparison would not be considered as solid and conclusive that the model performance is adequate or not. Why did the authors not use other measuring stations in the study domain? How can the authors be sure that the results are coincidental for some species due to the station location? I would suggest adding one or more stations in the evaluation section and if this is not possible, then try to strengthen the text by explaining why you included only one station and the possible drawbacks of this for the overall model evaluation. This should also be mentioned in the conclusions.

Response: Thanks for your critical comment. 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: one was the CGZ station and the other was the Qianmen station located at a high-traffic environment, which was used for model evaluation purpose in previous studies (Song et al., 2006a and Wang et al., 2008a). Unfortunately, the data from Qianmen station during the evaluation period were incomplete, 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. Because CGZ station was located at the roadside of a crossroad with high traffic flows, had a sampling height of about 4.5 m from ground, and had been well maintained with routine calibration of the measurement equipment by the BMEMC during the Games as a traffic monitoring site, hourly sequential monitoring data from this site 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 evaluation purpose. Moreover, as industrial production were restricted, construction sites were shut down, 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 modelling studies (Song et al., 2006 and Wang et al., 2008a) were conducted, using additional rural and industrial monitoring stations for the modelling evaluation. Therefore, the overall good model evaluation results in this study based on the CGZ monitoring station were not coincidental due to the station location, but was a true reflection of the particular characteristic of source emissions dominated by vehicles during the Games. Furthermore, since the analysis of the modelling results was focused on the predictions at the simulated roads and at the receptors, where the traffic-dominant emission characteristic was identified and the air quality responses have been evaluated, using the measurements from the representative traffic monitoring station (CGZ), it is reasonable to believe that the conclusions drawn based on the analysis were credible. Nevertheless, we admit that the possible drawback of using one traffic-representative station for model evaluation was that the model predictions in areas away from the simulated roads might have some unknown uncertainty. Accordingly, we have added these clarifications in Lines 585-614, Pages 31-32 and in Lines 1014-1017, Page 56 of the revised manuscript, to strengthen the credibility of the model evaluation, and mention the possible drawback in the conclusion.

(2) Clarification of the credibility of the good predictions of PM_{10} compared to observations for the model evaluation

Comment: Section 3.1.1, page 18: In several publications for Beijing, as referenced in this paper and elsewhere (e.g. Y.Song, M.Zhang, X.Cai: PM10 modeling of Beijing in the winter, Atmospheric Environment, Volume 40, Issue 22, July 2006, Pages 4126-4136), the high PM10 concentrations found in the area are a result of different sources emitting PM10 (industrial, residential, traffic and natural like dust) with a small contribution from the on-road traffic emissions. Of course, the percentage of contribution from each source depends on the season among others. In this study, the only emissions used are from traffic and someone would expect a significant underestimation of the PM10 model concentrations compared to the observations. This is not evident when looking at the scatter diagram of PM10 in Fig 3b or from the statistical evaluation (rather an overestimation is). Is it possible that this result is primarily caused by the selection of one station to evaluate the model results, making the evaluation coincidental? The authors should comment on that.

Response: 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., 2006a,b; Wang et al., 2008b), 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., 2008b). 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., 2008b), 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 and higher contribution 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 heights ranged from one story (about 5 metres) to five stories (about 25 metres) (Zheng et al., 2005; Song et al., 2006b), and even to 40 metres (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 tailpipe height was 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. Furthermore, we added the background concentrations of PM_{10} from a representative rural monitoring station during the modelling study, to take into account the contribution from other minor source emissions that were not included specifically in the model run. Thus, the distinct characteristic of source emissions during the particular Olympic period, larger influence of on-road vehicles on predicted PM_{10} concentrations in this study than previous measurements, and the use of background data from a rural monitoring station, resulted in reasonably good predictions compared to the observations, rather than an underestimation of predicted PM_{10}, as would be expected based on previous source apportionment studies with distinct source emissions, and the slight overestimation of PM_{10} was therefore not coincidental at the station chosen for model evaluation. Accordingly, we have added these clarifications of the credibility of the good predictions of PM_{10} compared to observations in the discussion of the model evaluation Section in Lines 490-527, Pages 26-27 of the revised manuscript.

2 Responses to other specific comments

(1) Clarification of control measures for vehicles

Comment: Page 4, lines 78-81: The list of control measures taken by the government for the traffic is very important in the text. The authors state 6 different measures, 3 of which are the same; decommissioning of high emissions vehicles, banning of large polluting vehicles from the roads and restricted use of high emissions vehicles. The authors should try to clarify these measures in a more appropriate way.

Response: Thanks for your comment. The previous unclear statement has been corrected in Lines 88-93, Page 5 of the revised manuscript according to the announced measures for on-road vehicles by the Beijing municipal government. The three measures are now clarified as two: decommissioning of high emissions vehicles, buses and taxis, and banning of non-local heavy duty diesel trucks within the Beijing Administrative area.

(2) Clarification of the use and role of traffic flow data and the calculation of emission rates

Comment: Page 5, lines 101-103: The phrase “This study, based on a modelling simulation with online-monitored data of on-road traffic flows at a high temporal resolution of two seconds from the ITS-TAP system, focuses…" indicates that the monitored data of the on-road traffic flows are used during the simulation time (online) of the dispersion model. From the input data section it is clear that the traffic flows are used to calculate the pollutant emission rates, indirectly taking part in the model simulation. Please clarify the text accordingly.

Response: Thanks for your comment. According to the definition of emission rates, as expressed by Equation (1), in which format the input data of source emissions are invoked by the ADMS-Urban modelling system, the emissions, lengths of road segments and travelling time of vehicles are needed, to calculate the emission rates on each road segment. More specifically, emission rates can be calculated based on four parameters: *EF*, *VP*, *L* and *v*, as shown by Equation (4), based on Equations (2-3). Traffic flows derived from the ITS-TAP system included the vehicle population (*VP*) of various vehicle types and the corresponding driving speeds (*v*) on each segment, which were used to calculate the emissions on each segment, based on additional information on the emission factor of each pollutant from various vehicle categories. The approach used to calculate the emission factors is given in the context. The travelling time (*t*) on each road segment was calculated based on the speeds and road lengths that were automatically identified by Arcview, a nested GIS (Geographical Information System) software of ADMS-Urban.

$$ER_s = \frac{E_s}{L_s \times t_s} \tag{1}$$

$$E_s = \sum_i EF_i \times VP_i \times L_s \tag{2}$$

$$t_s = \frac{L_s}{v_s} \times 3600 \tag{3}$$

$$ER_s = \frac{\sum_i EF_i \times VP_i \times v_s}{3600 \times L_s} \tag{4}$$

Where: ER_s is the emission rate on road segment *s*, expressed in *g/km/s*; E_s is the emission on road segment *s*; L_s is the length of road segment *s*; t_s is the time used to travel on the road segment *s*; EF_i is the emission factor of vehicle type *i*; VP_i is the vehicle population of vehicle type *i*; and v_s is the running speed of vehicles on road segment *s*.

Accordingly, we have clarified the previous context (Lines 25-30, Page 5144 and Lines 1-7, Page 5145) to explain more clearly about this issue in Lines 341-371, Pages 17-19 of the revised manuscript.

(3) Clarification of the reasons for selecting ADMS-Urban as the modelling

system

Comment: Page 6, line 123: It is not clear from the text why the authors selected the ADMS-Urban model instead of the other 2 proposed models by the Ministry of Environmental Protection. A comment on that would be appropriate in the text (better know-how of the model as users? Use of this particular model for a number of studies in China? Other?).

Response: Thanks for your comment. ADMS-Urban is a Gaussian dispersion model and it has been chosen for this study because of its features especially tuned to obtain best performance on urban areas (CERC, 2003). Its widely validation and applications both in UK and in China have showed good performance and reliability in air quality simulation or forecasting at the urban scale, which is mostly due to its advantages over the other two models, like the up to date parameterization of atmospheric boundary layer structure based on the Monin-Obukhov length and the boundary layer height, and the Gaussian concentration distributions in stable and neutral conditions, but non-Gaussian vertical distributions in convective conditions to take into account the skewed structure of the vertical component of the turbulence. Another reason we have adopted ADMS-Urban for the study is that this model has user-friendly interface and is particularly convenient to set up emissions, and to define the road source geometry and the output presentation in an accurate way, by means of the nested GIS tool (Arcview or Mapinfo). This is not possible with the US AEROMOD model, and the Calpuff model is known to be particularly applicable to domains with complex terrain or frequent calm wind fields, which is not quite the case in our current study. Therefore, ADMS-Urban is finally adopted. A briefly additional clarification have been added in Lines 141-153, Pages 7-8 of the revised manuscript, to clear possible puzzlement by readers.

(4) Additional information on the ADMS-Urban model setup provided

Comment: Section 2.1, page 8: Since the basis of this work is the use of the ADMS-Urban model, the authors should provide more information on how this model was setup for the simulations of the air quality over Beijing area. Information that is missing is whether they used deposition processes, continuous species emission in the domain (in time), the terrain is taken into account or not (buildings, street canyons, etc). What was the horizontal resolution used for the application? This information is important for understanding and criticizing the simulation results.

Response: Thanks for your suggestions. In comparison with the originally submitted manuscript, we have included more details for the model set up and configurations in the Methods and Data section in the current ACPD manuscript, which has been reorganized to better clarify the issue. Particularly, information on road structure and geometry like lengths and widths and canyon consideration was given in more details in section 2.2.2. Besides, information on background data was given in details in section 2.1. With your kind reminder, we have provided in Table 1, Pages 12-13 of the revised manuscript the additional information on the horizontal resolution used for the application, which was $0.35km \times 0.35km$ in a Cartesian grid created in the study domain. Also, we have mentioned in Lines 341-342, Page 17 of the revised manuscript that continuous species emissions from vehicles on the monitored roads at a time resolution of one hour were provided for the model run. Furthermore, the dry deposition process was considered by the dry deposition module of ADMS-Urban, which is actually a resistance model dependent of the pollutant species, the nature of the surface and the wind speed (CERC, 2009), while the wet deposition process was ignored during the modelling since the dry air and lack of rain during the evaluation period were not favorable for wet deposition of pollutants (Wang et al., 2008c). Accordingly, this clarification has been added in Lines 262-267, Pages 13-14 of the revised manuscript.

(5) More information on the study domain provided and clarification of the representativeness of the meteorology station

Comment: Section 2.2, page 8: In the description of the study domain it is important to know the townscape around the major roads. Are there tall buildings around? Is there a dense urban web structure or a sparse one? This information will clear the overall picture of the monitoring sites chosen for this study, especially because the authors used only one station for the air quality and one for the meteorological fields. The circulation of the pollutants and the meteorological conditions in the urban area are mostly influenced by the street plan.

Response: Thanks for your comment. There are few tall buildings along the simulated roads, and also few street canyons according to the width-height ratios. In addition, the UAB is a rather plain area with a surface roughness of about one meter, which was the major reason we did not specifically consider the detailed terrain elevation of the UAB and instead used only the optional surface roughness parameter. The road network, however, is a dense urban web structure, with the 2nd, 3rd, 4th RR and the major linkage roads being the main roads, and minor roads distributed around the UAB, as shown in Figure 1. For the difficulty in the accurate estimation of emissions from the minor roads, the current study focused on the emissions from major roads, and we believe the number of the considered road segments in the study was statistically adequate to assure the credibility of the results and conclusions of this air quality impact assessment study. This clarification has been added in Lines 275-279, Page 14 of the revised manuscript. Furthermore, the information on the locations of the monitoring sites was given in the Section 2.1 and illustrated by Figure 1. Since ADMS-Urban only uses one representative Observatory to provide the wind fields for the study domain, we have chosen the ZBAA Observatory as it is known to be representative of the wind fields for UAB (Wang et al., 2009). Accordingly, this clarification has been added in Lines 391-392, Page 20 of the revised manuscript.

(6) Clarification of the standard to determine and the reason for the “abnormal maximum” driving speeds, as well as the quantification of the “large quantity of missing data”

Comment: Section 2.3.1, page 10: Line 189: How did you determine the “abnormal maximum” driving speeds? What caused these abnormal speeds, a flaw in the automatic monitoring stations? Line 196: Indicate what did you consider as a “large quantity of missing data”, 50%, 60%, lower?

Response: Thanks for your comment. In the raw data of traffic flows derived from the ITS-TAP system, there was only one abnormal case for the monitored speeds, in which the speeds were recorded as 240 km/h. We regarded this to be impossible and abnormal, with the confirmation by technical experts of the data system. It was a flaw in the working or maintenance of the automatic monitoring cameras that caused those abnormal speeds. For those days with large quantity of missing data, we screened them out because the file sizes of the raw data on those days were abnormally much smaller than others, and the results of preprocessing the data proved our judgment. Specifically, the missing rates of data on 6th, 13th, 14th, 24th, and 28th were about 43%, 36%, 47%, 84% and 73%, respectively, due to the malfunction of monitoring cameras on many road segments during the days. We have added brief clarifications to this issue in Lines 312-316, Page 16 and in Lines 321-325, Page 16 of the revised manuscript.

(7) Clarification of the source emission characteristics and the credibility of modelling results and conclusions without compilation and use of a complete emission inventory

Comment: Section 2.3.1, page 11: In the discussion about the emissions in the urban area of Beijing, the authors should also describe what other sources of emissions are present in the domain. Industry, agriculture, biomass burning, residential? A critical discussion on the possible disadvantages of not using a complete emission inventory in the simulations must be added in the manuscript.

Response: Thanks for your critical comment. In addition to traffic control measures for the purpose of improving air quality during the Games, the Beijing Municipal Government also implemented a series of air quality improvement measures in other sectors including enhancing the utilization of natural gas to replace coal for heat supply and residential cooking, closing or relocating heavy industrial polluters (e.g., the Capital Steel Company), reducing local power generation by importing electricity from the surrounding areas, suspending construction activities as well as imposing strict control of VOC evaporation at gas stations (Wang et al., 2009). Besides, air pollution sources were strictly controlled in the surrounding provinces of Tianjin, Hebei, Shanxi, Neimenggu and Shandong to prevent regional contribution through long-range transportation, based on the evidences obtained in previous studies (Streets et al., 2007 and Wang et al., 2008a). Consequently, emissions from other sectors were expected to decrease significantly compared to usual periods, and on-road vehicles became the major source for air pollution in that particular period. Under such a circumstance, this modelling study involved only with on-road vehicles, partly because the information on the scarce and scattered emissions from other sectors was difficult to collect accurately and the inaccuracy of modelling could be considerable if all sources were considered, and partly because those control measures for sectors other than on-road vehicles were constantly in effect and remained the same for the pre-, during- and post-TRS periods, providing a unique opportunity to study the air quality impact and effectiveness of the TRS policy. Nevertheless, to assure the accuracy of the model predictions, it is important to account for significant underlying, or 'background' levels of pollutants in the atmosphere, and to account for any sources of pollution that are not otherwise included in the model run. Therefore, we selected the background data for CO, PM_{10} and NO_2 from a rural air quality monitoring station (DL), which is maintained by the local authorities and used by the atmospheric chemistry community as the background station for air quality studies in the UAB, and the background data for O_3 from a well-maintained regional background monitoring site (SDZ), during our modelling study. Furthermore, to conduct the evaluation of the air quality impact and effectiveness of the TRS policy, we analyzed the variations in air quality near the simulated roads, which were reflected by the receptors located near the monitored major roads distributed around the UAB, rather than analyze the air quality variations throughout the UAB, which benefited from all control measures including the TRS policy. Thus, we believe that this approach based on vehicle source only and the suitable background data was a good substitute for a complete emission inventory that was difficult to compile accurately and could probably raise large uncertainty, particularly during the period of implementation of high intensity of administrative regulations for emission control, when the industrial, agricultural, construction, biomass burning and residential emissions were reduced significantly and became sparse. Therefore, the modelling results and conclusions were credible, as far as the major objective of the current study is concerned, although we admit that the major drawback of not using a complete emission inventory in the simulations might cause some inaccuracy in the absolute values of the predictions, particularly in the areas near other ignored minor roads or away from the monitored major roads. Accordingly, we have added clarifications to this issue in Lines 76-88, Pages 4-5, in Lines 99-103, Page 5, in Lines 180-192, Pages 9-10, in Lines 193-207, Pages 10 and in Lines 269-294, Pages 14-15 of the revised manuscript.

(8) Correction to the contradicting statement about the dominant wind directions

Referee #1's Comment 8: Section 2.3.2, lines 246-258: The statement "reveals that northeasterly and southeasterly winds dominated in the daytime while southeasterly wind dominated in the nighttime" is different from the one in section 2.2 (lines160-161) where the prevailing wind is southeasterly during the day and northerly during the night. Please revise the text accordingly.

Response: Thanks for your corrections. We have made the correction by revising the context in previous Lines 160-161 in accordance to the statement in previous Lines 246-258.

(9) Clarification of the choice of background monitoring station for O_3

Comment: Section 3.1.2, page19: Indicate the time period that the plots in Figure 4 refer to. In Figure 4 you have added a background concentration for each species. Does this come from the DL monitoring station? If yes, then the station cannot be characterized as background for ozone since the values are higher than the observed ones, primarily due to the secondary production of ozone that leads the pollutant in the outskirts of the city away from the sources of the precursors. Please clarify this in the text.

Response: Thanks for making this critical comment. We have indicated in Figure 4 the time period in Line 551, Page 29 of the revised manuscript. The background concentrations for CO, PM_{10} and NO_2 came from the DL monitoring station, while the background concentrations for O_3 were obtained from the Shangdianzi (SDZ) regional atmospheric background monitoring site, one of the four regional atmospheric background monitoring sites established in China and located about 150 kilometers northeast of Beijing (40°39'/N, 117°07'/E), with further considerations on the suitable and representative background monitoring site for providing O_3 background data for the UAB: measurements from the SDZ background monitoring site are free of influence by motor vehicles and the SDZ site has been maintained to represent the background characteristics of atmospheric constitutes in northern regions of China including Beijing, reflecting the influence of human activities within the northern regions on the atmospheric background by long-term monitoring (Liu et al., 2007). Therefore, this site is suitable for providing the background O_3 measurement data for the current modelling study. We have provided additional information on SDZ and made the clarifications of its appropriateness for providing background O_3 in Lines 9-22, Page 5141 of the current ACPD manuscript (Lines 193-207, Page 10 of the revised manuscript).

(10) Technical corrections

Comment: Technical corrections offered.

Response: Thanks for your helpful technical corrections. We have made these technical corrections accordingly in the revised manuscript.

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

With best regards,

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