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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Vehicular emissions in China in 2006 and 2010" *by* N. Chao et al.

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We would like to thank editor and referees for your comments and helpful suggestions. We revised our paper according to these comments and suggestions.

Response to the comments by referee 3

Question 1: Line 25, page 4912 to line 3, page 4913: The populations of MCs and RVs are presented in the statistical year books for some provinces (e.g. Jiangsu). The authors could apply the existed data to validate their calculations.

Response 1: Thanks for your advice to get the populations of MCs from the statistical year books for some provinces. When we collected the population, we referred some provincial statistical year books, however not all the provincial statistical year book include this information, so we decided to calculate the population of MCs based

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on the MCs ownership per 100 households and the household data from the official statistical yearbook. This is a new way to get the population based on statistical data conveniently.

Question 2: Equation (2), Page 4913: where could you find the new registered vehicles for various fleets in each province? Did you consider the scrapped vehicles each year? Your classification of vehicles is not consistent with that in China's statistical yearbook. How did you merge the statistical data of vehicle population into your classifications? These issues should be clearly addressed in the paper, because they are important to evaluate you results.

Response 2: The population of newly registered vehicles for various fleets in each province can be found in the Chapter 16-26 of China Statistical Yearbook. According to the rules for eliminating the vehicles, the useful lifetime of each kind of vehicles is beyond 10 years. So in our study, we assumed that the vehicles registered after 2000 were all being used in 2010. Then the vehicles registered after the date of implementation of the new emission standard all can meet the new standard, and in this way, the vehicle population with each standard can be calculated. Vehicles are divided into passage cars and trucks, and each kind is divided into heavy-duty, middle-duty, light-duty and mini-duty. In our study, heavy-duty vehicles were the sum of heavy-duty and middle-duty vehicles in the statistical data, and the light-duty vehicles were the sum of light-duty and mini duty vehicles in the statistical data

Question 3: Line 22, page 4913: the authors applied VMT data of various fleets from one single literature to calculate vehicle emissions of different provinces in China. On one hand, there are great differences of VMT data existing among various studies, which could have greater uncertainties comparing with emission factors. One the other hand, the average VMT data of each vehicle fleet are different among various provinces. Actually, China's first pollution source census has already indicated that the VMT in regions are very different.

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Reposes 3: We totally agreed with your point that the VMT in regions are different. However, the VMT data in each province is not released by the Department of Motor Vehicles, and it is too difficult to do some researches in each province. What's more, the existing studies were just for individual cities or for limited fleets, and the representativeness and reliability of these results are uncertain, besides, these studies are based on different data source and method. If we used them in our study together, it may lead to greater uncertainties. After long deliberation, we chose the average result of Liu et al.in our study, which was more complete compared with others.

Question 4: Line 3, page 4914: the author determined China's vehicular emission factors by vehicle fleet, fuel types and emission standards based on several researches, which usually focused on some specific regions (e.g. Beijing) or China national level. However, the emission factors could be influenced by many local characteristics other than emission standards, such as temperature, altitude, driving characteristics, and etc. Local vehicle age (or accumulated VMT) distributions could also influenced the average emissions factors of a specific vehicle fleet (e. g. LDGV Euro 1). The author should clarify these local impacts and improve the quality of their vehicular emission factors.

Response 4: Thanks for your suggestions very much. During our work, we managed to investigate the emission factors in each province, but it is very difficult to obtain. Although there are some references about it at present, we think it is very unsuitable to apply these separated results to a national scale inventory systemically. The vehicle speed in each condition may have great influence on the emissions, but the traffic flow in the whole China is difficult to obtain, even in separate province. Therefore, simplify the calculation appropriately is a better way to develop under the present condition. Although the simplicity may lead to larger uncertainties, we can calculate a relatively reliable emission inventory completely. By referring some previous inventory on large scale, such as the INTEX-B and TRACE-P, they also could not obtain the data in detail, so they took measures to simply the calculation as well.

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Question 5: Line 4, page 4915: where could you find the vehicle population of each city in China? What is the problem to allocate provincial emissions, which including emissions from RVs and MCs, to various cities using the proportion of vehicles in each cities as proxy? Why do you apply the values of secondary and tertiary industries as proxy? Are there any results indicating local vehicle populations are closely related to the values of secondary and tertiary industries?

Response 5: The vehicle population of each city is accessible in China Automotive Industry Yearbook. However it just provides the total vehicle population of each city without classification, so we have to use the proportion of vehicles in each city as proxy. It is difficult to obtain the population of vehicle in the county level, so we analyzed the correlativity between the population of the vehicles in each province and the primary industry value, the secondary industry value, the tertiary industry value, the sum of primary and secondary industry value, the sum of primary and tertiary industry value, and sum of secondary and tertiary industry value. Then we found that there was good correlation between the population of the vehicles and the sum of secondary and tertiary industry value, we used the sum of secondary and tertiary industry value to allocate the emissions to each county.

Question 6: Equation (3), page 4915: Please provide the units of each parameter. What's the mean of Pm, k? Please clearly define it.

Response 6: We are really sorry for the omission of the units of each parameter in Equation (3) and the poor presentation of the mean of Pm,k, so here we added the units and modified the definition of Pm,k as follow:

Where k represents the grade of the road; Fm represents the average traffic density in province m (people or ton); Tm represents the passenger and cargo turnover volume in province m (100 million people$\times$km or ton$\times$km); TLm,total represents the length of transport routes in province m (10 thousand kilometers); Fm,k represents the road traffic density of grade k road in province m (people or ton); and Pm,k represents the

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proportion of standard daily traffic flow of grade k road (%) (Ministry of Transport of the People's Republic of China, 2004). The definitions of Fm and Tm are listed in detail and can be found in the instruction of each index in the Chapter 16 of the China Statistical Yearbook.

Question 7: Equation (4), page 4916: what's the mean of SF? How did you calculate SF? Please provide more information about it. The emissions are not only related to the road traffic volume, but also relate to the traffic flow compositions (e.g. the proportion of HDDV). This kind of information is important to the traffic emissions.

Response 7: SF in Equation (4) represents the standard traffic density, and it is the average traffic density of all the provinces. Zheng et al proposed a good way to allocate the vehicular emissions on the road, but the traffic flow needed in that method is inaccessible. To make this method more practicable, we use the passenger and cargo turnover volume and the length of transport routes from the China Statistical Yearbook to calculate the road traffic density to characterize the busyness of a road. So traffic density used in our study replacement for traffic flow in Zheng's study. We are so sorry that we are not quite with your question "The emissions are not only related to the road traffic volume, but also relate to the traffic flow compositions (e. g. the proportion of HDDV). This kind of information is important to the traffic emissions." The traffic flow compositions were considered in our calculation in equation (1), and we classified vehicles into light-duty gasoline vehicles (LDGVs), heavy-duty gasoline vehicles (HDGVs), light-duty gasoline trucks (LDGTs), light-duty diesel vehicles (LDDVs), heavy-duty diesel vehicles (HDDVs), light-duty diesel trucks (LDDTs), heavy-duty diesel trucks (HDDTs), rural vehicles (RVs), and motorcycles (MCs). Or is this question the same as question 8?

Question 8: Line 10, page 4916 to line 18, page 4917: the authors allocated vehicular emissions based on the road traffic information, which could also introduce problems. For example, RVs vehicles are mainly operated in rural area, heavy duty trucks and long distance buses are mainly operate on the roads in urban areas...It would be a

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big improvement if these factors were considered in this study. Line 27, page 4920: "All eight pollutants. . ." This result would be changed if you considered the various compositions of traffic flow different kinds of roads.

Response 8: Thanks for your advice to allocate the emission by considering the traffic flow compositions. We totally agree with your advice, and we managed to allocate the emissions by considering these factors during our study, however, there were few researches to reference for the whole China, so we had to assume that traffic flow of each kind of vehicle is evenly distributed on each grade of road.

Question 9: Line 18 to line 23, page 4912: authors could not draw the conclusion that their results are more reasonable. You should verify your results with other objective data, e.g. monitoring data. . .

Response 9: Thanks for your suggestion to use monitoring data to verify our results. Here we just made a preliminary comparison with some traditional methods, which show that pollutants are mainly centralized in areas with large population and developed economy. Considering that our inventory is for the whole China, there is not any monitoring data for such scale, so we hope that some researches can be done in this field in the future.

Question 10: Line 24, page 4921: The comparisons with other studies are superficial. The authors should further analyzing the key factors (e. g. emission factors, VMT..) causing those differences but not simply list the differences.

Response 10: Thanks for your advice to do some deep analysis, and we had improved this part as follow: Vehicular emissions of previous studies, both domestic and international, are summarized and compared with the results of this study in Table 5. As seen from the table, China's total vehicular emissions for each pollutant in 2006 in our study were highly consistent with the inventory developed by Zhang et al., which was one of important achievements of the INTEX-B program executed by NASA and which has been widely acknowledged for its reliability. Specifically, the differences in CO and NOX

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emissions were within 10.7% and 10.9%, respectively; VOCs and OC emissions were within 4%; and PM2.5 and PM10 were within 1%. In contrast, there was a large difference in BC emissions, up to 30.7%, which may have been caused by the uncertainties in emission factors. Since few researches had exerted on the vehicular emissions of BC emission factors, our emission factors of BC were calculated according to the fraction of these three particulate matters in relation to the total PM10 (Streets et al., 2001), this may be lead to the difference with the result of INTEX-B. A glaring discrepancy has emerged between the results of our study and RAINS. This discrepancy may caused by the method. RAINS calculated the vehicular emissions based on fuel consumption estimated by the RAINS-ASIA module, which used the fuel consumption in 1990 to predict the consumption in 2010. Fuel consumption based method was just used in early times to estimate the emission, and it inevitably led to uncertainties. The emissions in 2010 estimated in our study did not agree well with results calculated by Zhao et al. (except the NOX emission) either, because emission factors given in their paper were different from ours and there were some differences in vehicle classifications. For example, the unit of emission factor in Zhao's study is kg/tce, while in our study is kg/km. The Diesel and Gasoline car are divided separately in Zhao's study, but not in our study. Besides, the population of vehicles with each emission standards in our study is calculated by the newly registered vehicles, but no detail is described in Zhao' s study, and only the proportions of vehicle with each emission standards is shown in the supplement. Compared the estimated results for the year 2010 with the Vehicle Emission Annual Report released by the Vehicle Emission Control Center of Ministry of Environment Protection in 2011 (VECC-MEP), we found that our results were close to the VECC-MEPs', except the VOCs. However, RVs were included in our study, that is to say that emissions calculated in our study were smaller than the VECC-MEPs'. Since the source of the populations of vehicles and classifications were similar, these differences could be attributed to emissions factors and VKM. Vehicles emissions in BTH, YRD, and PRD regions had been calculated by some scholars and were also showed in table 5. Compared with these studies, differences could be found. These

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might have been caused by the sources of the VTM. In Zheng's study, the fuel ratio and VTM were from investigation and questionnaires. The VKM of trucks in our study was a little less than Zheng' s study, but the VKM of MC was larger than Zheng' s. Although the source of fuel ratio between Zheng's study and ours was different, there was little difference. It should be noted that emissions from RVs were significant but were neglected in Lang's and Huang's study, and the emission standards were out of consideration in Zheng' s study. Considering the old technology of vehicles registered earlier, emission factors of Euro 0 vehicles in our study were revised by referring previous studies, as discussed in Section 2.1.3. Therefore, big differences could be found in CO, NOX, and VOCs emissions, compared with these three studies. Emissions on the city scale were also compared in this study. For example, emissions in Hangzhou in our study were close to Wang's results, whereas emissions in Guangzhou and Xi'an were not. NH3 emission was just involved in Zhao' study, but it was much lower than our result, and this mainly caused by the differences in emission factors. At present, few researches have been conducted in vehicular emission of NH3, and this may lead to the underestimation of total NH3 emissions, therefore, more researches should be done on it.

Question 11: Section 4.2, page 4923: the authors analyzed the relationship between vehicular emissions and oil consumption in China. I am not sure what kinds of oil were included here. Except gasoline most oils (e. g. diesel, kerosene, etc.) were not consumed by vehicles in China.

Response 11: The gasoline and diesel were included in the oil consumption used in this section, and we added the corresponding introduction in section 4.2. Consumption of gasoline and diesel are accessible in the China Energy Statistical Yearbook compiled by the Department of Industry and Transport Statistics.

Question 12: Section 4.3, page 4923: except the urban area of some megacities (e, g. Beijing, Shanghai), the major NOx sources are still power plants and industries, which is different from USA and European countries. Therefore, satellite data of NO2 is not

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that suitable to verify China's vehicular emissions.

Response 12: It is difficult to evaluate the rationality of the spatial distribution, so we had to use the satellite data, which covered a wide range of China, to discuss the results generally. We really found some differences between the satellite data and our results, for example, the vehicular emissions in Tianjin, south of Hebei, and north of Shandong were less significant in 2010 compared with satellite data. To understand these differences further, we collected the coal consumption, which is also one of the most important contributors of fossil energy of NOX emissions. The statistical data showed that coal consumption in these areas ranked within the top five of the whole China.

Question 13: Section 4.4, page 4925: the scenario analysis of policy impact on vehicular emissions is weak in this study. I am not sure whether it could be deleted, because it less related to the major contents of this paper.

Response 13: In this study, we did some preliminary analysis to find out how the oil quality and emission standards had impact on vehicular emissions. We hope that this preliminary analysis would support some theoretical foundation to the vehicular emissions reduction in the future. These preliminary works could provide guide for our following work.

Question 14: Line 14, page 4927: the authors should provide the detailed probability functions of the key input parameters (e. g. emission factors, VMT and even vehicle population). Otherwise, readers could not evaluate the reliability of the uncertainty analysis.

Response 14: The probability functions is:

f<x|μ,δ>=1/($\delta\sqrt{2\pi}$)(exp((-(lnx-μ)ˆ2))/(2δˆ2))/x

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