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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Using a mobile laboratory to characterize the distribution and transport of sulfur dioxide in and around Beijing" *by* M. Wang et al.

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"General comments: The paper reports on using a mobile lab to take SO2 measurements in and the Beijing area to estimate fluxes of SO2 in the immediate region. Measurements were taken from August-September, 2008, coinciding with the Olympics. The mobile-based measurements were supplemented by three ground based measurements. While the mobile and fixed-site instruments supplied the SO2 concentrations, trajectory, wind direction and speed information was supplied by running HYSPLIT and WRF. The two are combined to give SO2 fluxes. They found varying levels of sulfur fluxes in the region, as one might expect. On the other hand, it was not apparent

what was leading to specific changes in fluxes, particularly from the same region at different times."

Response: We appreciate the referee 2 for precious comments to improve the quality of our paper. We have made extensive revisions according to your suggestions. Details of the changes can be found in the following responses.

"Major comments: My general concern with the paper is that they do not provide much context with their results. Is 1.56 kg/s a big flux? Does it make sense given the known/estimated emissions? How sensitive is the flux to the area chosen for assessment? Is this a level of concern for health or environmental reasons?"

Response: Thanks for the comments. We have thoroughly discussed the causes of the fluxes differences in days. In the section 3.3, three major impacting factors were attributable to the result: variations of emission patterns during the control and non-control period, variations of transport directions and dilution process on the way. Insight analysis on each cause has been made. Also, to estimate potential bias from flux calculation, we wrote section 3.5 to fully discuss possible uncertainty. In addition, the derived fluxes from the Ring Roads have been compared with reported references which were roughly equivalent to the emission rate from single big power plant or an industrial complex, thus, the magnitude is worth noting. The estimated fluxes have been compared with annual emissions from Beijing and surrounding city and provinces. We find that the influx of SO2 contributed a large amount to the emissions in Beijing, indicating the importance of regional transport of SO2. Meanwhile, the influx after transformation was also comparable to the emission inventory in Tianjin and Hebei province (section 3.4). Therefore, the measurements and flux estimation provide a meaningful way to understand the sources and contributions of SO2 during the measurement periods. The flux is sensitive not only to the changes of emission patterns due to the control policy but also to the transport directions in different source areas and dilution process on the way. This is worth of both environment and health concern because these pollution events occurred under emission control around the Olympics when the average SO2

concentration was expected low. Therefore, it is necessary for this study to find out the characterization and distribution of SO2 in regional transport and possible sources.

"A second concern is that a number of assumptions are made in this analysis, e.g., uniformity of concentration and winds. Both are not correct to some degree, possibly a large degree. Given all of the likely errors, what is the overall error in any one calculation? This should be provided. For one, I think it would mean that one significant figure is likely enough."

Response: Accepted. In section 3.5, we discussed potential errors that contributed to the deviations of flux calculation in terms of assumptions, accuracy of wind field in comparison to station network, vertical profiles of winds and SO2 distributions, updraft effects on high stacks, PBL modeling regarding to lidar, temporal fluctuations of wind field in the sampling period. The overall error is about 31%. This is still in the acceptable range in comparison to other studies (Ibrahim et al., 2010; Shaiganfar et al., 2011).

"Third (somewhat related to the first), the manuscript should provide a comparison of the expected SO2 fluxes (based on emissions) with the estimated fluxes."

Response: Accepted. We compared our estimated fluxes to the references. The derived fluxes of SO2 in the two days are at the similar level as the reported emission rate from power plants or industrial complex. The influxes was compared with the annual emissions in Beijing in both control and non-control period, indicating the transport of SO2 is of pivotal importance to the SO2 concentration in Beijing. We also retrieved the total SOx using SOR index from measured SO2 which implied comparable results to the annual emissions in the surrounding city or province of Beijing (section 3.4).

"Fourth, why does the estimated flux change with wind speed? They state it is due to changes in wind speed on observed SO2 concentration though that is not the underlying reason, that is just how the calculation is done. The underlying reason would be something like: 1) There is an emissions change (huge, in this case), 2) A weakness

in the calculation approach, 3) Errors in the measurements, 4) Errors in the modeling, or 5) A combination of those four and ones not identified. The paper should provide some insight as to what the reasons might be."

Response: Accepted. We provided thourough discussions on the potential errors in section 3.5 according to the suggestion.

"Additional comments: They use “may”, “could” and other non-definitive answers. Remember, unless you go through the hypothesis testing to show those can’t explain the results, it only says that the listed cause may be one of many. Little insight is provided. Provide some analysis that gives the reader confidence that the stated reason is a likely cause for the findings."

Response: Accepted. In this new version, we discussed the causes of SO2 variations in days in terms of the variability of emission pattern, variability of transport directions and dilution processes on the way which can be found in section 3.3. The aforementioned factors were resulting in ten-fold difference of flux in the two days. Besides, uncertainties for the flux calculations were stated in section 3.5 as well. These demonstrations are helpful to strengthen the confidence of our study results.

"A rationale behind the choice of the five days modeled should be provided."

Response: The rationale has been provide in section 2.3.

"As noted above, there really is not reason to provide three significant figures on the results. Two might be pushing it."

Response: Accepted, we retained one decimal for all the calculated results.

"What is “high standard” fuel."

Response: High standard fuel is the fuel that satisfy the vehicular emission standard equivalent to Euro IV. We provided (e.g. Euro IV) as supporting information in our text.

"You note the on-road measurements are used for two types of applications: examina-

tion of temporal/spatial trends and quantification of local and regional fluxes. There are more (exposures). "

Response: Accepted. So far as we know, three main applications are published using mobile laboratory. We re-wrote the sentence as follow:"On-road measurement platforms have been specifically designed and used for three types of applications: investigation of emission factors of individual vehicles by chasing study (Canagaratna et al., 2004; Herndon et al., 2005), examination of the temporal-spatial variations in air pollutants for exposure assessment (Bukowiecki et al., 2002; Weijers et al., 2004) and quantification of local emissions and regional transport flux (Johansson et al., 2009; Rivera et al., 2009)." .

"It is not apparent how the local turbulence influences the accuracy of measured data. Is the measurement accurate? If not, please explain why not."

Response: Our measurements were mainly conducted between urban and rural areas, the highway ring roads were far away from high buildings. Therefore, the influence by local turbulence(e.g. street canyon) was low. Besides, to avoid hotspots from nearby vehicles, we intentionally kept a distance (>10m) away from vehicles in front. Hence, we believe such influence was minor. This was also discussed in section 3.5.

"They say they make two hypotheses, I think they mean assumptions. A more thorough analysis of the assumptions should be provided."

Response: Accepted. We used "assumptions" in the text instead. Uncertainty due to assumptions was addressed in section 3.5.

"An API of over 100 does not imply adverse effects. The API is a scale chosen for communication and reflects some information about the severity of adverse effects. There is little question that adverse effects occur below this point. The government may find those effects reasonable. There is also little reason to bring in API's as being "in agreement" since the two may be based on different compounds. If you are going

to use API, you should provide what, exactly, the values noted mean in terms of SO2. "

Response: Accepted. We delete the text and figure related to API.

"Explain why it is obvious that SO2 on Sept. 4 was from the southern region... what about nearby?"

Response: In the revised manuscript in section 3.3, the source region of SO2 on 4 September was determined from southern mainland of China by backward trajectory, traveling though Henan, Shandong, Hebei provinces where amount of heavy industrial sources located.

"What do you mean by the flux calculations being reasonable with acceptable uncertainty. What is reasonable and what is acceptable? The answers to these questions vary with use and individual. Please define or just be more specific and quantitative and do not give such a subjective evaluation. "

Response: Accepted. Quantitative estimations for the errors have been thoroughly discussed in section 3.5.

"Grammar is in need of improvement, e.g., plurals of words, articles, etc.,"

Response: The manuscript has been improved by native English speaker.

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