Atmos. Chem. Phys. Discuss., 9, C10250–C10256, 2010
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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Latitudinal gradient and interannual variation of PM_{10} concentration over eighty-six Chinese cities" *by* W. J. Qu et al.

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Received and published: 28 January 2010

Response to Referee Comments: Latitudinal gradient and interannual variation of PM10 concentration over eighty-six Chinese cities

Referee #1 Comments and Responses

1. PM10 is set to 600 when API is 500. The authors should discuss uncertainty arising from this approximation, especially in north region where dust storms often impact PM in spring.

Answer: We agree that this approximation can introduce some uncertainty in the assessment. However, the instances when this happened during the study period were infrequent. For the full dataset, i.e., for all 86 cities, only twenty-five cities had maxi-

mum API records of API = 500. Furthermore, only four cities recorded more than ten days when API = 500; they were Lanzhou (47 days), Urumchi (36 days), Xining (24 days) and Beijing (12 days), and the days with API = 500 accounted for small percentages, about 1.9%, 1.5%, 0.98% and 0.49%, of the days with APIs (2451 days). Taken together, the other twenty-one cities had 57 records with a maximum API (API = 500). These included five cities (Harbin, Yinchuan, Dalian, Datong and Hohehot) with 4 to 9 days when API = 500, four cities (Xi'an, Chifeng, Shenyang and Shijiazhuang) with 3 days when API = 500, three cities (Changchun, Tianjin and Pingdingshan) with 2 days when API = 500, and nine cities (Anshan, Yantai, Qingdao, Lianyungang, Kaifeng, Hefei, Nantong, Luzhou and Chengdu) with 1 day when API = 500. Therefore, we would argue that the impact of this uncertainty should be quite limited. Nonetheless, we have added some discussion on this uncertainty to the revised manuscript.

2. PM10 is calculated from eq. 1 no primary pollutant is indicated. There are 40% of cases in south region, so again the authors should give a few words about data uncertainty in this case.

Answer: Based on the daily sub-pollution index (sPI) records we have collected for some cities, an inspection and comparison of the sPIs of PM10, SO2 and NO2 has shown that for these cases (API < 50 and no principal pollutant (abbreviation as Pprin) reported), PM10 pollution is most often associated with the highest sPIs. That is, for those cases, the APIs were most often a reflection of high PM10 loadings. Therefore for the days when no Pprin was reported, we assumed that PM10 was Pprin that day and deduced PM10 concentration according to equation (1). We have added an explanation of the uncertainties from this assumption to the revised manuscript.

3. Meteorology and terrain are key factors impacting PM10, so the authors should discuss these issues when spatio-temporal variation of PM10 is explained.

Answer: As suggested, some discussion concerning the impact of meteorology and terrain on PM10 concentration has been added to the revised paper.

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4. The median value is much better than the average here, especially in north china. One would expect small influence from inaccurate of PM10 on PM10 trend analysis when API is 500.

Answer: Yes, for PM10 trend analysis, we used the median value to avoid the influence of high values on the average. When API is 500, PM10 is set to 600, which is the maximum PM10 concentration in the dataset (although it is not the actual PM10 concentration). More important, this assumption does not influence the median PM10 concentration and the PM10 trend analyses presented here (which are based on the median values). Indeed, if this assumption has any influence, it may actually reduce the average PM10 concentration. Furthermore, as indicated in the response to comment #1 above, because the instances when API = 500 were infrequent, the influence of this uncertainty should be quite limited. We have added some discussion on this uncertainty to the revised manuscript.

5. The authors should provide strong evidence that different measures have been made during 2000-2006 in Beijing-Tianjing-Shijiazhuang area and its surrounding areas, if not, discussion of Olympic Games should be deleted.

Answer: This discussion has been deleted.

6. In section 3.7, trend is not independent of time interval selected in the analysis, so quite different trends of visibility or AOD from that of PM10 is not surprising.

Answer: Yes, the time intervals selected for the two studies were different, but during the same period as our study (2000 to 2006), the Wang et al. study suggested an increasing trend for the AOD in what the authors referred to as the “Asia (south)” region (which includes China, see Fig. 1 in Wang et al. (2009)). This is in contrast to the decreasing trend we found for PM10. Accordingly, we thought it was important to make note of this difference and to provide a possible explanation for the different trends observed. Some additional discussion has been added to the revised manuscript to help clarify this issue.

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Referee #2 Comments and Responses

I wonder about suitability of PM10 data at environmental monitoring sites for climate change studies from the following reasons.

Answer: The PM10 data alone are insufficient for in-depth climate change studies, and we did not mean to imply that they were. However, the results presented do provide insights into the spatial distributions and temporal variability of the atmospheric aerosol, and this improves not only our understanding of the aerosol but also the potential for climate effects. In addition, results of this study can contribute to a better understanding of air pollution in China, especially urban areas. The latter is necessary for the development and implementation of effective air-pollution control strategies.

1. Most of monitoring sites are located in a heavy air pollution area such as industrial area or central area of large city, so that the obtained data just reflect air pollution in a small area. It is just a point data on a surface as described in page 23155 (lines 2-9). Moreover, vertical distribution, at least aerosol optical thickness, of aerosols must be considered for climate change studies. I recommend a comparison of PM10 data with satellite aerosol data such as MODIS or with ground based observation such as AERONET. Although some discussions with TOMS aerosol index data are found, it is not sufficient because TOMS aerosol index is dependent on optical properties and vertical profile of aerosols. The discussion on the aerosol optical thickness is also just referring to other papers.

Answer: (1) Yes, the data represent points on a surface as Referee #2 has indicated, and this could be considered as the limitation of the dataset. Nonetheless, the data do provide useful information on the spatio-temporal distribution of the atmospheric aerosol, especially those areas most strongly affected by aerosol pollution. We agree that a comprehensive comparison between the PM10 study and AOD (AOT) measurements would be desirable; however this would be a major undertaking and would add more than a few pages of text, along with figures, etc to an already long paper. In ad-

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dition, the data as presented also provide information on aerosol loadings and trends in urban areas of China. (2) On the other hand, as suggested, a preliminary comparison of our PM10 data with ground based AERONET observation was added to the revised manuscript. Because of the limited overlap of the two datasets, this comparison was only made for three sites (Beijing, Guangzhou and Hefei). We would also note that Xia et al. (2006) presented a detailed comparison between AERONET AOT and PM10 concentration for 33 months in Beijing, and their analysis suggested generally good correlation between them, albeit with some differences in seasonal and diurnal variations. These results indicate that the AOT and the surface PM10 concentration measurements provide related but different information on the atmospheric particulates. Along these lines, the AOT measurements are influenced by a few of factors such as meteorology, transport, emission sources, and importantly the proportions of the different chemical aerosol components with scattering or absorbing properties. (3) A comparison of the surface measured PM10 data with the satellite aerosol data such as MODIS would likely be informative as well, but this would be a major undertaking, adding substantially to the length of the paper and we would argue beyond the scope of our study. Therefore, this kind of comparison would best be dealt with in a separate study.

2. Chemical components of aerosols may be different among the locations. Aerosols in the coast area where aerosols mainly consist of anthropogenic particles such as sulfate and black carbon are different from aerosols in inland area of western China where dust particles may be dominant even though the both observation sites are located along the same latitude. Chemical components of aerosols as well as size distribution are closely related to aerosol optical properties. Therefore PM10 mass concentration is insufficient for the study of aerosol impact on climate change.

Answer: (1) Yes, PM10 mass concentrations alone are insufficient for the study of aerosol impact on climate change; more detailed and specific information on the chemical components of the aerosol is needed. We recognize this as a limitation of the PM10

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dataset. However, through comparisons with results obtained from different methods, we can improve our understanding and knowledge of the spatio-temporal distribution of the atmospheric aerosol. These results provide only a first-order indication of where the aerosol impacts are likely to be significant. More to the point, a comprehensive analysis of aerosol impacts on climate would require detailed information on chemical composition and optical properties as a function of particle size along with a full set of meteorological and optical measurements. Data of this nature are only available from a few scattered sites and then for limited times. The development of other Chinese observation and measurement networks such as the China Atmosphere Watch Network will begin providing information on the size distribution of the aerosol components and the impacts of those materials on radiative forcing over China. (2) The important nature of the different chemical components of aerosols between the coast and inland locations (even though they are located along the same latitude), as Referee #2 has indicated, has been remarked in the revised manuscript when discussing the latitudinal gradient of the PM10 concentration.

3. Finally, it should be pointed out that this paper just shows spatial distribution of PM10 mass concentration and speculations for the distribution. For the latitudinal gradient of PM10, three reasons are discussed in page 23156 (lines 20-29). However, discussions are insufficient, and the more detailed analyses are required for the publication of this paper in ACP, for example, comparison with emission inventory data, and spatial and temporal analysis of precipitation, etc. Otherwise this paper only shows geographical map of air-polluted city.

Answer: Yes, the discussion is somewhat limited in places and speculative in others. Nevertheless, results of this nature, which represent the combined impacts of emissions, transport, dilution and removal on aerosol loadings over such a broad region of China, have not been presented previously to the best of our knowledge. We note that the relative influences of the emissions vs. removal mechanisms will vary from place-to-place, and a comparison of the PM data against emissions, precipitation etc.

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although potentially informative, is beyond the scope of the paper. Analyses of that nature would be appropriate for the future work, and the results we present may well form the basis for such studies. The revised paper now indicates that a specific comparison of the PM data against emissions and precipitation will be helpful to clarify this issue.

4. Specific comments: Page 23146, lines 10-11, 26: Referring to Zhang et al. (2003) and Chu et al. (2008), it is difficult to find detailed descriptions about API. The descriptions in these papers are almost similar to the present paper. More detailed descriptions are required.

Answer: API information from the website of the Ministry of Environmental Protection of the People's Republic of China (http://jcs.mep.gov.cn/hjzl/200604/t20060426_76155.htm) has also been cited. Accordingly, adequate information about API related with our study has been supplied in the revised manuscript.

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