Atmos. Chem. Phys. Discuss., 10, C13521–C13529, 2011
www.atmos-chem-phys-discuss.net/10/C13521/2011/

Atmospheric Chemistry and Physics Discussions

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Interactive Comment

Interactive comment on "Projections of air pollutant emissions and its impacts on regional air quality in China in 2020" *by* J. Xing et al.

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Received and published: 12 February 2011

We thank Mr. Z Liu for his comments on our manuscript that helped to improve the paper. Here we give a point-to-point reply to his comments. The manuscript is also revised accordingly.

1. I suggest the authors add a part 'current emission estimations' before Sect. 2.4 'Future emissions estimations', giving more detailed information on the 2005 base inventory, elaborating the advantages of their inventory over others

Reply: Thanks for the kind suggestion. We have another paper which gives the detailed description about the base year emission inventory as well as its validation compared to satellite and surface observation data (Xing et al., 2010).

Reference

Xing, J., Wang, S.X., Chatani., S., Cofala, J., Klimont, Z., Amann, M., and Hao, J.M. , 2010, Validating Anthropogenic Emissions of China by Satellite and Surface Observations, submitted to Atmospheric Environment

ïĆ§ Have the emission inventory used in current work been evaluated in chemical transport modeling studies before?

Reply: The base year emission inventory was validated through comparison of a regional air quality model (CMAQ) simulations with NO2 column retrieved from OMI, SO2 column retrieved from SCIAMACHY, AOD retrieved from MODIS, and ground observations of SO2, NO2, PM10, PM2.5 and its components. Model simulations were performed for year 2005. The model generally reproduces both spatial distribution and seasonal variation of tropospheric NO2 and SO2 column densities and AOD in China that have been observed by OMI, SCIAMACHY, and MODIS. The correlation coefficients between model simulated and satellite observed NO2 column densities, SO2 column densities and AOD over China are 0.85, 0.89 and 0.79, and the NMBs are -11%, -27%, and -27% respectively, which are comparable with the errors from satellite retrievals. Surface concentrations of NO2, SO2, and PM10 given by CMAQ model are also comparable with those observed in Beijing, Shanghai, and Guangzhou, with NMB ranging from 1%∼18%, -3%∼-25%, and -12%∼18%, respectively. The results suggest that the anthropogenic emissions of SO2, NOx, and PM10 used in this study are in line with both satellite and ground observations therefore are of acceptable accuracy.

ïĆ§ What are the uncertainties in the emission estimates, in terms of both total amount and spatial distribution? Uncertainties for some of the species have been suggested to be substantial (up to more than 100%) according to Zhang et al. (2009): e.g. ±31% (NOx), ±68% (NMVOC), ±70% (CO), ±132% (PM10), ±130% (PM2.5). What are the impacts of these uncertainties on the emission projections? ïĆ§ What are the advantages of this inventory, e.g. in terms of 'availability' of data, data quality, methodology,

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compared to other ones available in literature, e.g. Zhang et al. (2009) and all references therein?

Reply: We agree that all emission estimates have uncertainties. Efforts have been made to reduce the uncertainties in this study. First, data for emission factors were collected from field measurements performed by Tsinghua University and other published sources in China. The literature was thoroughly searched for published data for emission factors from domestic field measurements in power plants (Tian, 2003; Zhu et al., 2004; Yi et al., 2006; Zhao et al., 2008; Zhao et al., 2010a), industrial boilers (Wang et al., 2008; Li et al., 2008; Lei et al., 2008), and biomass and bio-fuel burning (Li et al., 2007; Li et al., 2010). A survey of the open burning of crop residues was conducted (Wang et al., 2008). Data on NMVOC emission characteristics measured in China were also collected which included stoves burning bio-fuel and coal, road transportation, certain solvent-use sectors, fugitive emissions from oil exploration and distribution, and open burning of biomass (Wei et al., 2008; Wang et al., 2009). High spatial and temporal resolutions of emissions from large point sources help improve the air quality model simulation. A unit-based methodology is applied to estimate emissions from large point sources including coal-fired power plants, iron and steel plants, and cement plants. The activity information includes geographical location, capacity, boiler type, starting year, annual running hours, fuel type, fuel quality, coal consumption per unit electricity-supply, and emission control technology of SO2, NOx and PM (Zhao et al., 2008; Lei et al., 2008). Detailed local emission information aggregated from the bottom-up investigation of individual power plants, heating boilers, and industries in Beijing (BJ), Yangtze River Delta (YRD) and Pearl River Delta (PRD) are also incorporated into the national emission inventory (Li et al., 2008; Zheng et al., 2009; Wang et al., 2010a). Compared to other ones available in literature, e.g. Zhang et al. (2009), the uncertainties in our base year emissions are lower. The uncertainties (i.e., 95% confidence intervals around the central estimates) of SO2, NOx, PM10, NMVOC in 2005 are estimated to be -14%∼12%, -10%∼36%, -12%∼42%, and -44%∼109% (Wei et al., 2009; Zhao et al., 2010b). Although the absolute emission amounts suf-

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fer from some uncertainties, the future emission trend is driven by the development of future economy as well as the pace of control strategy. The increase or reduction trends of future emissions will not change. For example, although the NOx emissions in 2005 suffer from ±20% uncertainty, the NOx emissions in 2020 are certainly going to increase 50% under [REF0] because of the economy growth. Therefore, the growth trend projected by this study provides important reference on how China's air pollutant emissions will change and how they will affect regional air quality in the future.

References

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Li, X. H., Duan, L., Wang, S. X., Duan, J. C., Guo, X. M., Yi, H. H., Hu, J. N., Li, C., Hao, J. M., 2007. Emission characteristics of particulate matter from rural household biofuel combustion in China, Energy & Fuels, 21, 845-851.

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lutants from Biofuel-Stoves in Rural China. Atmospheric Environment, 2009, 43(27), 4148-4154.

Wang, S. X., Zhao, M., Xing, J., Wu, Y., Zhou, Y., Lei, Y., He, K. B., Fu, L. X., Hao, J. M., 2010. Quantifying the Air Pollutants Emission Reduction during the 2008 Olympic Games in Beijing. Environmental Science and Technology, 44 (7), 2490–2496. DOI: 10.1021/es9028167.

Wei, W., Wang, S. X, Satoru, C., Klimont, Z., Cofala, J., Hao J. M., 2008. Emission and speciation of non-methane volatile organic compounds from anthropogenic sources in China, Atmospheric Environment, 42(20), 4976-4988.

Yi, H.H., Hao, J.M., Duan, L., Li, X.H., Guo, X.M., 2006. Characteristics of inhalable particulate matter concentration and size distribution from power plants in China. Journal of the Air and Waste Management Association, 56, 1243-1251.

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Zhao, Y., Wang, S. X., Nielsen, C. P., Li, X. H., Hao, J. M., 2010a. Establishment of a database of emission factors for atmospheric pollutants from Chinese coal-fired power plants. Atmospheric Environment, 44(12), 1515-1523.

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Zheng, J., Zhang L. J., Che, W. W, Zheng, Z. Y., Yin, S. S., 2009. A highly resolved temporal and spatial air pollutant emission inventory for the Pearl River Delta region, China and its uncertainty assessment, Atmospheric Environment, 43, 5112–5122.

Zhu, F. H., Wang, S., Zheng, Y. F., 2004. NOx emitting current situation and forecast from thermal power plants and countermeasures. Energy Environmental Protection,

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18, 1-5.

2. The model validation ïĆ§ The underlying uncertainties in the emissions need to be addressed here in the modeling as well, e.g. through sensitivity tests, as those used for assessing impacts in the paper, especially when the uncertainties might be larger than the trends, which often happen to be the case in China. Otherwise, it is hard to know if the projected trends make sense or not.

Reply: Since the emission is much related to the energy and human activity, its trend is driven by the development of future economy as well as the pace of control strategy, though the absolute value is suffering from some uncertainties. There're many successful applications in China to evaluation the control effectiveness through scenario analysis using CMAQ model, e.g. Streets et al. (2000), Wang et al. (2010). The purpose of this study is to identify the potential impacts of future emissions on the regional air quality and provide policy suggestions accordingly. Therefore, the scenario analysis is applicable. But we agree it's necessary to address the underlying uncertainties in the emissions. We have added some discussion about the limitation of this study in the revised manuscript, as follows. "There are several limitations in this study. First, the absolute values in this study suffer the uncertainties in the emissions, e.g., previous studies indicate that the uncertainties in our base year emissions are ±20% (NOx), ±50%(NMVOC), and ±121% (PM10), respectively. These uncertainties pose more difficulties for the accurate forecast of future air quality in China. However, this study aims to project the relative changes of future emissions according to the development of future economy as well as the pace of control strategy and the potential impacts of future emission on regional air quality in China. Therefore the results can provide important reference for the air pollution control policy-making."

Reference

Streets, D. G., Zhang, Q., Wang, Z. F., Hao, J. M., Wang, B. Y., Li, Z. P., Tang, X. Y., Zhang, Y. H., Fu, J. S., He, K. B., Wang, L. T., Jang, C. J., Yu, C., 2007. Air quality

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during the 2008 Beijing Olympic Games, Atmospheric Environment, 41, 480-492.

Wang, S. X., Zhao, M., Xing, J., Wu, Y., Zhou, Y., Lei, Y., He, K. B., Fu, L. X., Hao, J. M., 2010. Quantifying the Air Pollutants Emission Reduction during the 2008 Olympic Games in Beijing. Environmental Science and Technology, 44 (7), 2490–2496. DOI: 10.1021/es9028167.

ïĆ§ What are the resolutions of emission inventory and the meteorology inputs in the model? The resolution of the model (grids) is high (36x36km with a 12x12km nested domain), but do the emission and meteorology inputs have consistent resolutions? The emission inventory seems to be compiled on a province level (Figure 4); how is it regrid into the model resolution to reflect the hot spots, say, urban centers?

Reply: The resolutions of emission and meteorology inputs are consistent with CMAQ resolutions, that is, 36x36km with a 12x12km nested domain. From the bottom-up investigation of individual power plants, heating boilers, and industries, we locate the emission source to exact spatial grid based on the spatial information with precise latitude and longitude. For area sources, representative index (such as GDP, population, network) has been chosen as the weighted factor, distributing emission value from coarse grids into fine grids. A good reference for gridding method is Woo et al. (2003).

Reference

Woo, J.H., Baek, J.M., Kim, J.W., Carmichael, G.R., Thongboonchoo, N., Kim, S.T., and An, J.H., 2003. Development of a Multi-Resolution Emission Inventory and Its Impact on Sulfur Distribution for Northeast Asia. Water Air and Soil Pollution, 148(1-4): 259-278.

ïĆ§ Has this current model formulation been evaluated against any observation? Although the authors mentioned that in sect. 3.1, CMAQ as a model has been implemented before in China, but those previous studies were using different emission inventories with different resolutions for different regions. Some of the previous studies

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actually encountered problems of the inaccurate emission inventories, especially VOCs and PM (Fu et al., 2009). Does the model in this study have the same problem?

Reply: As we discussed before, we have validated our CMAQ system. Generally the CMAQ model with our emission inventory gives good performance. There is overestimation for SO2 and underestimation for PM10 in some industry-intensive areas because of the inaccuracy of temporal allocations. CMAQ model also significantly underestimates PM2.5 concentration in Beijing, mainly due to the limitation of SOA formation mechanism used in the model and underestimation of primary OC and EC emissions. Therefore more efforts shall be made to improve the primary emission estimates of OC and EC, as well as the temporal allocation factor of emissions. We have added some discussions on this in the revised manuscript, as follows. "Secondly, the model biases may affect the results of future projections on air quality. For example, the limitation of SOA formation mechanism used in the model may underestimate the impact from the future growth of VOC emissions, which is considered as another important species to fine particles. Nevertheless, the model has the ability in simulating the multi-aspects of air quality including gas-phase, particles and deposition simultaneously."

ïĆ§ What are the emission input species for aerosols, e.g. OC, EC, PM? The authors only mentioned PM10 in emission inventory (2.4.3). So does the emission inventory have all the aerosol species used in CMAQ?

Reply: The emission inventory includes PM10, PM2.5, OC, and EC. The OC and EC emission control implementation is same as that for PM. Due to the limitation of page, we did not provide OC and EC results in manuscript, but it is considered in our CMAQ simulation.

3. Other than the bar plots in current form (Figures 6,7,8), I suggest the authors also consider spatial distribution of the responses on a map, which I feel might be more straightforward and interesting to the readers.

Reply: Thanks for the good suggestion. We have added the spatial distributions in

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different future scenarios in the revised manuscript.

4. None of the references in Sect. 3.1 can be found in the reference list. Please correct.

Reply: We have added all the missed references in the revised manuscript.

Please also note the supplement to this comment:
http://www.atmos-chem-phys-discuss.net/10/C13521/2011/acpd-10-C13521-2011-supplement.pdf

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Interactive comment on Atmos. Chem. Phys. Discuss., 10, 26891, 2010.

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