Atmos. Chem. Phys. Discuss., 13, C6158–C6164, 2013
www.atmos-chem-phys-discuss.net/13/C6158/2013/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "NO_x emissions in China: historical trends and future perspectives" *by* B. Zhao et al.

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Received and published: 26 August 2013

Along with implementation of emission control on SO2 and primary PM, NOx pollution has become a new challenge for China's air quality improvement. Under the national policy of energy conservation and emission control, the combustion technologies, energy efficiencies and emission control devices for certain sources are changing dramatically in recent years, making it complicated to estimate China's NOx emissions. This manuscript focuses on such changes and conducts a comprehensive analysison the historical and future trends of China's NOx emissions. Reasonable results are presented with reliable methodology of emission inventory study. Before it can be published, however, I think some issues of the manuscript should be clarified or revised.

Response: We thank the reviewer for his/her positive attitude towards the contents and quality of our manuscript. We also appreciate his/her comments which help us improve the quality of our manuscript. We have taken all the comments of the reviewer to improve our manuscript.

1. As the authors mentioned, there are some published papers working on the NOx emission trends since 1995. The methodology applied is similar and even the resultsare close. I suggest the authors clearly state what the progress they've made on their estimate for historical trends of NOx emissions.

Response: We thank the reviewer for this comment. Firstly, this paper presents a historical NOx emission inventory for China during 1995-2010 using a consistent model structure and detailed Chinese data sources for activity data and emission parameters. Secondly, compared with previous studies, our model has more detailed representation of energy technologies (see Table 3, Figure 1, Figure 2, and Figure 3 of the revised manuscript), considers the dynamic changes of energy technology mix and efficiency of each technology, and closely couples the energy technologies and end-of-pipe control technologies. In this way, we not only obtained more reliable emission estimates, but also facilitated the projection of future energy consumption and pollutant emissions envisaging various policies with consistent model structure. Thirdly, nearly all the previous studies neglected the emissions from several "small industries". This study improved the emission inventory of small industries including the production of bricks, glass, lime, ceramics, and nitric acid by reanalyzing the activity levels and emission factors (see section 2.1.1 and section 2.2).

We have clearly state the progress accordingly in the revised manuscript (Page 2, Line 26-30; Page 3 Line 27 to Page 4, Line 10). Please find the revised manuscript in the supplement.

2. Regarding the future estimate, I am not quite convinced on the provincial and gridded emissions. In my opinion, even the prediction of energy use and emission factors

at the national level is quite uncertain. How did the authors differentiate those parameters at provincial level? I think it needs more explanation.

Response: We appreciate the reviewer's valuable comment. We agree with the reviewer that it is difficult to fully address the different policies in different provinces in the future. In this study, we differentiated the assumptions at provincial level where we are fairly sure that significantly different policies would be applied depending on provinces, otherwise consistent assumptions were made throughout the country. We present below some examples of different assumptions at provincial level in this study.

For power plants, the progressive control strategy (BAU[1]/PC[1] scenario) was developed based on the governmental plan of China, which set more stringent requirements for "key regions" (the Greater Beijing region, the Yangtze River Delta, and the Pearl River Delta). The 12th Five Year Plan (for the period of 2011-2015) requires that all new-built thermal power plants be equipped with low NOx combustion technologies and flue gas denitrification (SCR/SNCR). Existing thermal power plants should be upgraded with low NOx combustion technologies, and flue gas denitrification is required for large units ($\geq$300 MW). In the "key regions", nearly all coal-fired power plants are requested to be equipped with flue gas denitrification (The State Council of the People's Republic of China, 2010, 2011). Similar assumptions were made for industrial boilers based on the governmental plan (The State Council of the People's Republic of China, 2011). In the progressive control strategy, newly built industrial boilers are required to be equipped with LNB across the country, and existing boilers in the "key regions" are beginning to be retrofitted with LNB during 2011-2015. Therefore, by 2015, the penetrations of LNB are predicted to be 41% and 23% in the "key regions" and other regions, respectively.

In the domestic sector, we differentiated the assumptions on energy service demand and technological structures at provincial level considering the notably different climate, life style, and energy structure in different regions. Heating intensity (heating demand per unit building area) is influenced by climate, the proportion of heating area, heating

service quality, thermal insulation of the building envelope, and heating duration. As an integral effect, the heating intensity of urban area in north China is expected to decrease, while that of rural area and transition region (between north and south China) is expected to increase. The technology mix for heating also differs greatly depending on provinces. In urban area, heating demand is mainly supplied by district heating, coal-fired boilers and coal-fired stoves in north China, while electric heater and heat pump dominate the heating technologies in the transition regions. Under the policy scenario, we assume coal-fired boilers and coal-fired stoves would be gradually replaced by district heating, gas-fired boilers and gas heater in north China, while heat pump is the major technology to be promoted in the transition regions.

In the transportation sector, the implementation of vehicle emission standards in Beijing and Shanghai has been 2-3 years ahead of the national legislation, and such a trend is assumed to continue in the future (Wang and Hao, 2012). We have distinguished Beijing and Shanghai from other provinces both for the estimation of historical emissions and for the development of future scenarios.

In the revised manuscript, we have added the explanations above or revised the original descriptions accordingly. (Page 16, Line 12-18; Page 17, Line 4-8; Page 10, Line 18-22; Page 11, Line 4-10; Page 18, Line 16-18 in the revised manuscript)

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Wang, S. X., and Hao, J. M.: Air quality management in China: Issues, challenges, and options, Journal of Environmental Sciences-China, 24, 2-13, Doi 10.1016/S1001-0742(11)60724-9, 2012.

3. For transportation, the authors listed the sources of emission factors, but the readersare still not quite clear how those factors are compiled as shown in Table 5. In particular, the EF from non-road sources are more uncertain. Moreover, although starting of Euro I-III are quite uniform over the country (except for mega-cities like Beijing and-Shanghai), the application of Euro IV and after seems to vary considerably by region. How do the authors consider such effects on the emission factors and emissions at provincial (if any) and national level?

Response:

We thank the reviewer for this comment. For on-road vehicles, there have been fairly large numbers of measurements in the last decade. Our emission factors are compiled mainly based on some systematic measurement studies, e.g., Huo et al. (2012a) and the literatures therein for light-duty gasoline vehicles and Huo et al. (2012b) and the literatures therein for diesel vehicles. Considering the complex real-life driving conditions and the detailed classification of vehicle types in the our model structure, we also referred to some studies of vehicle emission estimation using transportation emission models, including Cai et al. (2007), Xie et al. (2006), Li et al. (2003), and Greenhouse Gas and Air Pollution Interactions and Synergies (Gains)-Asia project (available online at http://gains.iiasa.ac.at/models/). The final emission factors, including uncontrolled factors, and controlled factors under Euro-âĚă, Euro-âĚą and Euro-âĚć, were derived using field measurements as a starting point, which were subsequently adjusted based on the results of transportation emission models to refect the complicated driving conditions in China. As for non-road vehicles, we agree with the reviewer that their emission factors are quite uncertain, as there is only limited number of studies where emission performance of non-road vehicles has been analyzed. We rely on Tian (2003) for trains and agricultural tractors and conveyers, Wang et al. (2007) and Tian (2003) for agri-

cultural and construction machinery, and Ding et al. (2000) and Song (2007) for inland waterway ships. It is valuable to do more measurements of the emission characteristics of non-road vehicles in the future. We have added the explanations accordingly in the revised manuscript (Page 14, Line 5-23).

We assumed uniform implementation of new vehicle emissions standard across the country except for megacities like Beijing and Shanghai, which have been 2-3 years ahead of the national legislation, and such a trend is likely to continue in the future. We have differentiated Beijing and Shanghai from other provinces in this study. We agree with the reviewer that the application of Euro IV and after seems to vary by region. We have notified the importance to further address this issue in the revised manuscript. (Page 15, Line 23-27; Page 18, Line 16-18 in the revised manuscript)

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I suggest the paper be accepted with minor revisions.

Response: We thank the reviewer for supporting the publication of our manuscript. We also appreciate his/her comments which help us improve the quality of our manuscript. We have addressed the reviewer's comments above.

Please also note the supplement to this comment:
http://www.atmos-chem-phys-discuss.net/13/C6158/2013/acpd-13-C6158-2013-supplement.pdf

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Interactive comment on Atmos. Chem. Phys. Discuss., 13, 16047, 2013.