Atmos. Chem. Phys. Discuss., 9, S2705–S2712, 2009
www.atmos-chem-phys-discuss.net/9/S2705/2009/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Asian emissions in 2006 for the NASA INTEX-B mission" *by* Q. Zhang et al.

Q. Zhang et al.

Received and published: 6 July 2009

The paper deals with the compilation of an anthropogenic inventory of Asian emissions for eight major chemical species in the year of 2006, which is a good complement to the previous studies. The authors illustrate monthly variations of China's emissions, which is an important contribution to the determination of China's emission characteristics. However, the methodology, data compilation, and discussion within this context all aim at China's emissions, and this paper has little discussion about emissions from other Asian countries, the comparisons among these countries, and spatial distributions of Asian emissions. Therefore, there is some bias in the whole context which stresses the situation in China, resulting in the noncoincidence between the title and the content.

Response: The purpose of this paper is to provide an update of previous emission inventories for Asia to the year 2006 to be used to drive atmospheric modeling and assessment studies under the NASA INTEX-B program. The overall objective was to generate gridded emissions data that would most accurately represent the real-

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world emission situation at the time of the NASA INTEX-B field campaign in 2006. By studying the composition of Asian emissions in 2006 and growth since the last NASA TRACE-P emission inventory for 2000, it was clear that emissions in China needed to be re-estimated. Emissions from China comprise roughly 60 percent of Asian emissions for most species, and any error in China's emissions would dwarf any errors in the emissions from other countries. It is for this main reason that the methodology part of this paper stresses emissions from China. For other countries, we adopted a different approach from TRACE-P, as recommended to us a by a number of emission researchers in relevant countries. They recommended, and we agreed, that we would be better advised to use national emission estimates developed within the countries themselves that would be: (a) more accurate than we could estimate ourselves, (b) endorsed by the national governments, and (c) obtainable with minimal expenditure of resources. This we have done, but we cannot fully describe the methods used because they are not always available to us – we only can reference relevant literature where it exists. For other countries, where detailed local inventories do not exist, we grew emissions in accordance with known patterns of growth in economy and other proxy factors. This is a simple approach that does not require extensive documentation. It is for these reasons that the methodology and results sections stress the new work that was performed for China. Nevertheless, the paper does present detailed tables of emissions in all Asian countries (Table 8) and gridded Asia-wide maps of emissions (Figures 8 and 9), thus the title is indeed descriptive of information contained in the paper. In summary, the paper presents emissions for all of Asia, as the title indicates, but the methodology and results sections focus on by far the most important and controlling component of those emissions – emissions from China, for which we have developed new estimates using a new approach and new data. We hope the reviewer can appreciate this.

In the methodology part, authors claimed that they have implemented six aspects of improvements. Actually, most of them (improvements a, b, d, and e) are not innovative, but are methodological transplantation from authors' own or others' research. For ex-

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ample, regarding the estimation of size-fractioned primary PM emission inventory, the authors should clarify what improvements have been achieved based on their previous methodologies (Zhang et al. (2006, 2007a)) that led to an improved inventory.

Response: As the paper states, we implemented six aspects of improvements to the previous TRACE-P inventory to improve it. We did not state that all six improvements were innovative and had never been described before. Naturally, when undertaking this work, we made sure to implement methodological improvements that we had developed for Asian emissions estimation since the TRACE-P work was done nine years ago. These improved methods had been described elsewhere in specialized studies of CO emissions, size-resolved PM emissions, and NOx emissions, as referenced in the paper. As can be imagined, when we apply an improved methodology that was developed and tested specifically for CO emissions, it also improves the description of emissions of other species to some degree.

The authors described their improvements of methodology by saying "We update China's emissions to the year 2006 with these new methodologies. Second, we update emissions for other Asian countries to the year 2006 following the methodology of the TRACE-P inventory but using the most recent statistics available. Third, we incorporate the best available datasets for some selected regions, where good national inventories exist that are thought to be more accurate than the TRACE-P inventory, being built on local data sources and local knowledge." Why did not the authors use the improved methodologies to estimate all the other studied Asian counties as they did for China? Different methodologies tend to increase the difficulties in comparing emissions from China and other countries in Asia.

Response: The simple answer to this question is that it would require a very large expenditure of additional resources to implement the new methodology for all countries of Asia. If one examines the breadth of information acquired and used in this paper for the development of new emission estimates for China, one can understand that this amount of information would need to be multiplied by a factor of 21 to do all the

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countries of Asia in the same way – and the majority of these countries do not possess the necessary information required to implement the methodology in any case. And there is little point to adopting that approach when most of these countries contribute little to the Asian total. As we explained in the answer to the first question, in discussions with emission experts in other countries, it was resolved to take a different approach that would be more reliable, more acceptable to national governments, and far less demanding on resources. The purpose of this work is not to enable country emission estimates to be inter-compared but rather to assemble an emission dataset for Asia that would be most representative in magnitude and spatial distribution of the period when INTEX-B experimenters would be measuring pollutant concentrations in the northeastern Pacific region. In some sense, it is the total flux of pollutants leaving the Asian continent at a given point in time that is of greatest importance and subject to test through measurement and modeling.

As for the determination of activity rate, the authors stated that "Data inconsistency in Chinese energy statistics downgrades the accuracy of emission inventories that largely rely on statistics (Akimoto et al., 2006)". However, they still chose activity rate data from China Energy Statistical Yearbook. This is a contradiction and the uncertainty of the accuracy for these activity rate data is not evaluated.

Response: It should be understood that in our work we critically evaluated the quality and reliability of current Chinese energy statistics and applied several adjustments to the data contained in the China Energy Statistical Yearbook. These include: using coal consumption data in the provincial energy balance tables of the China Energy Statistical Yearbooks (CESY) to reflect the actual coal production and consumption; using diesel consumption data in the national energy balance table of CESY to avoid the "lost diesel" from inter-province transportation; and a model approach for fuel consumption for each vehicle type, as these data are not available in statistics. Other researchers often use the statistical data without any adjustments. So this is not a contradiction. In Section 3.2, Section, 3.3, and Section 4.5 of Zhang et al. (2007b), we explained why

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those approaches were thought to better represent the real-world situation in China.

(Zhang, Q., et al.: NOx emission trends for China, 1995-2004: The view from the ground and the view from space, J. Geophys. Res., 112, D22306, doi:10.1029/2007JD008684, 2007b.)

As for the estimation of emissions from other countries in Asia, activity data for the year 2006 are extrapolated from 2000-2004 IEA energy data using the average growth rate during 2000-2004, and the accuracy of the results is certainly questioned. So, it is necessary for the authors to conduct quantitative uncertainty analysis regarding these problems.

Response: This is a commonly used method when developing emissions for large field campaigns, which require emission inventories to be representative of the real-world emission situation at the time of the campaign. It is no good to provide emissions that are five years out of date, for example. Because statistical data have a lag time of 2-3 years in most countries, we rarely have the luxury of being able to use current statistical data in developing emissions for field campaigns. Data for the most recently available year must be extrapolated to the present. For the TRACE-P inventory, we used this same method to develop activity data in 2000 by extrapolating 1995 data. The post-mission data analysis indicated that the TRACE-P inventory performed quite well, though we agree that this method will definitely introduce a level of uncertainty. In the case of the INTEX-B inventory, the uncertainties from the extrapolation of energy data were mainly confined to the Southeast Asia region. If this extrapolation gains 10 percent bias per year (a high-end estimate for a short-term extrapolation), the bias from this method on the final emission estimates could be about 20 percent for Southeast Asian countries. This translates to about 2-5 percent for Asia as a whole. We have added a note in the text to warn users about this issue if they intend to use the inventory specifically for Southeast Asia.

In the discussion part, some of their results are close to those from other studies, but

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it is does not mean that the accuracy of the estimates is high. Therefore I suggest the authors should conduct a quantitative uncertainty analysis of their inventories to explain the quality of their work and the reliable ranges of inventories.

Response: We have conducted an uncertainty analysis for China using exactly the same method as was used in the TRACE-P inventory (propagation-of-errors method) and added it to the text. This analysis shows improvements to the accuracy of the emission estimates since TRACE-P. It is impossible for us to conduct such an analysis for the whole of Asia, since we use several local emission inventories and their uncertainties are not known. However, in order to add confidence to the present inventory estimates, we have added a new section to the paper that reports on the results of related INTEX-B and other studies that have used this inventory. This new section is called "Applications and Evaluations of the Inventory", and it summarizes the relevant studies and the implications for the present inventory.

Besides, here are some more specific comments for the paper:

(1) Page 4, Line 15, "Emissions of methane (CH4) and ammonia (NH3) were not updated from TRACE-P in this work, because their sources are dominated by agricultural activities that have not changed significantly in recent years." The authors must provide convincing evidence to support their statement and explain clearly why it is not necessary to update the emissions of methane and ammonia.

Response: We made a decision early on in the INTEX-B program not to include updates to methane and ammonia emissions. The major reason was that we did not expect these emissions to have changed much in recent years. They are not driven by the same kinds of economic forces that have caused the large upsurge on emissions of some species in Asia since 2000. The REAS inventory presented the recent trends of CH4 and NH3 emissions in Asia (Ohara et al., 2007). They estimated that CH4 emissions in Asia were 89.9 Tg in 2000 and 90.3 Tg in 2003, an increase of just 0.4 percent in three years; and NH3 emissions in Asia were 28.1 Tg in 2000 and 28.4 Tg

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in 2003, an increase of 1.0 percent in three years. We have added this reference into the revised paper. (Ohara, T., Akimoto, H., Kurokawa, J., Horii, N., Yamaji, K., Yan, X., and Hayasaka, T.: An Asian emission inventory of anthropogenic emission sources for the period 19808211;2020, Atmos. Chem. Phys., 7, 4419-4444, 2007.) Also, neither NH3 nor CH4 were high priorities of the INTEX-B mission (Singh et al., 2006). It was not expected that ammonia would be measured on-board the aircraft, and even though CH4 would be measured, it was not an important species in the chemical modeling world due to its long lifetime. (Singh, H. B., Brune, W. H., Crawford, J. H., Fuelberg, H., Jacob, D. J.: The Intercontinental Chemical Transport Experiment - Phase B (INTEX-B): An update, 2006.) Therefore we were advised by INTEX-B science team leaders to treat these two species as of lowest priority in developing the new INTEX-B emission inventory. For these two reasons we determined to hold their emissions constant at TRACE-P values.

(2) Page 7, Line 4-5, there are some data obtained through "personal communication", please annotate the method used or some necessary information in that personal communication to justify the credibility of the chosen data.

Response: We have deleted all references to "personal communication"; and replaced with references provided by our colleagues in these countries. The following references for Taiwan and Korea inventories were added: Fu, J.S., Yeh, F.L., Jang, C.J., Chen, R.J.C., and Chuang, M.T.: Air quality modelling: an investigation of the merits of CMAQ in the analysis of trans-boundary air pollution from continents to small islands. Int. J. Environ. Technol. Manage., 10,150-166, DOI: 10.1504/IJETM.2009.023520, 2009. NIER (National Institute of Environmental Research of Korea): Annual Report for The 5th year's Joint Research on Long-range Transboundary Air Pollutants in Northeast Asia (277pp), Government Publication Registration Number: 11-1480083-000286-10, 2005. NIER (National Institute of Environmental Research of Korea): 2006 Greenhouse Gas and Air Pollutants Emissions in Korea, 2008

(3) Page 17, Line 21, "Table 3b" should be "Figure 3b".

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Response: This has been corrected.

(4) Page 18, Line 23, "OC emissions decreased by 9 percent, but this cannot be viewed as a real emission decrease, because in this 2006 inventory, we used lower estimates of emissions from Reddy and Venkataraman (2002a, b) than the TRACE-P estimates." The authors must clarify the reasons for using the estimation from Reddy and Venkataraman (2002a, b) instead of some other recent research, and what the emission decrease of 9 percent represents.

Response: As indicted throughout the paper, we have not only adopted real trends in emissions since the 2000 TRACE-P inventory, but we have also improved data and methodologies where we know of shortcomings in the original TRACE-P methodology. From comparison work we have done, we know that Reddy and Venkataraman adopted improved emission factors for OC and some other species, based on new measurements conducted by their research group in the field and in the laboratory. We felt that it was important to reflect these new data in the INTEX-B inventory. Their research group was willing to share their inventory with us, so we agreed to this. Reddy and Venkataraman (2002a, b) estimated that OC emissions in India were 1.0 Tg in 1999, much lower than the TRACE-P estimate of 2.2 Tg in 2000. The main reason for this difference is that Reddy and Venkataraman (2002a, b) used lower OC emission factors for biofuel combustion. We have added text to the revised manuscript to explain this.

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 4081, 2009.

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