

Interactive comment on “Process analysis and sensitivity study of regional ozone formation over the Pearl River Delta, China, during the PRIDE-PRD2004 campaign using the CMAQ model” by X. Wang et al.

X. Wang et al.

xswang@pku.edu.cn

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Response to Reviewer #2

Thanks for your constructive comments. The followings are our responses.

General comments:

(Q1) The manuscript describes an air quality model study with a nested model system over the Pearl River Delta in China, a region with poor air quality. The manuscript is well structured and provides a comprehensive analysis of a selected period in October 2004

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where a field experiment took place in this region. Some aspects in the manuscript could be clarified as outlined below. After taken these clarifications into account, I recommend publishing this manuscript as ACP paper.

(A1) Thanks for your general comments.

Specific Comments:

(Q2) The authors use many abbreviations throughout the manuscript. Even though they are explained, it is sometimes difficult for the reader to have all these abbreviations in mind. Therefore I recommend to write the full names for those which are only seldom used, e.g. OPE, IPR. Not every expression needs an abbreviation.

(A2) We have double-checked the abbreviations used in the manuscript and replaced some rarely used abbreviations with their full names (e.g., OBM, MRF, RRTM, and FDDA). We removed the following abbreviations from the text and but kept them in the tables or figures: CHEM, HTRA, VTRA, DDEP, N075V100, N100V075, and N075V075. We kept IPR and OPE since they are frequently used in the context. IPR (integrated process rate) is a key technique used in simulated data analysis, and OPE (ozone production efficiency) is one of major issues addressed in the manuscript.

(Q3) introduction: CTM studies over Hong Kong are cited, but references to modeling studies over the Pearl River Delta are not cited. As it is mentioned that limited studies are reported and 3-D studies have rarely been performed, references to such studies should be provided.

(A3) The studies reported by Wang et al. (2005) and Wei et al. (2007) are 3-D CTM studies over both the inland PRD region and Hong Kong. We have briefly described their works in the manuscript. For a clear expression, we changed the sentence in lines 13-15 as the following:

“In spite of the works by Wang et al. (2005) and Wei et al. (2007), there are still very limited studies to address these issues for O₃ episodes over the inland PRD region.”

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(Q4) section 2.1: It should be clarified how the MM5 model is set-up over the largest domain. With NCEP data only or additionally, with data from the field experiment? In addition, it is not clear if the smaller domains receive the meteorological initial and boundary condition from the respective domain around it or always from the largest domain. If so, it remains unclear why the 12 km resolution model simulation is carried out as all the presented model results seem to be from the 4 km resolution simulation.

(A4) The meteorological simulations on the MM5 triple-nested domains are configured with the same physics options as described in section 2.1, and run by one-way nesting. The NCEP data and the available meteorological observations from the field campaign are used to prepare the initial conditions for all the three domains for the MM5 initialization. And all the data (including NCEP data and from the field experiment) are also used to prepare the boundary conditions (BCs) for the 36-km coarse domain, whereas the BCs for the 12-km domain are derived from the output of the 36-km domain, and BCs for the 4-km domain are based on the results of 12-km domain. The PRD region is of the most interest in this manuscript, therefore, all the presented model results are from the simulation over the 4-km domain.

(Q5) section 2.1: The emission inventory of Streets et al. (2003) has been set-up for the year 2000. What changes happened in the Pearl River Delta region from 2000 to 2004? As economy and traffic volume and associated emissions are changing rapidly in China, it would be helpful to discuss briefly such potential influences. In addition, does biomass burning, which is not included in the inventory has any effect in this region during the autumn season?

(A5) Economy and traffic volume changed rapidly in PRD from 2000 to 2004, which resulted in the changes in source emissions and further influence the O₃ pollution over the region we studied. Considering the above changes in emissions and their potential influences, the TRACE-P emission inventory for the year 2000 were only used for the simulation in 36-km coarse domain, whereas a local inventory developed specifically for year 2004 were used for simulations in 12-km and 4-km grids. This local inventory

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included the influences of the economy, population and traffic volume as well as other activity parameters relating to emissions over Guangdong province and PRD in 2004. The use of year 2000 inventory at 36-km domain will affect the simulation in inner domains only in boundary conditions (BCs). However, this impact would be very limited since the large coverage of our 12-km domain and less emissions from near distance of its outside.

In addition, the unique topography is also favorable to minishing the influence outside PRD. PRD lies in the central southern coastal part of Guangdong province of China. The landscape consists of a flat plain between the Nan Ling Mountains in the North and the South China Sea in the south. PRD is surrounded by hills in the east, west and north (Zhang et al, 2008). The mountains would block long-range transport of the polluted air mass from the outside into the PRD region under weak synoptic weather conditions dominating inland PRD with northerly winds during the campaign. Therefore, the influence of the uncertainties the TRACE-P emissions on the PRD region, propagated mainly through northern BCs in the October, would be further weakened.

The biomass burning is considered in the TRACE-P inventory, divided into three major categories (forest burning, grassland burning and the burning of crop residues in the field) (Streets et al., 2003). The biomass burning emissions in the local emission inventory for Guangdong province were estimated based on the investigation by Cao et al. (2005) (which developed an emission inventory of biomass burning over China for the year of 2000, including the emissions of SO₂, NO_x, NH₃, CH₄, CO, VOCs, EC and OC from crop residue, firewood, forest and grassland burning) and the annual data of crop residue production and consumption in 2004 from statistical books (National Bureau of Statistical of China, 2005a, b). Although we considered the burning of crop residues over the areas characterized agricultural land-use, we had limited exact information of the place and time of biomass burning occurrence, which would cause the uncertainties in the corresponding emission estimation and further influence the simulated levels of ambient pollutants.

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(Q6) section 2.2: what is the performance of the MM5 simulations in the other resolutions, which influence the simulation in 4 km resolution?

(A6) We have added the performance of the MM5 simulations in the 36-km and 12-km domains to Table 2.

Table 2. Quantitative performance statistics for the MM5-simulated meteorological parameters against surface observations during 1–31 October 2004 (See the supplement).

(Q7) section 3: even though model results of ozone, NO₂ and VOC compare reasonably well with observations at the measurement sites, a more thorough discussion of the deviations between model results and measurements would raise the value of the Manuscript

(A7) We added the followings in Section 3.1 to extend our discussion on the deviations between model results and measurements of O₃ and precursors:

“The measurements of NO_x and VOCs are greatly influenced by local emissions. October is harvest season for agricultural crops in PRD and biomass burning in open fields was significant and was observed during the campaign. Although the emissions by burning crop residues were considered in the inventory, an exact estimation of precursor emissions was difficult due to the limited information on the details of burning events (i.e., place and duration of biomass burning, amount of burned crop residues), which resulted in the uncertainties in the simulated precursors concentrations and O₃ levels as well, especially at rural sites (e.g., Tianhu, Wanqingsha and Xinken). Another important uncertainty in estimating VOCs emissions comes from the lack of local representative emission factors of VOCs from industrial and domestic solvent use, which also accounts for the under-prediction of ambient VOCs concentrations, especially for aromatic levels. Nighttime vertical diffusions are not easily simulated by current mesoscale meteorological models, especially over the complex topography and land use in PRD, which is an important reason for higher deviations of precursor levels

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between model results and measurements during night and early morning. In addition, observations reflect the on-site levels of ambient pollutants, whereas the model results represent the concentrations averaged in a grid cell with a horizontal resolution of 4 km, different spatial resolution is also a factor causing the deviation of simulations from observations.”

(Q8) section 3.1: table 3: it is unnecessary as it consists only of one row and expect one number, the others are already mentioned in the text

(A8) We added the similar statistics for NO₂ and NMHCs evaluation in Table 3. In addition, we removed the cut-off of 40 ppb for the O₃ performance statistics. For more detailed discussion on the removal, please refer to the response to the second question of reviewer #4.

Table 3. CMAQ performance statistics for the simulated hourly concentrations of surface O₃, NO₂ and NHMC against observations over the PRD during 4–31 October 2004 (See the supplement).

(Q9) summary: the manuscript would benefit from some remarks about the new insights that came out in comparison to what was already known before (maybe in relation to the limited studies and 3-D studies that have rarely been performed, as mentioned in the introduction)

(A9)We revised the lines 20-26 in conclusion on page 26835 as the followings:

“Compared with previous studies, an in-depth understanding of the regional O₃ formation over inland PRD area is obtained by process analysis. Through the transport process during nighttime and morning, O₃ precursors originating from northern source areas (i.e. urban Guangzhou and Foshan) and from southern areas (i.e. Dongguan, Shenzhen and Hong Kong) are usually mixed and transported to western or southern rural areas, where they are then involved in the daytime O₃ photochemical production. Such close interactions among precursor emissions, physical transport, and gas phase

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chemistry resulted in significant O₃ chemical production on a large regional scale in the daytime. The sea-land circulations played an important role on the regional O₃ formation and distribution over PRD during the campaign.”

(Q10) Fig. 8a: TRAN is obviously not the sum of VTRA and HTRA. Also in Fig. 8c TRAN seems to be incorrect.

(A10) We double checked the data presented in Fig. 8 and found no error. The values of TRAN are illustrated by yellow line, whereas those of VTRA (pink), HTRA (cyan), CHEM (blue) and DDEP (green) are shown in stacked columns.

Technical issues:

(Q11) title: in my opinion, abbreviations should be avoided in the title (PRIDE-PRD2004, CMAQ), it would read better as follows: . . . during a field campaign using an air quality model system

(A11) The PRIDE-PRD2004 campaign is one of the largest field campaigns to investigate in depth the air pollution problem in China in recent years. We use the abbreviation of the campaign for providing more exact clues to our study for the readers and for a concise expression as well. We change the title as the following:

“Process analysis and sensitivity study of regional ozone formation over the Pearl River Delta, China, during the PRIDE-PRD2004 campaign using the Community Multi-scale Air Quality modeling system”

(Q12) abstract: PRD should be introduced when used first

(A12) We now spell out PRD in the abstract at its first appearance.

(Q13) introduction: page 26836, line 15: raised instead of drawn; page 26837, line 10: ‘CTM’s are fundamental tools’ instead of ‘A CTM is a fundamental tool’

(A13) Accepted and corrected.

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(Q14) section 3.1, line 15: insert at 'the' monitoring and line 16: delete across

(A14) Accepted and corrected.

References:

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Zhang, Y. H., Hu, M., Zhong, L. J., Wiedensohler, A., Liu, S. C., Andreae, M. O., Wang, W., and Fan, S. J.: Regional integrated experiments on air quality over Pearl River Delta 2004 (PRDIE-PRD2004): Overview, Atmos. Environ., 42, 6157-6173, 2008.

Please also note the supplement to this comment:

<http://www.atmos-chem-phys-discuss.net/9/C11888/2010/acpd-9-C11888-2010-supplement.pdf>

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