CMAQ APPLICATION TO THE OZONE POLLUTION IN PEARL RIVER DELTA OF CHINA

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1. INTRODUCTION

The Pearl River Delta (PRD) was one of the very first areas of rapid economic development in China. Program of Regional Integrated Experiments of Air Quality over Pear River Delta (PRIDE-PRD) was developed to provide as comprehensive as possible descriptions of the air pollution in this quickly developing South-Eastern region of China. Based on the result of field observation in PRIDE-PRD2004 campaign, maximum ozone concentration in most sites which had its observation was higher than China's national ambient air quality standard. Especially, the down wind area of PRD and Pearl River Estuary (PRE) had high ozone concentration record. The maximum ozone concentration observed at the monitoring site –Donghu (the site of B in Fig.1).

To better understand the serious ozone pollution in PRD, the third generation of air quality model (Models-3/CMAQ) was applied to simulate the ozone episode in October 2004, regional ozone distribution and the related meteorological features of PRD were analyzed. Cities in PRD and monitoring sites were shown in Fig1. Site A was located in Guangzhou City, site B was a coastal site of PRE. In this study, the inland PRD was controlled by the northeast wind, therefore site C was the down wind of Guangzhou, which was the largest pollutant emission source in PRD.

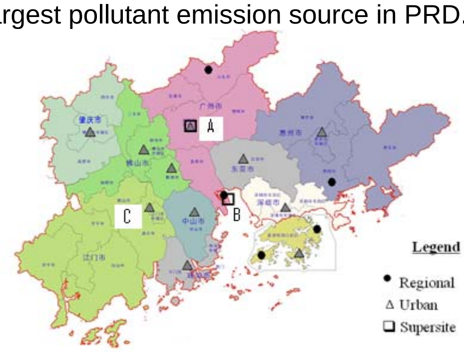

Figure-1. Pearl River Delta of China (A, B,C –the monitoring sites for the model performance test)

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2. PRIMARY RESULTS OF OZONE SIMULATION OVER PRD

This modeling system using MM5, SMOKE, CMAQ was run with a configuration of three nested domains as shown in Fig2. The resolution was 36km over the domain1- China, 12km over the domain2- south China, and 4km over the domain3-PRD. The emission data for the domain1 was based on the TRACE-P emission inventory in 2000(Streets DG et al., 2003). Those of 12km and 4km were prepared on the basis of the PRD emission inventory–2001 from Hong Kong EPD and updated (Song Xiang-yu et al., 2006, Zhao Jing et al., 2006). The chemical mechanism used in this modeling study was SAPRC-99. As an initial modeling study, the simulation was run from 17^{th} to 23^{rd} October 2004 with two days for a spin-up.

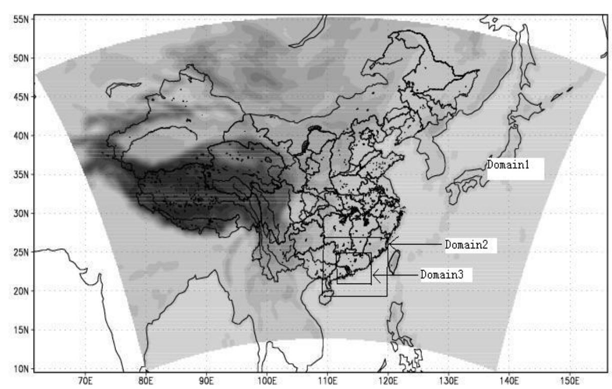


Figure-2. Three nested domains of this modeling study

In this modeling study, three monitoring sites (the three marked sites in Fig1) were chosen for testing the model performance. Model predictions were compared with observed data of three monitoring sites. Generally, the simulation can capture the variation of ozone at the monitoring sites. High ozone concentration was found at the southwest of PRD- the site of Donghu, while the site of Xiken over the PRE has also recorded a high ozone concentration.

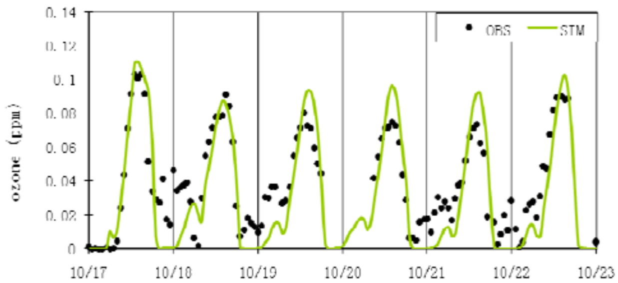


Figure-3. Observation and simulation ozone concentration at the monitoring site of Luhu (A in Fig.1)

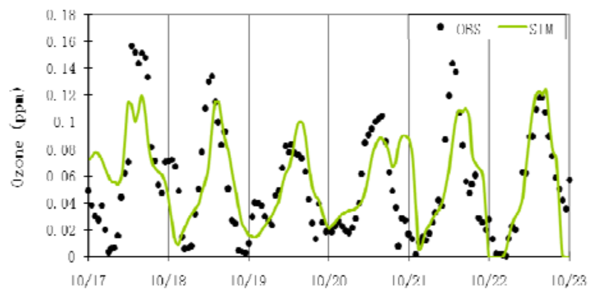


Figure-4. Observation and simulation ozone concentration at the monitoring site of Xinken (B in Fig.1)

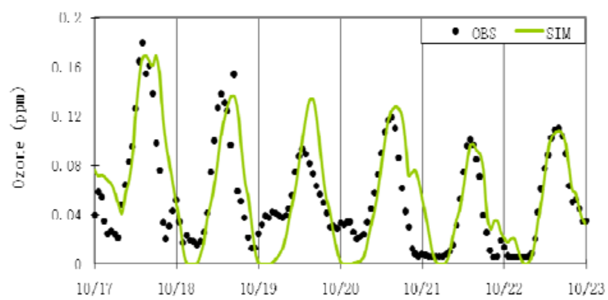


Figure-5. Observation and simulation ozone concentration at the monitoring site of Donghu (C in Fig.1)

3. RESULT ANALYSIS AND DISCUSSION

3.1 Regional Distribution of Ozone Pollution

In the following study, we focus on the features of ozone distribution and meteorology at 14:00 17th October, as their features were similar everyday. As shown in Fig6, was the ozone concentration distribution over PRD at 14:00 17th October. High ozone concentration was found at the site B, which might be strongly influenced by the emission source of Guangzhou. Meanwhile the coastal areas at both sides of PRE also had high ozone concentration.

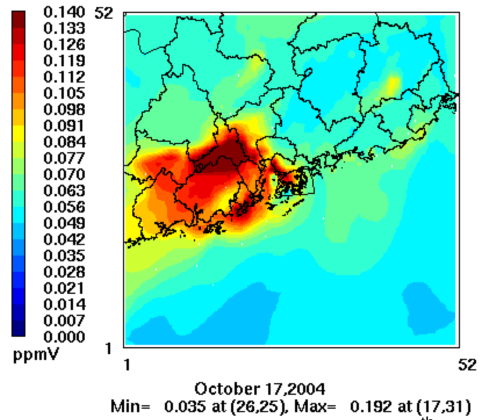


Figure-6. Ozone concentration at 14:00, 17th October

3.2 Meteorological Features over PRE

Land sea breezes play an important role in transporting air pollution over PRD (Lo JCF et al., 2006, Ding A et al., 2004). During 17th to 23th October, land sea breezes were predominant over PRE. As showed in Fig7, a band-shaped area of a low wind speed (<1.0 m/s) was formed, which might lead to the accumulation of pollutants transported from the emission sources, when land wind and sea wind encountered in the afternoon. To further examine the structure of land sea breezes, the vertical wind stream was plotted. Fig8-(a) presents a cross-section (latitude-sigma level) of u-w wind stream, and Fig8-(b) shows a cross-section (longitude-sigma level) of v-w wind stream, both of which were taken over the monitoring site of Xinken (Longitude:113.6^0, Latitude: 22.6^0). Fig7 and Fig8 revealed that strong air circulations existed over PRE. This pattern of air circulation and land sea breeze were frequently captured during the simulation. In Fig8-(a) and Fig8-(b), the axis of Y showed the sigma levels, the minimum sigma level is approximately equal to the height of 1700m. The height of the air circulation in Fig8 was about 700m. As shown in Fig8, there was a up-down air flow at the monitoring site of Xinken, which was formed by the air circulation over PRE.

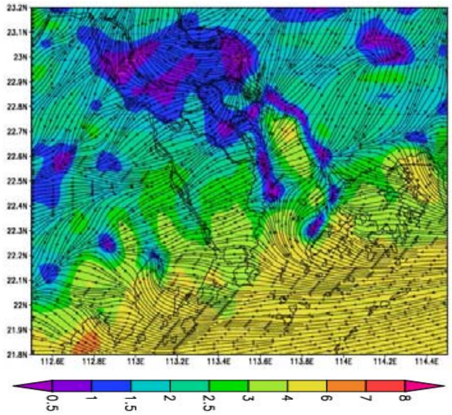
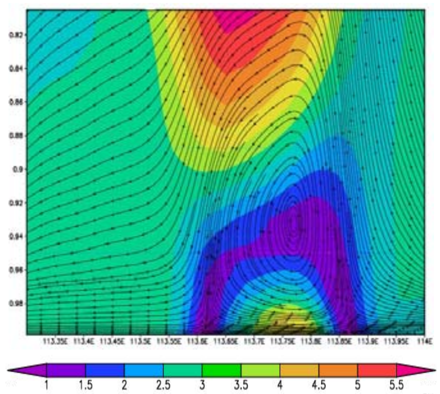
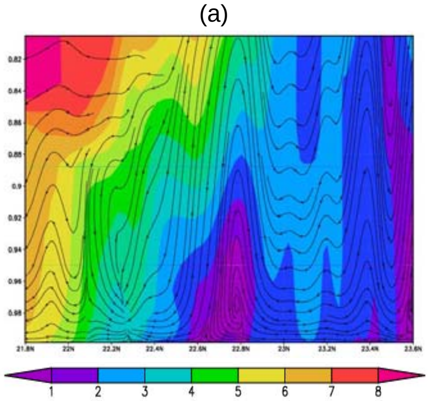


Figure-7. Horizontal distribution of surface wind stream at 14:00 17th October(colors show the horizontal wind, unit: m/s).



(a)

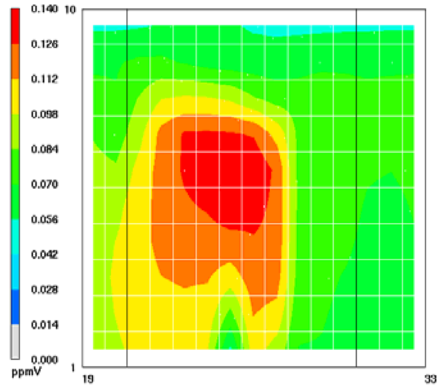


(b)

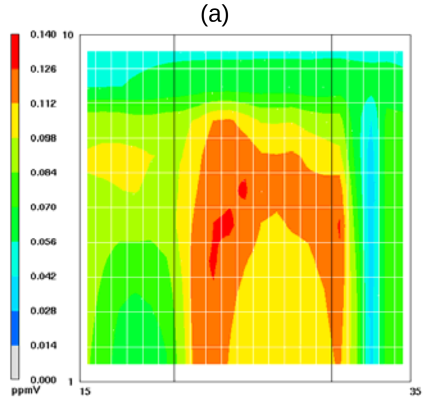
Figure-8. Vertical cross sections of wind stream taken over the monitoring site of Xinken at 14:00 17th October (a: u-w, b: v-w, colors show the horizontal wind, unit: m/s)

3.3 Vertical Ozone Profile over PRE

Fig9 showed the vertical ozone profile (vertical layer of CMAQ), which were taken over PRE. In both vertical profiles, the maximum ozone concentration was located at the sixth layer of CMAQ, approximately equal to the vertical height of 800m. And the distribution of vertical high ozone concentration had a similar shape with the vertical cross section of low wind speed area in Fig8. The high ozone concentration on the ground was dominated at both sides of PRE, which were also the locations of the band-shaped areas with the low wind speed (as shown in Fig8).



(a)



(b)

Figure-9. Vertical ozone concentration of Xinken at 14:00 17th Ocoter (a: latitude-vertical layer, b: longitude-vertical layer)

3.4 Process Analysis of Ozone over Xinken

To further analyze the ozone formation and transport over PRE, process analysis(PR) of ozone was carried out for Xinken. As shown in Fig10, most ozone concentration at the monitoring site of Xinken was contributed by vertical advection and vertical diffusion,while horizontal advection is the greatest process to consume ozone. Vertical and horizontal transport contribution of ozone can be revealed from Fig-8 and Fig9. As compared to transportation processes, chemical reactions contribute relatively less ozone concentration.

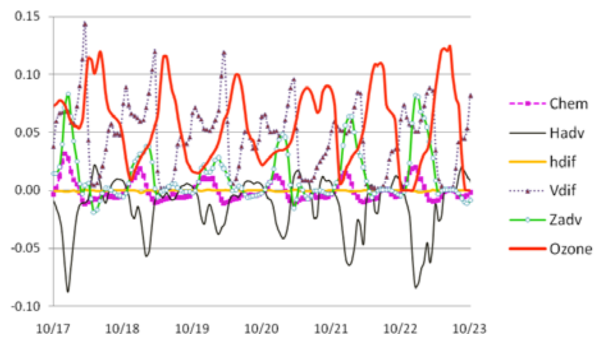


Figure-10. The contribution of various processes to ozone concentration at the monitoring site of Xinken (Chem- Chemistry reaction, Hadv- Horizontal advection, Hdif – Horizontal diffusion, Vdif- Vertical diffusioin, Zadv- Vertical advection)

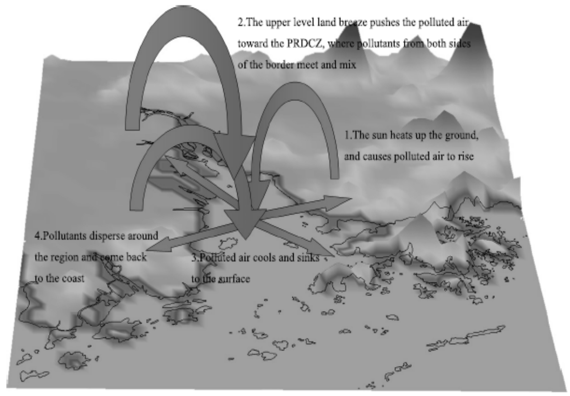


Figure-10. Schema of cross-section air pollutant transport and trapping mechanism by the air circulation over PRE (Lo JCF et al., 2006)

3.5 Conceptual Model

To better clarify the process of ozone transport and formation over PRE, a conceptual model was presented. Fig11 is a schematic picture showing the air pollutant transport and trapping mechanism over PRE. Pollutants are routinely emitted from power plants, vehicles, as well as from industrial commercial or residential buildings. In the sunny afternoon with weak background winds, the coastal urban areas can have temperature a few degrees higher than the surrounding oceanic areas. Air tends to rise over the urban areas because of higher temperature; thereby drawing in air from the oceanic areas, resulting in a convergent inflow at the lower levels into the inland urban areas during the day (the band-shaped areas with low wind speed shown along PRE in Fig7.). However, the air typically will only rise up to about one to two kilometers, and then it will spread out in the horizontal, and eventually sinks back in the nearby oceanic areas, forming a closed vertical circulation (as the ones shown in Fig8.) These land-sea breeze circulations are significant for air pollutant transport, as the air pollutant can come back to the inland area through the returning branch of the air circulation, leading to the trapping of air pollutants.

4. CONCLUSION

The models-3/CMAQ system was applied to simulate the ozone episode over PRD in October 2004. Comparison between the observed and simulated ozone concentration from three monitoring sites, indicated that the model prediction was in agreement with the measurement. The regional high ozone concentration was distributed at the southwest of Guangzhou, and the coastal areas at both sides of PRE also had high ozone concentration. There was a band-shaped low wind speed area over PRE, which was formed by the land-sea breeze. The air circulation over PRE was revealed by the vertical analysis of wind stream, vertical ozone profile and process analysis of ozone concentration at the monitoring site of Xinken indicated that the air circulation over PRE played an important role in transport and trapping ozone and its precursors at the coastal areas, then subsequently lead to high ozone concentration in these area.

5. ACKNOWLEGDGEMENT

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6. REFERENCE

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