EVALUATION OF $PM_{2.5}$ CONTROL POLICIES THROUGH APPLICATION OF SOURCE APPORTIONMENT TECHONOLOGY IN THE PEARL RIVER DELTA REGION

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1. INTRODUCTION

Hong Kong and the adjacent Pearl River Delta (Hong Kong/PRD) region, situated on the south coast of China have been experienced fast deterioration of ambient air quality due to the increasing population and rapid economics development. The most common phenomenon of air pollution in PRD is the regional haze days caused by high concentration of fine particles in the atmosphere (Fung et al., 2005; Zhang et al., 2008; Kwok et al., 2010).

In order to improve the air quality level in this complex region, understanding the relationship between emission source regions, emission categories and ambient $PM_{2.5}$ concentration is very important. In this study, The Particulate Source Apportionment Technology (PSAT) implement in CAMx is utilized to study this relationship. We firstly describe model configurations and source apportionment method. In section 2, shows basic result for model simulation. And the Particulate Source Apportionment Technology (PSAT) method is used to analysis contribution of different emission categories and source regions to ambient $PM_{2.5}$ level of all cities within the PRD region. Finally, results are summarized in section 5.

2. DOMAIN SETTING AND MODEL CONFIGURATION

Detail model configurations, including both emissions input and meteorological field are described in Li et al. (2012). Source apportionment method PSAT, implemented in CAMx model is used to study source apportionment information for ambient PM concentrations. Detailed PSAT algorithms can be found in the manual of CAMx model (http://www.camx.com).

In order to run PSAT, different source groups, in terms of geographical regions and emission categories should be defined. In this study, the whole domain D3 is divided into 11 source regions (Figure 1) while 7 source categories are defined, they are powerplant sources, industry sources, mobile sources, marine shipping sources, biogenic sources, area sources and anthropogenic sources outside the PRD economic zone (INTEXB). Besides, boundary and initial conditions are always tracked as separate source groupings. Thus there are 83 source groupings in total.

According to PSAT algorithm, total concentration of $PM_{2.5}$ in a receptor site is:

$$C\_PM_{2.5}(n) = \sum_{i=1}^{11}\sum_{j=1}^{7} S(i,j) \qquad (1)$$

Where $S(i,j)$ represents $PM_{2.5}$ concentration in receptor n from a certain source region (i) and emission category (j). For each receptor, define source contribution form within the city as a local contribution, from all the other cities' contribution within the PRD region defined as the regional contribution, and the remaining part are labeled as super-regional contribution which including all the boundary effect and non-PRD area within D3 region (INTEXB impact).

3. RESULTS AND DISCUSSIONS

In this study, two month simulations, December 2011 and April 2012 have been carried out, so as to investigate the change in pollutant sources at different background situations. Waglan Island station is a background site, which is largely influenced from synoptic scale (Lo, et al., 2006) (Figure 1). Figure 2 is the wind rose at Waglan Island representing background wind in two different times. December is the typical winter time in this region, prevailing wind direction is mainly northerly due to the northerly winter monsoon, which brings cold, dry and stable air mass from the continent. While in April easterly and occasional southwesterly winds are observed.

3.1 Monthly average for source apportionment results

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Figure 3 shows local, regional and super-regional contribution to ambient $PM_{2.5}$ level in actual amount for nine receptor regions in both December and April. Super-regional contribution is similar, with high in December and Low in April. Averaged super-regional contribution to the nine regions is 34.1 $\mu g/m^3$ in December and 13.1 $\mu g/m^3$ in April, explains 58% and 42.6% of $PM_{2.5}$ within the region respectively. Change in background wind decreases Super-regional contribution from December to April. Strong wind favors long-range transport, while weak wind favors the accumulation of local pollutants. In winter with strong northerly wind, it is possible to bring a large number of pollutants from outside to this region in a short time. The magnitude of Local contribution is similar implies the dominant emission category has small seasonal variation.

Figure 4 summarizes the contribution of different source categories to monthly averaged ambient $PM_{2.5}$ level for nine receptor regions in December and April. In December, for every receptor region, mobile emission is the dominant one, having highest contribution to ambient $PM_{2.5}$ level. Averagely, 22.1% (12.2 $\mu g/m^3$) of $PM_{2.5}$ in the PRD region contributed from mobile emission. In April, mobile emission is still the most important category for most of the cities except Hong Kong. Averaged mobile contribution for the nine receptor regions is 10.5 $\mu g/m^3$. Marine emission becomes an important emission source in April for some coastal cities, such as Hong Kong. In April, up to 4.7 $\mu g/m^3$ of ambient $PM_{2.5}$ in Hong Kong originates from this category. With moderate wind speed and appropriate wind direction in April favors the accumulation of $PM_{2.5}$ from marine vessels over Hong Kong. Industry and area emission are the other two important categories. Industry emission occupies ~7% of the total $PM_{2.5}$, while ~6% to 9% of $PM_{2.5}$ comes from area emission. Averagely powerplant contribution shows an increasing trend from December to April, related with enhanced vertical advection in an unstable atmosphere under higher temperature.

3.2 Source apportionment in city level

Three cities are detail analysis in this study, Guangzhou, a major emission region in PRD, Jiangmen, a downwind region, and Hong Kong, a coastal city strongly affected by landsea breeze effect (Lo et al., 2006). For Guangzhou, $PM_{2.5}$ transported from outside PRD can go up to 36.0 $\mu g/m^3$ (54.9%) in December and 13.1 $\mu g/m^3$ (32.5%) in April. Apart from super-regional transport, local/regional contributions to $PM_{2.5}$ concentration from mobile source and industry source are very important which are about 8.2 $\mu g/m^3$, 4.1 $\mu g/m^3$ in December; the corresponding contributions are 14.2 $\mu g/m^3$, 5.5 $\mu g/m^3$.

In Jiangmen, according outside PRD bring more than 45% of $PM_{2.5}$ in both December (31.1 $\mu g/m^3$) and April (11.7 $\mu g/m^3$). Besides, contributions from mobile source, industry source to $PM_{2.5}$ concentration are about 12.9 $\mu g/m^3$, 7.3 $\mu g/m^3$ in December; the corresponding contribution are 6.0 $\mu g/m^3$, 2.2 $\mu g/m^3$ in April. With different wind directions, Jiangmen generally served as downwind region for different cities in December and April. In December, Jiangmen is regarded as downwind region of Foshan and Guangzhou; it is obvious Jiangmen would have a large impact by the emission from these two cities. Total contribution from these two upwind regions is 15.6 $\mu g/m^3$, accounting for 26.3% of total $PM_{2.5}$ in Jiangmen. In April time, along with the change of prevailing wind direction, Guangzhou and Foshan no longer plays as the dominant upwind region, contribution from these two regions drop to around 2.5 $\mu g/m^3$, only 15% of that in December. Prevailing easterly winds will bring the pollutants from other upstream regions instead.

In Hong Kong, two important contributions are mobile source (8.3 $\mu g/m^3$) and area source (3.1 $\mu g/m^3$) in December; marine source (4.9 $\mu g/m^3$) and mobile source (2.9 $\mu g/m^3$) in April. In December, 75% (6.7 $\mu g/m^3$) of the mobile emission in Hong Kong is coming from the PRD regions especially Shenzhen, explains more than half (4.3 $\mu g/m^3$) of it. In April, with lower wind speed, only 38.5% of mobile emission is transported from regions outside of Hong Kong. Marine emission contribution is quite different in two different times, increased from 0.7 $\mu g/m^3$ in April to 4.9 $\mu g/m^3$ in December, this is probably related to much strong landsea breeze effect in April (Lo et al. 2006). Huge difference is associated with different background wind speeds and directions. Although the mixing height is typically lower in December than April, the wind speed is bigger and further affects vertical advection and diffusion.

Overall, the mobile emission from PRD regions is one of the major emission categories which needs further control management to reduce the ambient $PM_{2.5}$ concentration. Apart from mobile emission, industry emission and marine emission is also important. Reduction on this two emission types could potential have large reduction in $PM_{2.5}$ level.

4. CONCLUSION

The PSAT source apportionment technology results show that in 9 different cities in the PRD region, local contributions ranges 3.8 μg/m^3 to 15.6 μg/m^3 in December and 2.2 μg/m^3 to 22.0 μg/m^3 in April of the ambient $PM_{2.5}$ level, while regional contribution ranges 3.5 μg/m^3 to 16.2 μg/m^3 in December and 4.6 μg/m^3 to 15.0 μg/m^3 in April.

For source apportionment by emission categories, PSAT results also suggest that mobile emission is always the dominant emission category in different cities across the PRD region, ranging from 4.4 μg/m^3 (9.3%) to 16.6 μg/m^3 (26.4%) in December and 2.9 μg/m^3 (11.4%) to 16.8 μg/m^3 (42.7%) in April. The other major emission categories are industry and area emission. The marine emission becomes an important source in April for some particulate regions, such as Hong Kong.

4. ACKNOWLEDGMENT

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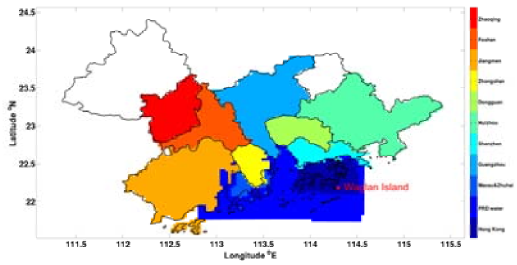

Fig. 1. Source regions for PSAT in the domain 3 represented by different colors; also show the location of Waglan Island (represent the background wind).

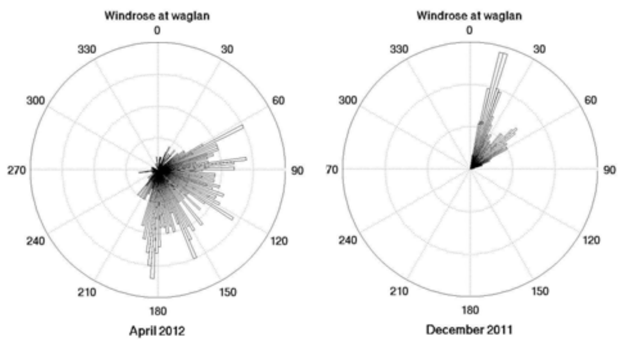

Fig. 2. WRF wind rose for December and April at Waglan Island wind station. (See Figure2 for the location of Waglan Island)

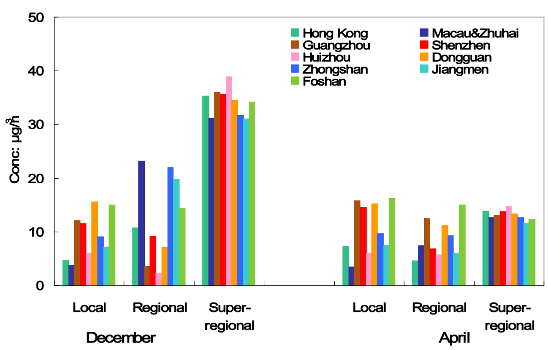

Fig. 3. Actual amount of local, regional and super-regional contribution of $PM_{2.5}$ to nine receptor regions in December and April.

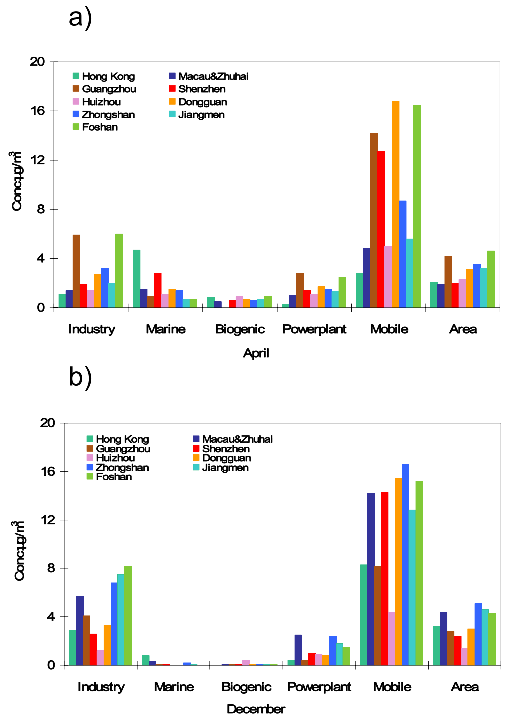

Fig. 4. Source category contributions to monthly averaged $PM_{2.5}$ at nine receptor regions in December (a) and April (b), due to sources in the PRD only.

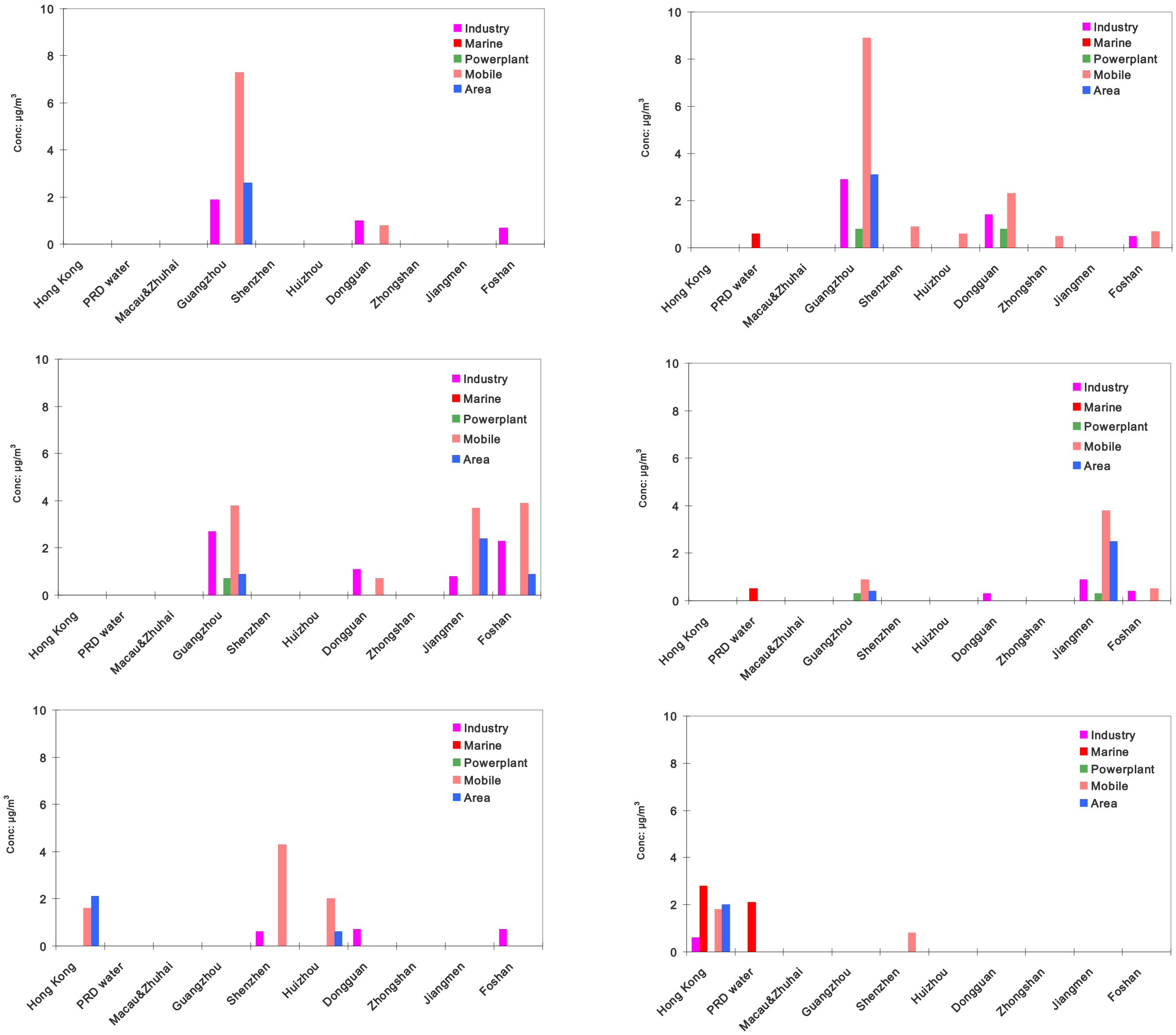

Fig. 3. Source apportionment results (µg/m^3) at Guangzhou (upper), Jiangmen (middle) and Hong Kong (down) in December (left) and April (right). (Contributions less than 0.5 µg/m^3 are not shown in the figure).