A modeling study of regional sources contributing to atmospheric $PM_{2.5}$ of Taiwan

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The effect of transboundary long range transport (LRT) on the areas located at downstream of large emission source is play a major role to air quality (Shimadera et al., 2009; Koo et al., 2008; Wang, 2005). Air pollutants emitted in East Asia were increasing for past ten years because of rapid economic growth (Ohara et al., 2007). The atmospheric $PM_{2.5}$ of Taiwan, located at downstream of East Asia's continental outflow, should be affected significantly by the other countries in East Asia.

Taiwan EPA announced a new strict air quality standard for $PM_{2.5}$ in 2012. To meet the standard, Taiwan has to implement a number of proper control strategies, which is determined for various regional and local sources by a series of studies. The study is subjected to explore the relative importance of various regional sources for atmospheric $PM_{2.5}$ in Taiwan. MM5/CMAQ was adopted to simulate air quality of East Asia and Taiwan by a configuration of three-level nested domains shown in Figure 1. Four emission scenarios were designed to simulate and assess the contribution of various regional sources for 2007 including Taiwan-self source, direct and indirect effects of LRT by East Asia source, as well as background concentration of East Asia. The four scenarios are (a) base case (BS): all sources of Taiwan and the other countries are considered; (b) zero East Asia case (ZE): Taiwan sources are considered only without East Asia sources; (c) zero Taiwan case (ZT): East Asia sources are considered only without Taiwan sources; and (d) all zero case (ZA): all sources of Taiwan and the other countries are not considered.

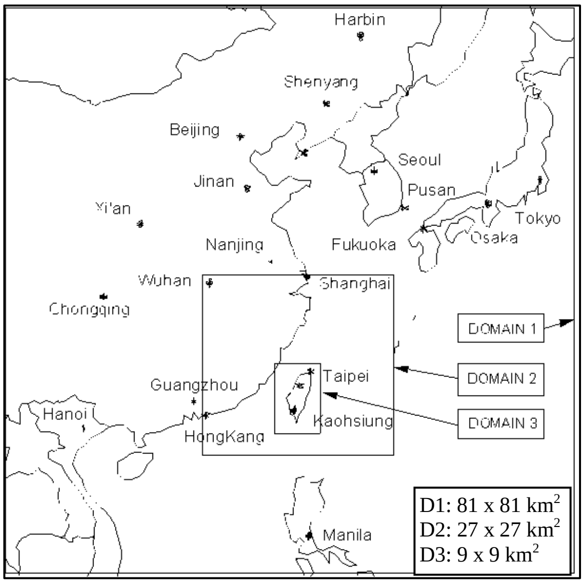

Fig. 1 Configuration of three-level nested domains.

The simulation and analysis results shown in Table 1 indicate that Taiwan-self sources contribute a highest ratio of 60% to Taiwan's atmospheric $PM_{2.5}$ in 2007, LRT of East Asia's sources contribute a second ratio of 37% (27% and 9% for direct and indirect effects), and background of East Asia contribute the rest of 3%. It also indicates that the effects of LRT are almost higher than 40% for all seasons except summer with 14% only.

The indirect effect of LRT means that the precursors are transported from the other countries to Taiwan and reacted with the precursors emitted in Taiwan to form $PM_{2.5}$. Therefore, the indirect effect of LRT is controllable for Taiwan in contrast of uncontrollable direct effect of LRT. The contribution ratio of various regional sources to secondary $PM_{2.5}$ is shown on Table 2. The direct LRT effect for sulfate is as high as 57%, while that for nitrate is 7% only. Thus, the sulfate consisted in $PM_{2.5}$ is difficult to be reduced by SO_2 emission reduction in Taiwan, however, the nitrate is relative easy to be controlled by NOx emission reduction in Taiwan.

Tab. 1 Contribution ratio of regional sources for atmospheric $PM_{2.5}$ of Taiwan in 2007 (%)

	Taiwan-self	LRT of East Asia		Background of East Asia
		direct	indirect	
Spring	56.9	30.1	10.2	2.8
Summer	81.0	8.8	5.8	4.3
Fall	57.7	29.0	9.9	3.4
Winter	57.5	30.5	9.8	2.3
Whole year	60.3	27.3	9.4	3.0

Tab. 2 Contribution ratio of regional sources for secondary $PM_{2.5}$ of Taiwan in 2007 (%)

	Taiwan-self	LRT of East Asia		Background of East Asia
		direct	indirect	
SO_4^{2-}	31.9	56.8	6.0	5.2
NO_3^-	57.5	6.9	35.6	0.0
NH_4^+	43.2	32.4	24.2	0.2
SOA	73.8	10.2	16.0	0.0
Secondary $PM_{2.5}$	44.6	34.5	18.6	2.3

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