PM10 dispersion during air pollution episode in Saraburi, Thailand

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Abstract

The Hybrid Particle and Concentration Transport model (HYPACT) with Lagrangian option and the Regional Atmospheric Modeling System (RAMS) was applied to simulate PM10 dispersion emitted from main sources in mineral products industrial area (MPIA) in Saraburi during PM10 episodes 2005. Comparison of model results with observations showed that the simulated concentrations were in reasonable agreement with observations. The model results revealed dispersion of PM10 and peak concentration area. Additionally, it was found that these sources impacted mainly on local area.

Keywords: PM10, Dispersion Model, Saraburi, Spatial Variation

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Introduction

The particulate matter with an aerodynamic diameter less than 10 μm (PM10) is the main air quality problem in Thailand. Particulate problem at "mineral producs industrial area (MPIA) in Saraburi is the second air quality problem for Thailand (Pollution Control Department, 2005). In 2005, the PM10 concentrations at MPIA, Nah Phra Laan subdistrict measured by Pollution Control Department (PCD) exceeded the 24-hr National Ambient Air Quality Standard (NAAQS) for more than 100 days/year. PM10 is a type of inhalable atmospheric pollutants and its existence in the atmosphere badly endangers both human health and atmospheric environment. Previous study found that PM10 in Nah Phra Laan effected human health (Chawana, 1999; Moondee et al., 2004).

For air quality management, the basic questions should be answered: Where do the PM10 problems occur?. Where is the highest PM10 concentration?. However, there is only one monitoring station in Nah Phra Laan. The point measurement can represents ambient concentration only small area around monitoring site when pollutant concentration gradients are high. Air quality models are powerful tools to predict dispersion of pollutant in atmosphere. They enhance the ability to depict the spatial distribution of pollutant concentration. Nah Phra Laan topography is a complex terrain. The Lagrangian particle model is appropriate for simulation near a source region and in a complex terrain. Therefore, the Hybrid Particle and Concentration Transport model (HYPACT) with Lagrangian option and the Regional Atmospheric Modeling System (RAMS) was applied for calculating dispersion of PM10 for this study. According to winter and rainy seasons which were the first two seasons of particulate problems in Saraburi, the dispersions of PM10 during typical PM10 episodes were studied with 6 cases in winter and 5 cases in rainy season.

Methodology

PM10 concentration fields were simulated by HYPACT using three-dimensional meteorological field from RAMS. HYPACT is a code developed to simulate the motion of pollutants under the influence of atmospheric flow, including turbulence. It can account for multiple sources emitted into highly complex local weather regimes, including mountain/valley winds and other situations in which the traditional Gaussian-plume based model are known to fail (Walko et al.,2001). RAMS is a comprehensive mesoscale meteorological modeling system for simulating meteorological phenomena.

The study model domain is 300×300 km centered at (14.7 N, 100.9 E) with 2 km grid resolution (Figure 1). There are 32 vertical layers in the σ_z coordinate system unequally spaced from the ground to ~20 km. The lowest grid layer is 20 m and grid spacing is stretched by a ratio of 1.2 until it reaches a maximum value of 2,000 m near the top. For meteorological initial and boundary conditions, reanalyzed datasets with $1^{o}\times1^{o}$ resolution from the National Center for Environmental Prediction (NCEP) were used.

HYPACT used hourly emission rates of PM10 from main sources in Nah Phra Laan and its vicinities (i.e., transportation, crushed stone plants, lime plants, phosphate plants, cement plants, and quarries). These emission rates based on yearly emission inventory developed by PCD in 2005 (Pollution Control Department, 2006). For this study, emission inventory were developed additionally by updating traffic data and allocating them to hourly emission rates. Location of emission sources in Nah Phra Laan and its vicinity are shown in Figure. 2.

Furthermore, PM10 distributions were analyzed by using ventilation coefficient in both seasons. Ventilation coefficient is the product of mixing height and wind speed.

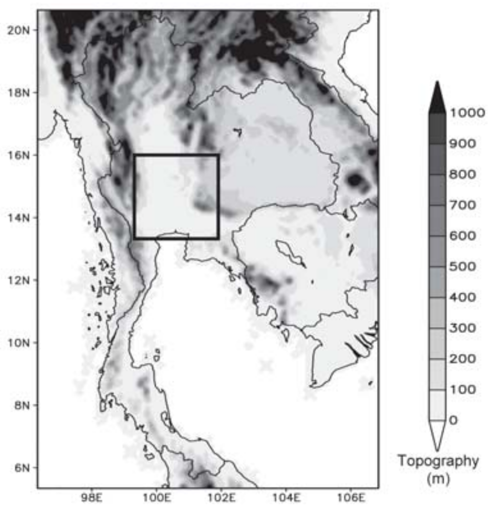
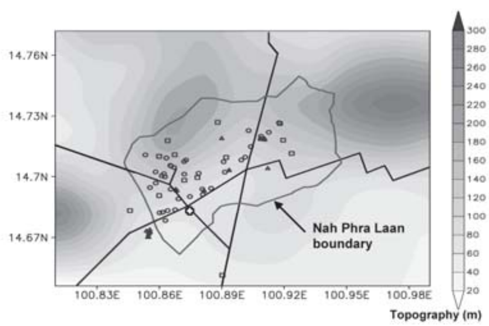


Figure 1. Thailand topography (unit in meter) and the embedded box is the boundary of the modeling domain



✚ Nah Phra Laan monitoring station
Crushed stone plants □ Quarry —— Road
○ Cement/Lime/Calcite/Phosphate plants

Figure 2. Monitoring station and emission sources in Nah Phra Laan and its vicinity

Results and discussions

Model evaluation

Figure 3 shows comparison of simulated and observed daily average PM10 concentrations for winter and rainy season episodes. The comparison shows that simulated values are generally in good agreement with the observation of both time variations and level of PM10 concentrations. Furthermore, simulated hourly average PM10 concentrations are within a factor of two of the observations more than 80% for every episode. This performance is in the acceptable range of criteria applied in other studies (Kumar et al., 2006)

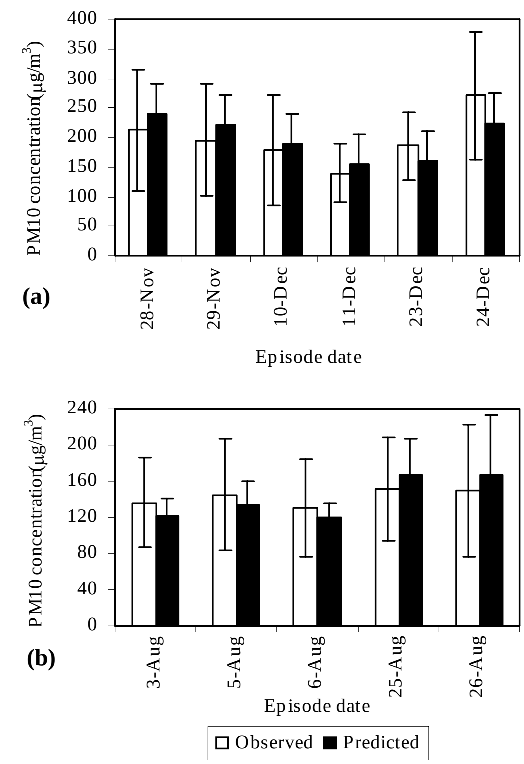


Figure 3. Comparison between observed and simulated values of daily average PM10 concen trations during (a) winter episodes and (b) rainy season episodes

Distributions of PM10 concentrations

The simulated results show that the PM10 distribution patterns of the 6 winter cases are similar and the PM10 dispersion patterns of the 5 rainy season episodes are also similar. Therefore, some representative simulated cases were used to study typical PM10 distributions in each season. Pollutants are dispersed by atmospheric motions. During winter, Saraburi is influenced by the northeast monsoon and prevailing wind is northeasterly wind. Whereas, prevailing winds are southwesterly and southerly winds in rainy season under the influence of the southwest monsoon. Wind speed and wind direction during the PM10 episodes can be observed from wind roses as shown in Figure 4.

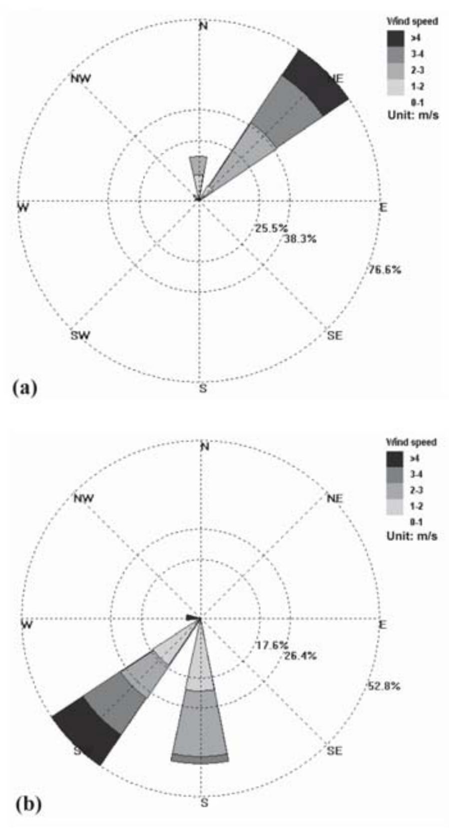


Figure 4. Wind rose at Nah Phra Laan monitoring station during (a) winter episodes, (b) rainy season episodes

In winter, the wind blows the particulate matters from emission sources toward the southwest. Figure 5(a) shows the PM10 distribution in winter episode on 24 November 2005. The highest daily average PM10 concentration appears about 5 km southwest from the monitoring station. The peak concentration is about 300 μg/m^3 that is nearly three times of the 24-hr NAAQS.

Figure 5(b) shows the PM10 distributions in rainy season episode on 3 August 2005. The southwesterly wind transport particulate matters from emission sources toward the hill. The highest daily average PM10 concentration is about 250 μg/m^3 at Nah Phra Laan center. The highest concentration is about two times of the 24-hr NAAQS.

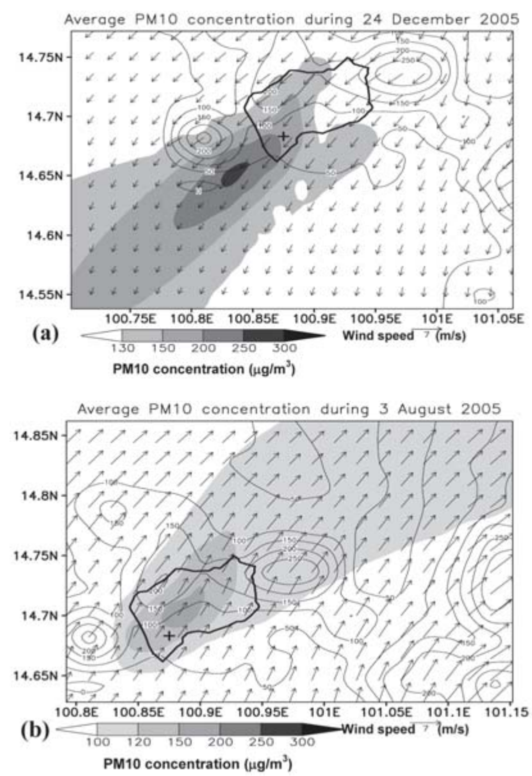


Figure 5. Horizontal distributions of daily average PM10 concentrations (μg/m^3) at surface layer and wind vector on (a) 24 December 2005 (in winter) (b) 3 August 2005 (in rainy season)

Table 1. Meteorological data for winter episodes and rainy season episodes

	Winter episodes (%)	Rainy season episodes (%)
WS[1] $\leq$ 4 m/s	87	86
VC[2] < 6000 m^2/s and WS $\leq$ 4 m/s during 13-17 LST	83	67
MH[3] < 500 m and WS $\leq$ 4 m/s at 7 LST	88	100

[1] WS is wind speed,

[2] VC is ventilation coefficient,

[3] MH is mixing height

The high PM10 concentrations appear near the sources. It may be due to the high proportion of coarse particles emitted from the sources. From the information of emission inventories at Nha Phra Laan and its vicinity in 2005, it shows that 76% of PM10 is emitted from resuspended road dust and crushed stone plants, which generally are the sources of coarse particles. Typical travel distance of coarse particle is short (McMurry et al., 2004). Moreover, most of meteorological conditions in Nah Phra Laan during the PM10 episodes are high pollution potential as shown in Table 1. The high pollution potential criteria classified by the US National Meteorological Centre and Atmospheric Environment Services, Canada was applied in many studies (Goyal et al.,2006; Manju et al., 2002). The criteria classified that the high pollution potential occurs when the afternoon ventilation coefficient is < 6000 m/s^2 and mean wind speed does not exceed 4 m/s and during morning hours, the mixing height is < 500 m and the mean wind speed does not exceed 4 m/s (Goyal et al., 2006). The percentage of hour that wind speed does not exceed 4 m/s is more than 85 % for both episodes. According to the afternoon ventilation criteria, high pollution potentials occurred in winter episodes (83 %) more than in rainy season (67%). In addition, the weather conditions according to morning criteria show high pollution potential with 88 % in winter episodes and 100 % in rainy season episodes. High pollution potential conditions result in pollutant accumulation or low pollutant dilution in Nah Phra Laan.

Conclusions

HYPACT/RAMS modeling system was applied to simulate PM10 dispersion at MPIA in Saraburi during the PM10 episodes 2005. The simulated PM10 concentrations are generally in good agreement with the observations. The information of the model results is useful for air quality management. The model results reveal the dispersion of PM10 emitted from significant sources in Nah Phra Laan and its vicinities. It is found that PM10 emitted from this area impact mainly on local area. The high PM10 concentrations appear near sources that can be explained by a large number of coarse particles and low atmospheric ventilation conditions. Model results show the highest concentration areas that are different locations between winter and rainy season. In winter episodes, it appears about 5 km southwest from the monitoring station. While in rainy season episodes, it appears around Nah Phra Laan center. These areas should be monitored and studied impact of particulate pollution.

Acknowledgments

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