Weather Research and Forecasting/Chemistry Model for Ground Level Ozone Study in Bangkok Metropolitan Region, Thailand

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Abstract

The objective of this research is to study ground level ozone in Bangkok Metropolitan Region (BMR) by using the WRF-Chem model. The period of study is March 2013. The simulation domain was configured with one mother domain and two nested domains with spatial resolution 27 x 27, 9 x 9 and 3 x 3 km^2, respectively. The air pollutant emission rate was obtained from global emission inventory for all domain in CASE I and global emission inventory for mother domain and locally developed emission inventory with spatial resolution 1 x 1 km^2 for two nested domains in CASE II. The results revealed that the model could predict the temporal variations of ozone concentration. The peak of ozone concentration was observed around noon-2:00 PM (local time in Thailand, UTC +7:00 hours) and the high ozone concentration was observed around northern area of Bangkok, a part of Nonthaburi, Pathum Thani and Nakhon Pathom. When compared modelled results with monitoring data, the time series of ozone concentration of the two datasets has similar pattern. However, the simulation results are underestimated the high concentration of ground level ozone at noon-2:00 PM . The sensitivity study on using different emission inventory revealed that local emission inventory yielded the better results than global emission inventory.

Introduction

Ground level ozone is known as a secondary pollutant that is not emitted directly but forms when precursor gases react in sunlight. These precursor gases are carbon monoxide (CO), nitrogen oxides (NOx) and volatile organic compounds (VOCs). Precursor gases come from natural sources and human activities such as biomass burning, industrial emission, residential and transportation. Ozone is known to have significant effects on human health such as eye and skin irritation, respiratory system problem and increased asthma attacks. In addition, its effects on human health, ozone can significantly impact vegetation and decrease the productivity of some crop.

The purpose of this study is evaluation of the ability of WRF-Chem to capture the temporal and spatial distribution of ground level ozone concentrations over Bangkok Metropolitan Region which covered 5 provinces namely: Nakhon Pathom, Pathum Thani, Samut Sakhon, Nonthaburi and Samut Prakan during March 2013, together with comparison of two emission inventories include EAGAR and RETRO or global emission inventory and Thailand emission inventory or local emission inventory used within the model. The evaluation of model performance was performed by comparing results to the PCD (Pollution Control Department) monitoring station.

Simulation Method

In this study, WRF-Chem version 3.6 was used as a tool to simulate ground level ozone concentration over BMR. The modeling domains are presented in Fig.1. The three nested domains were configured. The mother domain (d01) covers Southeast Asia and part of China with spatial resolution 27x27 km^2, centered at 13.20° N, 103.50° E with Lambert Conformal Conic projection. The first nested domain (d02) covers Thailand with a spatial resolution 9x9 km^2.The second nested domain (d03) covers Bangkok Metropolitan Region with a spatial resolution 3x3 km^2. The vertical structure of the model includes 30 layers which covering the whole troposphere. The model was initialized by real boundary conditions using NCAR-NCEP's Final Analysis (FNL) data with a spatial resolution of 1° × 1° (~111 km × 111 km) and 6 hourly temporal resolution.

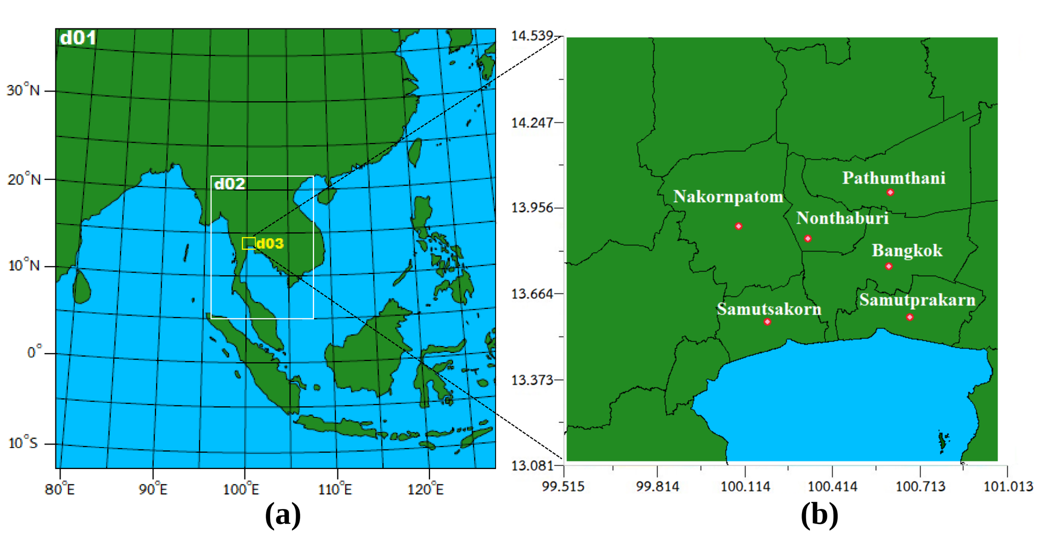

Figure 1. The simulation domain settings in WRF-Chem, including (**a**) the mother and two nested domains and (**b**) the details of domain 3 that mainly covers the Bangkok Metropolitan Region (BMR).

Model Configuration

WRF-CHEM V3.6

- Gas-phase chemical mechanisms: RACM
- Photolysis schemes: Fast-J photolysis
- Aerosol schemes: GOCART
- Biogenic Emission: MEGAN
- Anthropogenic Emissions:

CASE	DESCRIPTION
I	EDGAR and RETRO for all domain.
II	EDGAR and RETRO for mother domain and Thailand Emission inventory for two nested domains.

Results

Simulated results of ground level ozone concentration will be discussed into three aspects; Spatial Distribution of ground level ozone over BMR; comparison of model results with monitoring data and Model sensitivity on different of emission inventory datasets.

- Spatial Distribution

The spatial distributions of ground level ozone over BMR simulated by WRF-Chem model in CASE I and II are shown in Figure 1 and 2. The high ground level ozone concentration were observed around northern area of Bangkok, a part of Nonthaburi, Pathum Thani and Nakhon Pathom.

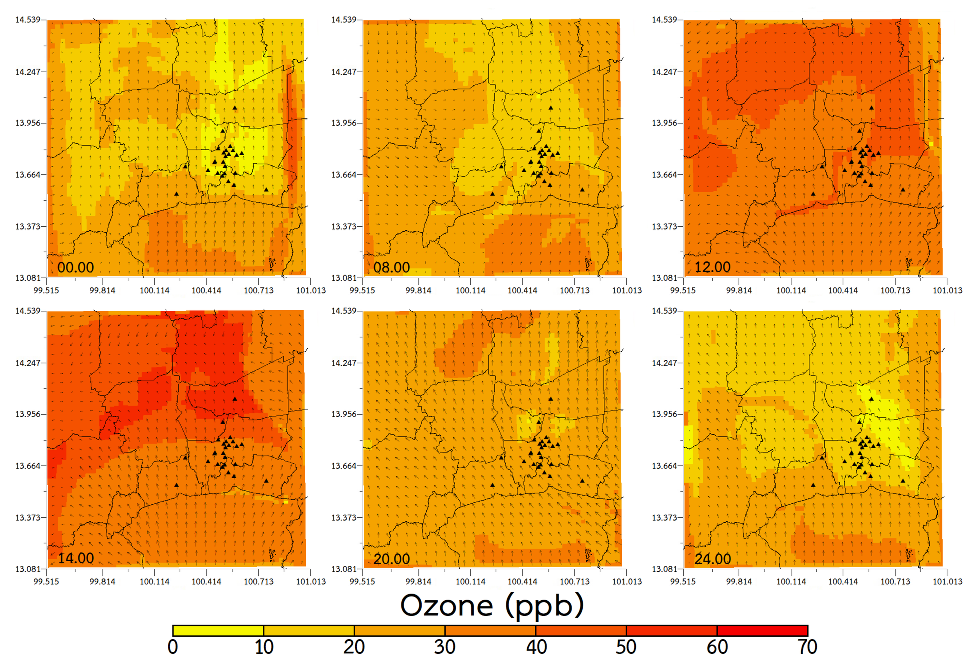

Figure 2. Hourly spatial distribution of ground level ozone concentration over BMR on 17 March 2013 (CASE I)

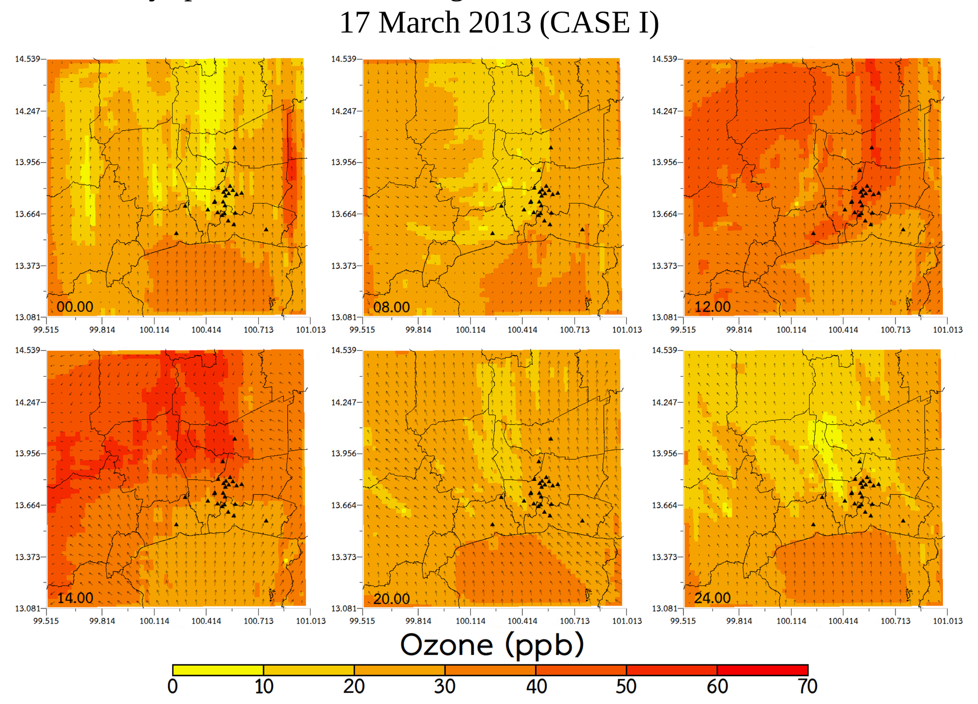

Figure 3. Hourly spatial distribution of ground level ozone concentration over BMR on 17 March 2013 (CASE II)

- A comparison of WRF-Chem simulation results and monitoring data.

Observed concentrations of ground level ozone at 4 monitoring stations in BMR were used to validate the performance of the WRF-Chem model. The locations of the monitoring stations are shown in Figure 4.

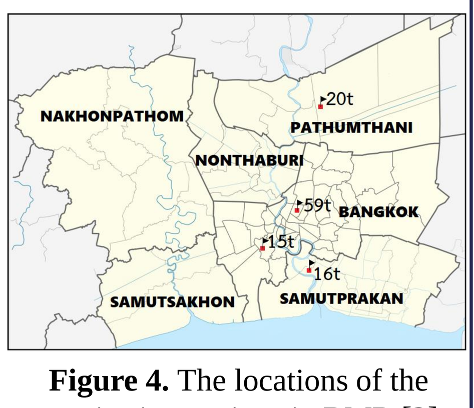

Figure 4. The locations of the monitoring stations in BMR.[2]

In Figure 5 provides a comparison of simulated ground level ozone concentrations and monitoring data from 1 March to 1 April 2013. The results revealed that model could capture the trend of monitoring data in most of study period, except for the high concentration during noon-2 pm, which the simulations underestimated the ozone peak.

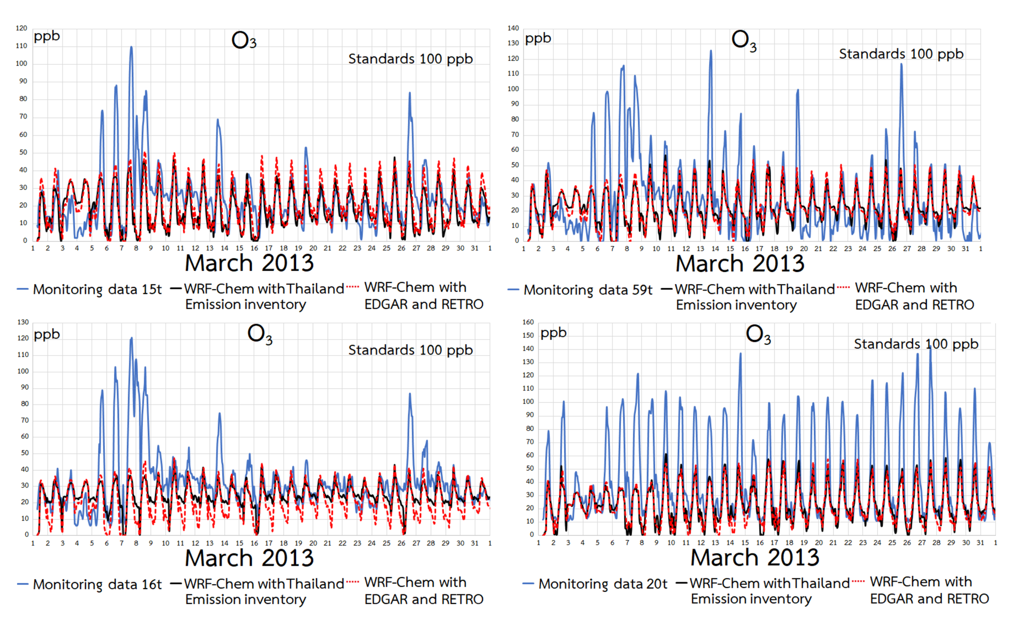

Figure 5. Comparison of time series ground level ozone concentrations from 1 March to 1 April 2013, between the WRF-Chem simulation results (CASE I – red line, CASE II – black line) and the data of difference monitoring stations (blue line).

- Model sensitivity on different of emission inventory datasets.

The hourly scattered plot of ground level ozone concentrations from WRF-Chem model CASE I and II were compared with monitoring data of 4 monitoring stations are shown in Figure 6. The results were revealed that simulated results were reliable since those points were lied in the region of factor of two (line 1:2 and 2:1).The statistics analysis of hourly ground level ozone concentrations were also shown in Table 1. Based on the scatter plot and statistical analysis, it was inferred that CASE II has a better performance on simulation of the ground level ozone concentrations than CASE I.

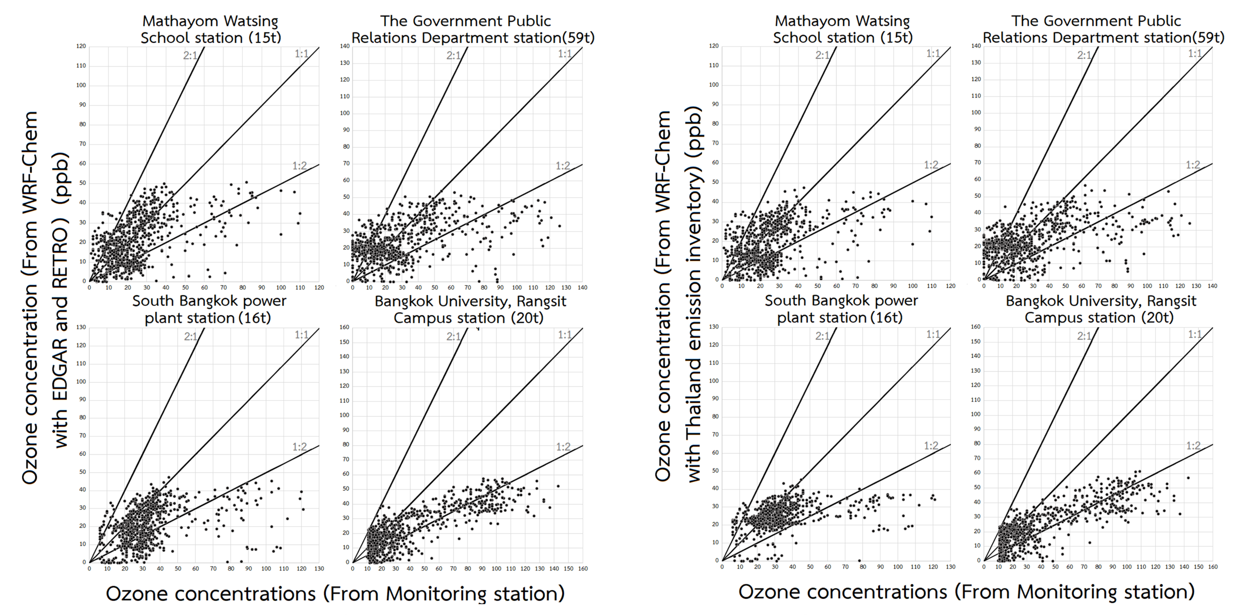

Figure 6. Scatter plot of ground level ozone concentrations from 1 March to 1 April 2013, between the WRF-Chem simulation results (CASE I – left, CASE II – right) and the data of difference monitoring stations.

Table 1. Statistics for WRF-Chem results against hourly observations data.

	Station 15t		Station 59t		Station 16t		Station 20t	
	CASE I	CASE II	CASE I	CASE II	CASE I	CASE II	CASE I	CASE II
Mean Obs (ppb)	24.56		28.30		33.39		41.30	
Mean Mod (ppb)	21.09	22.26	23.39	23.90	20.97	25.01	23.63	24.40
MB (ppb)	-3.47	-2.30	-4.91	-4.39	-12.42	-8.37	-17.67	-16.90
FAC2	0.86	0.90	0.83	0.84	0.63	0.75	0.57	0.59
NMB (%)	-14.12	-9.35	-17.36	-15.54	-37.19	-25.1	-42.79	-40.91
NME (%)	43.57	41.95	54.07	51.67	43.21	35.08	47.75	46.63
FB	-0.15	-0.02	0.07	0.09	-0.45	-0.21	-0.45	-0.43
NMSE	0.45	0.43	0.76	0.68	0.65	0.44	0.82	0.78
RMSE (ppb)	15.33	15.19	22.45	21.47	21.37	19.16	28.26	27.92

Conclusion

The results from this study revealed that WRF-Chem model could capture variations of ground level ozone concentration over BMR in March 2013.

- The peak of ozone concentration was observed around noon-2:00 PM (local time in Thailand, UTC +7:00 hours).
- The spatial distribution revealed that high ground level ozone concentrations were observed around the northern area of Bangkok, a part of Nonthaburi, Pathum Thani and Nakhon Pathom
- The WRF-Chem simulation results (CASE I and II) can capture the trends of monitoring data except the high ground level ozone concentrations during noon to 2:00 PM.
- The comparison and evaluation of the simulated results of using two different emission inventory datasets revealed that local emission inventory yielded the better results than global emission inventory.

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