Surface Level Wind Forecast Simulation over the Land-Sea area and Mountain-Valley area in Thailand

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The Asian Conference on Sustainability, Energy & the Environment 2016
Official Conference Proceedings

Abstract
It is known that the dispersion of pollutants from the source mainly depends on velocity and direction of the wind. For the purpose of air quality surveillance of Electricity Generating Authority of Thailand (EGAT), the Regional Atmospheric Modeling System (RAMS) is applied for simulating 168-h low-level wind forecasts over the area of two largest power plants, the Mae Moh Power Plant which is located in a mountain-valley area, and the Bang Pakong Power Plant which is located in a land-sea area. The simulation results were compared with observational wind speed, wind direction, and temperature from various local-based meteorological stations. The comparison shows that the modeled values are generally in good agreement with observations in both land-sea area and mountain-valley area. Furthermore, the model can capture many features of the observed data well and the precision level was internationally acceptable. As a consequence, EGAT's wind forecast simulation project was very effective for further implementation.

Keywords: Regional Atmospheric Modeling System (RAMS), Mae Moh Power Plant, mountain-valley area, Bang Pakong Power Plant, land-sea area

1. Introduction

The atmospheric flow is a key of the dispersion of pollutants from the sources. The movement of pollutants, the spread of pollutants, and the dilution of pollutants are all depends on it. Nevertheless, the wind flow data over area in varies attitudes is limited due to sparse meteorological data, particularly in regions of complex terrain. The realistic wind and turbulence fields can improve the mechanisms of pollutants dispersion in further air quality investigation of EGAT. The improvements are not possible while the wind homogeneity hypothesis is employed in most of the regulatory Gaussian dispersion models. It is known that the complex of terrain can cause large changes in wind speed and direction and in the turbulent fluxes that strongly affect to pollutant dispersion. Hanna, S.R. and Strimaitis D.G. (1990) listed some situations of pollutants distribution that are believed to lead increased concentration in complex terrain such as plume impingement on high terrain, pooling of pollutants in valleys, drainage towards population centers and persistence due to channeling inside valleys. The circulations that can give rise to recirculation of pollutants, like sea and mountain breezes. Moreover, breeze circulations can be disturbed by external processes such as synoptic forcing and orography.

The two prior power plants of EGAT, Mae Moh power plant is located in complex terrain, surrounded by mountain ranges where is considered as mountain-valley area and Bang Pakong Power Plant, the location is not far from Bangkok and close to gulf of Thailand where is considered as land-sea area influent. Thus both of these two important power plants are located in the complex terrain of Thailand. This numerical wind flow model is focused to use for meteorological driving in air quality around the power plant area of EGAT in next stage. However, even wind field simulation with meteorological models is a very powerful tool to use in air quality studies but there are a few models that can provide information about the wind behavior in the atmosphere near the surface well. In this study Regional Atmospheric Modeling System (RAMS) version 6.0 is considered to be applied for Mae Moh Power Plant area and Bang Pakong Power Plant area as it is widely using in air quality study. Moreover, the meteorological forecast in the area surrounding Mae Moh Power plant and Bang Pakong Power Plant are expected to be able to predict the distribution of pollutants from the combustion process that can be well-distributed, well-diluted in the atmosphere or the condition of the wind causes a low distribution and accumulation of pollutants in the area. Moreover, the forecast can be able to predict whether the wind blow pollutants from other sources into the power plant. The study would bring benefits in the prevention and mitigation of environmental impact and social issues surrounding the Mae Moh Power Plant and Bang Pakong Power Plant.

This study focuses on the wind field forecasting in those two power plants area by using RAMS, which permitted the study of the interaction of the different scales of motion in defining the regional- and local-scale flow through its nesting capabilities. Model results are also evaluated through analysis of the available meteorological data.

2. Description of the Model and Model Setup

a. The RAMS Model

RAMS was developed at Colorado State University and the ASTER Division of the Mission Research Corporation (Pielke et al. 1992). RAMS is constructed around full set of primitive dynamical equations which govern atmospheric motions, and supplements these equations with optional parameterizations for turbulent diffusion, solar and terrestrial radiation, moist processes including the formation and interaction of clouds and precipitating liquid and ice hydrometeors, sensible and latent heat exchange between the atmosphere, multiple soil layers, a vegetation canopy, surface water, the kinematic effects of terrain, and cumulus convection. It is the successor of coupling a cloud model developed by W.R. Cotton and a mesoscale model developed by R.A. Pielke. Continued development of RAMS has followed the philosophy of including a broad range of capabilities within one model system.

An important feature of RAMS is its capacity to perform two-way interactive grid nesting, which allows local fine-mesh grids to resolve small atmospheric systems, while simultaneously modeling the large-scale environment of the systems on a coarser grid. The important features of RAMS are summarized in Pielke et al. (1992). RAMS is using worldwide in difference purposes. Recent air quality studies in Asia region based on the application of RAMS can be found in many references such as Seiji Sugata et al. (2001), Meigen Zhang (2005), Meigen Zhang et al. (2006), Surachai Sathitkunarat et al. (2006), Sittichai Pimonsree et al.(2009), Xiao Han et al. (2009), Cui Ge et al. (2011), Yi Gao et al. (2014) and Zhen Peng et al. (2015).

b. Model Setup

After several preliminary testing, the suitable model lateral boundary domain configuration for area over Mae Moh Power Plant and area over Bang Pakong Power Plant can be set. For the present study, a two-nesting model domain has been defined for both areas as follows.

1) The outer model domain has a horizontal grid increment of 3 km with 120×120 grid points.

2) The inner model domain has a horizontal grid increment of 1 km with 152×152 grid points centered at 18.3N, 99.7E for Mae Moh Power Plant area, and 13.5N, 101.0E for Bang Pakong Power Plant area.

Thirty vertical levels following the topography were used in all grids beginning with 30-m vertical spacing near the ground, the vertical thickness increasing up to 1,500 m at an altitude and remaining constant up to about 15 km. The horizontal perspective of outer and inner domain configuration for Mae Moh Power Plant area and Bang Pakong Power Plant area can be displayed as in Fig. 1 and 2 respectively. As seen in Fig. 1 and Fig.2, Mae Moh Power Plant is surrounded by mountains and Bang Pakong Power Plant is closed to the sea of gulf of Thailand.

Daily initial meteorological input dataset for RAMS calculating is downloaded periodically in each day, 4 times a day at 00 UTC, 06 UTC, 12 UTC, and 18 UTC, from the National Centers for Environmental Prediction (NCEP), National Oceanic Atmospheric Administration (NOAA). The dataset consists of set of parameters such as Pressure, Geopotential Height, Temperature, Humidity, Vertical Velocity, V-component Wind Speed, U-component Wind Speed, Accumulated Precipitation, Soil

Moisture, Total Cloud Cover, Radiation Fluxes, Categorical Precipitation, Convective Available Potential Energy, Convective Inhibition, Absolute Vorticity, and Albedo.

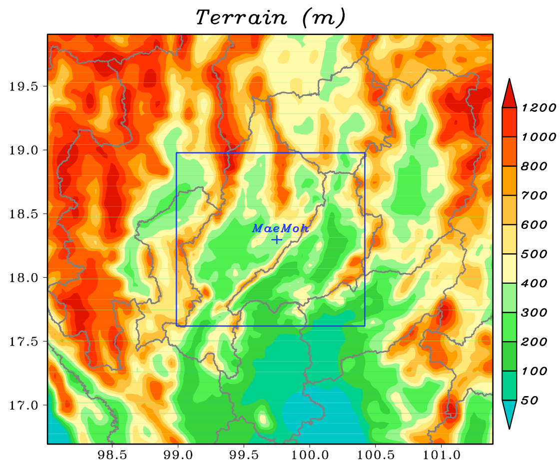

Figure 1 Outer and Inner Domain of Mae Moh Power Plant area.

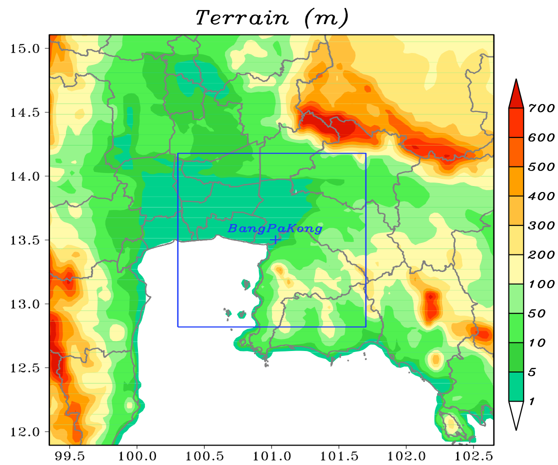

Figure 2 Outer and Inner Domain of Bang Pakong Power Plant area.

3. Simulation Results and Discussion

a. Model Performance

The performance of the modeling system was evaluated by comparison of simulation output and observation in whole year 2013. The statistical parameters which using for model performance evaluation are Mean bias (MB), Root mean square error (RMSE), and Fraction bias (FB).

Model Performance over Mae Moh Power Plant Area: The output results from RAMS, i.e., wind direction, wind speed, and temperature are compared with the observational data from 10 monitoring stations of EGAT.

– Wind direction: the evaluation of wind direction is done under the consideration of percentage of difference in modeled and observed wind directions less than 45^{o}. The percentage which ≥50 shows the good performance of the simulation, from the comparison found comparison at 6 from 10 stations has ≥50 percentage that difference in modeled and observed wind directions less than 45^{o}. From the observed hourly wind speed data over Mae Moh Power Plant area shows the greatest portion of wind speed is lesser than 1.5 m/s (more than 50 percent) and when consider in the Beaufort wind force scale which provides an empirical description of wind speed based on observed sea and land conditions, the Beaufort wind force scale 1 is classified by wind speed 0.3–1.5 m/s with the land condition found leaves and wind vanes are stationary. Thus, even the wind over Mae Moh power plant area is light; we can say the model simulation output can reflect the wind direction quiet well. well.

Table 1 Model comparison results of wind direction

Station		Symbol	N	45°	MB	RMSE	FB
1	Phatupha Army Camp	PC	5889	64.66	15.56	67.19	0.19
2	Ban Thasi	TS	3407	48.64	29.08	78.07	0.41
3	Ban Sadet	SD	5280	43.30	29.46	90.94	0.27
4	Ban Hua Fai	HF	6969	38.56	25.39	89.14	0.25
5	EGAT Housing Ban Huai King	HK	1528	61.78	10.38	64.19	0.20
6	Government Center	GC	5705	58.05	-1.47	65.59	0.05
7	Ban Sop Moh	SM	4253	52.10	-1.26	75.72	-0.03
8	Ban Sop Pad	SP	2405	50.31	23.39	77.22	0.11
9	Ban Mae Chang	MC	4987	47.48	40.30	87.34	0.30
10	Ban Mai Ratanakosin	RS	4423	53.29	25.57	67.76	0.13

Note: N = number of modeled and observed data paired in time and space
45^0 = percentage of difference in modeled and observed wind directions less than 45^o

– Wind speed: The comparison of wind speed is shown in Table 2. It is found MB is greater than zero in almost all stations, this comes from the most of simulation wind speed is greater than observed. By the way, the value of FB mostly is in range -0.5 to 0.5 (acceptance range is −2.0≤FB≤+2.0), it can be said the RAMS is the best performing model in simulation of wind speed over Mae Moh Power Plant area.

Table 2 Model comparison results of wind speed

Station		Symbol	N	mean observed	mean modeled	standard deviation of observed	standard deviation of modeled	MB	RMSE	FB
1	Phatupha Army Camp	PC	5889	1.13	1.06	90.00	99.69	-0.07	0.62	-0.17
2	Ban Thasi	TS	3407	0.93	1.07	79.75	98.53	0.14	0.80	-0.11
3	Ban Sadet	SD	5283	1.16	1.29	70.79	94.59	0.13	1.04	-0.24
4	Ban Hua Fai	HF	6969	1.30	1.00	70.47	96.57	-0.30	0.96	-0.58
5	EGAT Housing Ban Huai King	HK	1528	0.76	1.52	63.87	88.74	0.76	1.25	0.37
6	Government Center	GC	5705	1.18	1.32	74.53	96.77	0.13	0.92	-0.12
7	Ban Sop Moh	SM	4253	1.20	1.21	70.30	94.12	0.01	1.05	-0.30
8	Ban Sop Pad	SP	2405	0.90	1.20	74.97	96.13	0.30	0.94	0.00
9	Ban Mae Chang	MC	4998	1.08	0.97	80.87	98.32	-0.11	2.62	-0.36
10	Ban Mai Ratanakosin	RS	4423	0.93	1.29	78.02	97.11	0.36	0.87	0.08

– Temperature: Table 3 shows the comparison of temperature at each monitoring stations. It is found the value of FB is in range -0.5 to 0.5 in every monitoring station. . It is also found most of model temperature is greater than observed as the MB is greater than zero in all stations.

Table 3 Model Comparison results of temperature

Station		Symbol	N	mean observed	mean modeled	correlation coefficient	standard deviation of observed	standard deviation of observed	MB	RMSE	FB
1	Phatupha Army Camp	PC	8655	24.21	25.81	0.82	4.71	5.11	1.59	3.36	0.06
2	Ban Thasi	TS	8679	24.85	26.94	0.81	5.99	5.12	2.09	4.13	0.09
3	Ban Sadet	SD	8708	26.23	28.40	0.80	5.76	5.76	2.17	4.22	0.08
4	Ban Hua Fai	HF	8695	26.01	26.57	0.83	5.49	4.43	0.56	3.13	0.03
5	Meteo. Main Station	MS	8705	25.56	26.94	0.82	5.32	4.61	1.39	3.32	0.06
6	EGAT Housing Ban Huai King	HK	8676	25.84	26.80	0.82	5.22	4.55	0.96	3.15	0.04
7	Government Center	GC	8578	25.66	26.34	0.83	5.15	4.38	0.68	2.98	0.03
8	Ban Sop Moh	SM	8646	26.06	27.31	0.82	5.45	2.39	1.25	3.98	0.07
9	Ban Sop Pad	SP	8660	24.70	26.86	0.78	5.22	4.68	2.16	3.94	0.09
10	Ban Mae Chang	MC	8591	25.79	26.75	0.83	5.29	4.58	0.96	3.09	0.04
11	Ban Mai Ratanakosin	RS	8634	25.26	27.32	0.80	5.82	5.55	2.06	4.12	0.09

Besides the statistics evaluation, to see the hourly variation change in each day of temperature from modeled and observed, the time series plot is used such as Figure 3 and Figure 4. It is shown that the variation of modeled is in good agreement with observed. Besides it is found the magnitude of modeled in dry season is in better agreement with observed than in wet season.

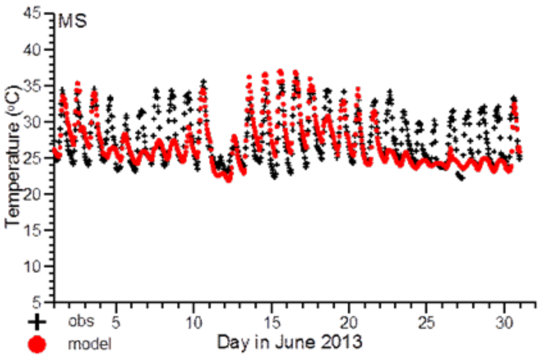

Figure 3 Time series plot of temperature between modeled and observed at Meteorological Main Station in June 2013 (wet season)

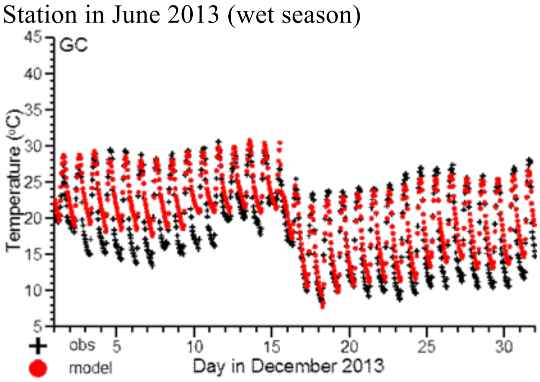

Figure 4 Time series plot of temperature between modeled and observed at Government Center Station in December 2013 (dry season)

Model Performance over Bang Pakong Power Plant Area: The model simulation results from RAMS are compared with the observational data from 2 monitoring stations of EGAT.

– Wind direction: The comparison is done for number of modeled and observed data paired in time and space comes from the paired data which observed wind speed is equal or greater than 0.5 m/s. This comparison found percentage of difference wind direction less than 45^{o} greater than 70% in both monitoring stations, even the results from RAMS is the averaging over both space and time while the observed is the averaging over time only. That means the model output can reflect the wind direction over Bang Pakong Power Plant area much better than Mae Moh Power Plant area.

Table 4 Model comparison results of wind direction

STATION		SYMBOL	N	45^{O}
1	Bang Pakong Training Center Station	TC	7735	73.55
2	Wat Lang Station	WL	7512	73.62

Note: N = number of modeled and observed data paired in time and space
45^{0} = percentage of difference in modeled and observed wind directions less than 45^{o}

– Wind speed: The evaluation of RAMS' simulation for wind speed over Bang Pakong area. It is found MB is greater than zero in both stations that means the model wind speed is greater than observed. It is found the value of FB is in range -0.5 to 0.5.

Table 5 Model Comparison results of wind speed

Station		Symbol	N	mean observed	mean modeled	standard deviation of observed	standard deviation of modeled	MB	RMSE	FB
1	Bang Pakong Training Center Station	TC	7735	1.92	3.00	38.97	71.21	1.09	1.79	0.31
2	Wat Lang Station	WL	7512	1.52	2.39	50.21	85.05	0.87	1.36	0.36

– Temperature: The model can predict the value of temperature below the observed data at Bang Pakong Training Center Station (MB < 0) and over the observed at Wat Lang Station (MB>0). The value of FB is in range -0.5 to 0.5.

Table 6 Model Comparison results of temperature

Station		Symbol	N	mean observed	mean modeled	correlation coefficient	standard deviation of observed	standard deviation of observed	MB	RMSE	FB
1	Bang Pakong Training Center Station	TC	8606	28.81	28.53	0.64	2.57	1.60	-0.28	1.98	-0.01
2	Wat Lang Station	WL	7676	28.23	29.17	0.86	3.19	3.70	0.95	2.13	0.03

Time series plot of temperature in wet and dry season shows the good agreement in variation. The modeled shows temperature variation in dry season better than wet season.

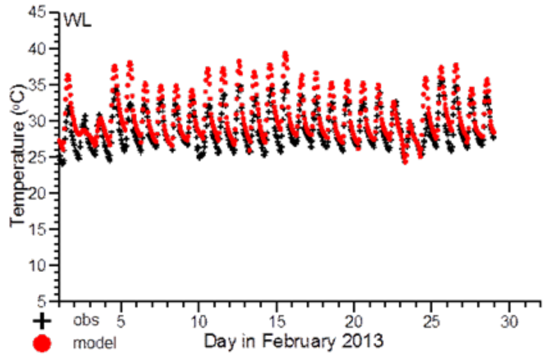

Figure 5 Time series plot of temperature between modeled and observed at Wat Lang Station in February 2013 (dry season)

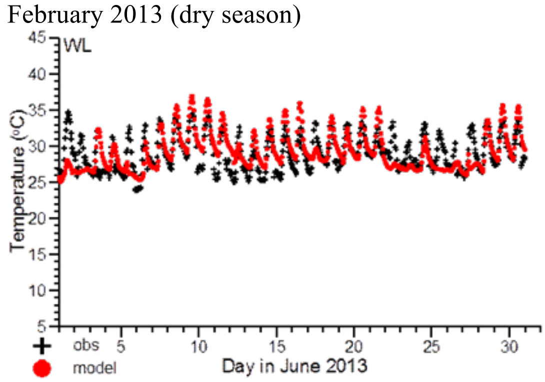

Figure 6 Time series plot of temperature between modeled and observed at Wat Lang Station in June 2013 (wet season)

b. Wind Circulation over Land-Sea area and Mountain-Valley area

It is known that the terrain morphology can give the effect to surface wind circulation when the effects of synoptic weather is not strong. During the period that synoptic force is weak in area over Mae Moh Power Plant; in night-time the cooling of the air on the mountainsides generates downward streams (Figure 7) and in day-time after sunrise, opposite streams is progressively established at these mountains (Figure 8). This is the mountain-valley breeze found over Mae Moh Power Plant area.

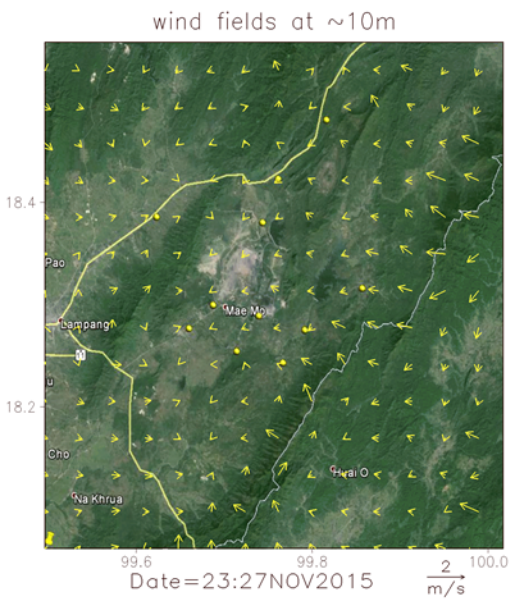

Figure 7 Mountain-breeze in night-time over Mae Moh Power Plant Area at 23:00 o'clock, 27 November 2015

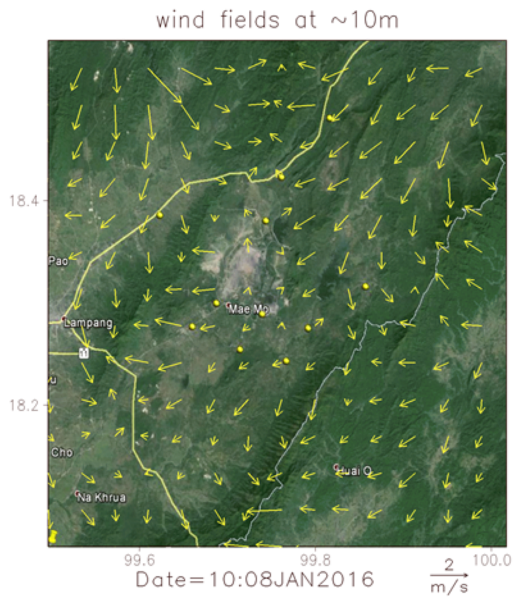

Figure 8 Valley-breeze in day-time over Mae Moh Power Plant Area at 10:00 o'clock, 8 January 2015

It is found that the boundary layer wind field over Bang Pakong Power Plant area is strongly dominated by effect from synoptic condition in almost whole year. However, when the synoptic condition is weak, surface wind is controlled by the morphology of the landscape. In day-time after sunrise temperature rising over the sea surface is relatively slower rate than temperature rising over the land surface, result in cool air from sea flow towards the lower pressure (warm temperature causes the air to expand, becoming less dense) over land as seen on Figure 9.

Figure 9 Sea-breeze in daytime over Bang Pakong Power Plant Area at 10:00 o'clock, 13 November 2015

4. Conclusion

The Regional Atmospheric Modeling System (RAMS) is selected to simulate the planetary boundary wind over two complex terrains, the mountain-valley area and land-sea area in Thailand. The model evaluation was done for different weather condition in whole year 2013. Analysis of the model results indicates that the model can simulate major features of synoptic condition, terrain induced circulation and diurnal variations in temperature well.

The model still shows the simulation performance of temperature in dry season better than wet season. It is the impacts of clouds on radiative heating. In present, clouds forecasting is still one of the weakness aspects of the meso-scale meteorological modeling system in tropical region. The improving of the cloud process is still going on and need the more data in tropics.

Nowadays the simulation system of RAMS over area of Mae Moh Power Plant and Bang Pakong Power Plant can be run automatically every day. The modeling system output gives meteorological condition in hourly prediction for 168-hours (7 days) ahead in each daily period of simulation. The modeling output is extracted to show the results in graphic display on EGAT’s website for all users at http://aether.egat.co.th.

References

Hanna, S.R. and Strimaitis D.G., 1990: Rugged terrain effects on diffusion, in Blumen (Editor) Atmospheric processes over complex terrain, American Meteorological Society, Boston, 323 pp.

Pielke, R.A., Cotton, R.W., Walko, R.L., Tremback, C. J., Lyons, W.A., Grasso, D.L., Nicholls, M.E., Moran, M.D., Wesley, D.A., Lee, T.J., and Copeland, J.H., 1992: A Comprehensive Meteorological modelling System - RAMS, Meteorol. Atmos. Phys., 49, 69-91.

Seiji Sugata, Daewon W. Byun, and Itsushi Uno, 2001, Simulation of sulfate aerosol in east asia using models-3/CMAQ with RAMS meteorological data, Air Pollution Modeling and Its Application XIV, Edited by Gryning and Schiermeier, Kluwer Academic/Plenum Publishers, New York

Meigen Zhang, A multi-scale air quality modeling system and its evaluation I. Introduction to the model system and simulation of meteorological parameters. Chinese J. Atmos. Sci., 29(5), 805-813, 2005.
Meigen Zhang, A multi-scale air quality modeling system and its evaluation II. Simulation of tropospheric ozone and its precursors in East Asia. Chinese J. Atmos. Sci., 29(6), 926-936, 2005.

Meigen Zhang, Hajime Akimoto, Itsushi Uno, A three-dimensional simulation of HOx concentrations over East Asia during TRACE-P, J. Atmospheric Chemistry, doi:10.1007/s10874-006-9015-0, 2006. (SCI)
Meigen Zhang, Itsushi Uno, Renjian Zhang, Zhiwei Han, Zifa Wang, Yifen Pu, Evaluation of the Models-3 Community Multi-scale Air Quality (CMAQ) modeling system with observations obtained during the TRACE-P experiment: Comparison of ozone and its related species. Atmos. Environ., 10.1016/J.Atmos. Env.2005.06.063, 40(26), 4874-4882, 2006. (SCI)

Surachai Sathitkunarat, Prungchan Wongwises, Rudklao Pan-Aram, and Meigen Zhang, Carbon monoxide emission and concentration models for Chiang Mai urban area, Advance in Atmospheric Sciences, 23(6), 901-908, 2006.

Sittichai Pimonsree, Prungchan Wongwises, Rudklao Pan-Aram, Meigen Zhang, Model analysis of PM10 concentration variations over a mineral products industrial area in Saraburi, Thailand, Water, Air, & Soil Pollution, 201, 239–251, 2009.

Xiao Han, Meigen Zhang, Xiaohong Liu, Steven Ghan, Xin Jinyuan,Wang Lili, Development of RAMS-CMAQ to simulate aerosol optical depth and aerosol direct radiative forcing and its application to East Asia, AOSL, 2(6), 368-375, 2009.

Cui Ge, Meigen Zhang, Zhiwei Han, and Yanju Liu, Episode simulation of Asian dust storms with an air quality modeling system, Advances in Atmospheric Sciences, 28(3), 511-520, 2011.

Yi Gao, Chun Zhao, Xiaohong Liu, Meigen Zhang, L. Ruby Leung, WRF-Chem simulations of aerosols and anthropogenic aerosol radiative forcing in East Asia, Atmospheric Environment, 92, 250-266, DOI: 10.1016/j.atmosenv.2014.04.038, 2014. 2014.

Zhen Peng, Meigen Zhang, Xingxia Kou, Xiangjun Tian, and Xiaoguang Ma: A regional carbon flux data assimilation system and its preliminary evaluation in East Asia, Atmos. Chem. Phys. 15, 1087-1104, doi:10.5194/acp-15-1087-2015, 2015.

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