REGULATORY AIR MODEL FOR A SEASIDE INDUSTRIAL COMPLEX

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ABSTRACT
In Thailand, regulators are faced with the problem of resolving the different predictions of the concentrations sulfur dioxide and nitrogen dioxide obtained from two US EPA regulatory models, ISCST and CALPUFF. The models are evaluated according to the maximum ground level concentrations (MAX GLCs; a criterion used by the board of environmental policy for decisions on the approval of new industrial facilities) of the two gaseous pollutants. Tests of the two models have been made using a case study based on the Maptaphut industrial complex on the Eastern Seaboard of Thailand. The model domain incorporates 291 point emissions sources and an array of community receptors set within a geographic domain characterized by gently rolling hills and 25 km of coastline. The two transport schemes – CALPUFF and ISCST – are based on different sources of information for the underlying meteorological transport fields. CALPUFF uses meteorological input data from its meteorological preprocessor, CALMET, which incorporates data from 12 surface stations in additions to output from a prognostic meteorological model, MM5. ISCST, on the other hand, uses observations from a single surface measurement site in the model domain along with upper air profiles that have been collected at the only available measurement site outside the model domain. Although ISCST had previously been used to evaluate MAX GLCs, tests have revealed predictions of this model to be higher than established standards. Pressure from industry to obtain more realistic estimates of pollution exposure has forced consideration of a more refined Gaussian puff model – CALPUFF – that would avoid overprediction of pollutants at receptor sites. However, in tests at the Maptaphut industrial complex, CALPUFF predicted MAX GLCs that were 30% higher than the predictions of ISCST. These unexpected results have forced the national board of environment to evaluate which model is more skillful in simulating the correct MAX GLCs. This work attempts to address that problem and to present the analysis in a systematic format to lead way towards the final decision, i.e. specifying a cap on total emission and a fair goal for emission trading, judging on ambient air quality impact of the country key industrial development.

INTRODUCTION
The Maptaphut Industrial Estate (MTPIE) of the Industrial Estate Authority of Thailand (IEAT) consists of approximately 50 companies representing the petroleum refining, petrochemical and chemical, fertilizer manufacturing and steel refining industries. Also located at this estate are coal-fired power plants, marine bulk loading terminals, a common wastewater treatment plant, numerous private wastewater treatment plants, and a common wastewater drainage channel. This complex, which was established in 1990, is situated on 2400 acres and is located in an environmentally sensitive zone due to its close proximity to a school, a religious temple, a residential community and a port.

In recent years, IEAT has expanded this complex. Farmland that previously bordered the communities and the school has been replaced by industry. Since then, community leaders, local religious leaders, teachers and students have made numerous odor and health complaints. The complaints have been addressed to the media and other government agencies. As a result, in early 1998, IEAT established the Maptaphut Environmental Taskforce (MTPET) to supervise a consultant firm on the Maptaphut air pollution carrying capacity study. Preliminary air quality modeling indicates that emissions of sulfur dioxide and nitrogen dioxide from MTP industries may cause or contribute to violations of Thailand's ambient air quality standards. IEAT requires a thorough SO_2, NO_2 emissions evaluation. It also requires the selection or development of an air quality model that can be used to accurately predict current and future ambient air impacts from these sources.

METHODOLOGY

The meteorological/ ambient air quality network used for this study consists of 8 stations. Six of the stations are ambient air quality stations that collected concentrations of criteria air pollutants and some of the parameters, such as wind speed/direction, temperatures. In addition, there is one 100-meter meteorological mast, with instruments at the near ground and elevated levels 50, 75 and 100 m, and a wind Profiler, which is a meteorological remote sensing that provides an alternative to a balloon sonde measurement. The RADAR/RASS, LAPTM-3000 (Radian Corporation) measured the profile of wind speed/direction and virtual temperatures at an interval of 60 meter, starting from 130-meter level. Under the clear atmosphere, the capability of the RADAR/RASS for wind and temperature can be respectively as high as 3,000 and 1,500 meter. See locations of the stations and sources in Figure 1.

MATHEMATICAL MODELLING

Since good resolution of the meteorological fields is critical for accurate determination of the transport and diffusion of pollutants using the CALPUFF model. The land-sea breeze circulation is an important feature of the flow in the Maptaphut area, as well as the complex terrain to the NW and NE of the source region. Therefore, as a complement to meteorological observations, the output from a mesoscale prognostic model was used to initialize CALMET. The prognostic model selected for this purpose was the PSU/NCAR Mesoscale Model System (MM5) (Grell et. al., 1995)Also, this gave remedies to the fact that no wind observations located over water, which are important for purposes of evaluating flow re-circulation effects.

The MM5 model was run in non-hydrostatic mode for the full simulation year, over 4 two-way nested domains of increasing spatial resolution, producing hourly three-dimensional meteorological fields at resolutions as fine as 3km (Domain 4), along with larger scale fields at 9km (Domain3), 27km (Domain 2), and 81km (Domain 1). Geographical locations of the domains are presented in Figure 2.

In the modeling protocol, a CALMET/CALPUFF modelling domain of 25km x 25km with horizontal grid cells of 250m in size was proposed. This design treats the immediate vicinity of the sources and monitoring sites with a fine-scale resolution (250m), thus resolving land use variability, terrain elevations, and the land-water coastal boundary very well. In the vertical, CALMET has 11 layers of increasing thickness. The layer centers are located at: 10, 30, 60, 110, 190, 330, 560, 900, 1400, 2100, and 3050 metres above ground (terrain following coordinates).

Two CALMET runs with different options were tested for four-month model evaluation period, June – September 2002, which is the wet season but when winds are southwesterly: (1) Observations model including the available surface, upper air and overwater observational data as well as the MM5 gridded meteorological fields; and (2) No-Observations (No-Obs) model including only the MM5 data (i.e., without the direct use of any observational data in CALMET).

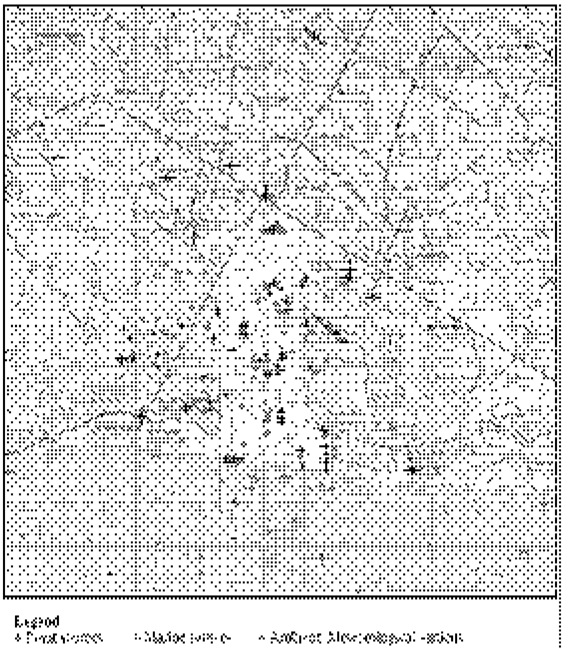
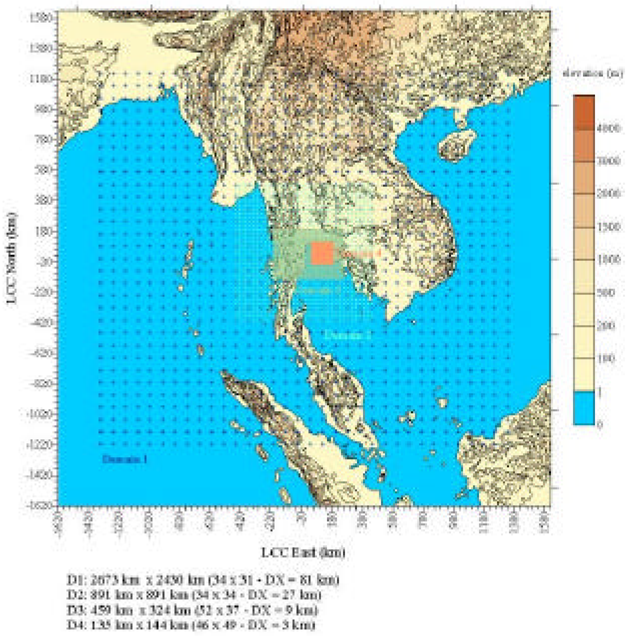


Fig. 1; locations of the emission sources, and ambient air and meteorological stations



Fig, 2; MM5 nested domains for meteorological input to the CALMET modelling

Since the simulation result of CALMET with No-Observations (No-Obs) mode using the MM5 dataset and the evaluated the effects of building downwash by using the PRIME method gives better results, we took this option for the final full year maximum impact assuming full production emission conditions for all sources. The CALPUFF model was run for 297 stacks (point sources) in the MTP Industrial Estate and nearby areas. The emissions of SO_2 and NO_x from each source were based on an assumption of maximum production. The PRIME building downwash model was used for stacks with sub-Good Engineering Practice (GEP) height stacks. Eight areas containing marine vessels were modeled as points sources centered in each of the areas. Wind-direction specific background pollutant concentrations were evaluated using monitor measurements of pollutants for the next year period, November 2002-October 2003.

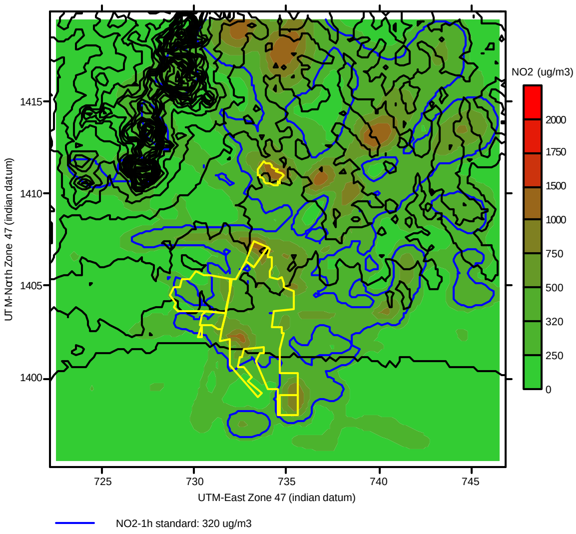


Figure 3; Map shown maximum impact evaluation of the NO_2 using CALPUFF model

As shown in Figure 3, when all sources are simultaneously emitting at their potential maximum production rates, the modeling predictions indicate potential violations of the 1-hour NO_2 and SO_2 Thai ambient air quality standards.

DISCUSSION

The maximum evaluation study revealed that the high concentrations of SO_2 were found to be limited within the area of industrial estates and the vicinity area. The NO_2 concentrations were found to be distributed on the wider area of more that 10 km in radius. The high concentrations were observed in the industrial estate area, and at the distance of 6 to 12 km in the northeast and north of the industrial estate, which was the local wind direction.

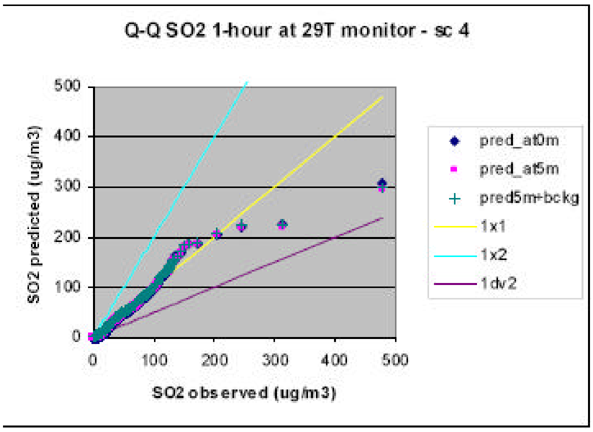


Fig. 4; Q-Q plot of the SO_2 prediction performance of which its option was taken

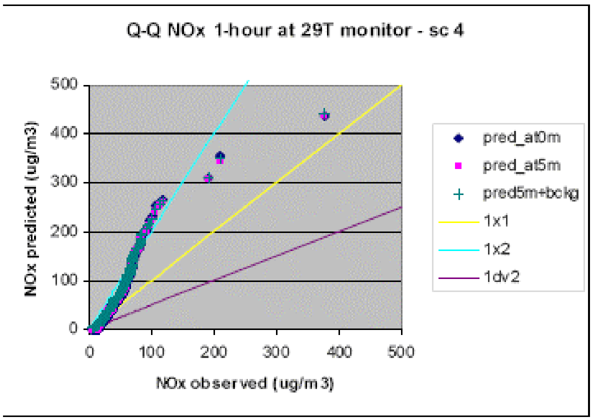


Fig 5; Q-Q plot of the NO_2 prediction performance of which its option was taken

The high impact results of the study make the public queried back into the methodologies and whether the (CALPUFF) model was trustable or was fine tuned enough to be applicable to the temperate climate. There was an issue asking if the Quantile-Quantile plots as shown in Figure 4 and Figure 5 were the sufficient tools for assessing the model. In facing this issue, the authority was forced to make a more comprehensible plot like scatter plots, so that the wider community could see the time-space dependence of the model performance. As shown in Figure 6 and Figure 7, the plots revealed very low correlation between the observed and predicted values. With this circumstance, modelers are then forced to look back into how to improve the modelling work.

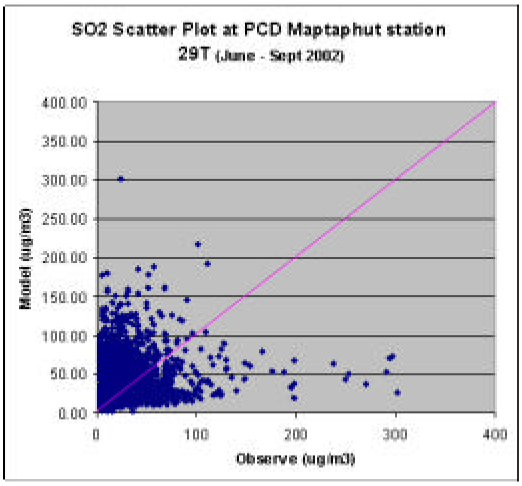


Fig. 6; Scatter plot of SO_2 using data during model evaluation period

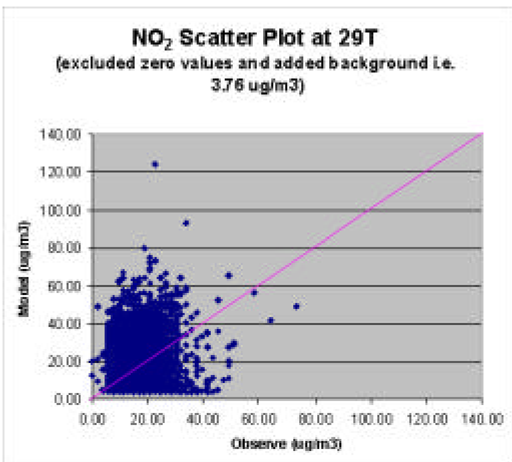


Fig. 7; Scatter plot of NO_2 using data during model evaluation period

CONCLUSION

There are several issues surrounding the selection of air dispersion models to be taken as the best and most suitable one for the seaside industrial estates. One of the important factors is the lack of understanding in technical differences between the models. The industrial emission source owners were misled that a more refined model may give a lower maximum impact than the Gaussian Plume models such as ISCST, whereas the results have shown the opposite. In this case, they become responsible to the potential violation that their sources might contribute. It is a challenging task of the regulator to convince them which air dispersion model is the acceptable tool to control and make investment possible together with safe environment in such the area.

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Grell, G., Dudhia, J. and Stauffer, D., 1995. A description of the fifth-generation Penn State/NCAR mesoscale model (MM5). NCAR/TN-398+STR. http://www.mmm.ucar.edu/mm5/documents/mm5-desc-doc.html.