# PREDICTING SULFUR DIOXIDE DISPERSION FROM MULTIPLE SOURCES IN MAJOR CITIES IN KLANG VALLEY USING INTEGRATED MM5-SMOKE-CMAQ MODEL SYSTEM

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## Introduction

During the 19th and 20th centuries, the anthropogenic emission of sulphur dioxide (SO2) has increased along with the industrialization and fossil fuel combustion (Lefohn *et al*,. 1999). When the $SO_2$ deposited as acid rain or particle, it contributes to the acidification of soils and surface water, causing nutrients leaching and increased toxic aluminum (USEPA). The study conducted by Sunyer *et al.*, (2002) suggested that the $SO_2$ pollution may play an independent role in triggering ischemic cardiac events. Thus, air pollution has become public's major concern with the rapid growth of traffic, industrialization, and urbanization within the major cities around the world. (Zhang *et al.*, 2008, Bhanarkar *et al.*, 2005; Colvile *et al.*, 2002; Engardt and Leong, 2001; Siniarovina and Engardt, 2005 ). Therefore, a proper and strategic town planning is essential to minimize the impact of urbanization on the environment and improve health condition in the urban area. According to Molina and Molina (2004) the air quality management policies are the outcome of series of complicated and time consuming processes, which include air quality monitoring, emission inventory preparation and control strategies delineation, and long-term compliance monitoring. In the process of developing an appropriate air quality plans, emission estimation from different type of sources becomes essential. The advances of air quality modeling systems have been substantial in the last decade. From the first and second generation of the air quality modeling systems that related to the points source emissions that releases to the surrounding atmosphere, to the third generation of air quality modeling systems which could simulate the transport and transformation of chemical pollutants in a more realistic way. (José *et al.,* 2005). The complexity of the urban surface characteristic and turbulence patterns has suggested numerical models to predict and manage urban air pollution. Detailed urban parameterization such as surface roughness and urban heat fluxes must be taking into account while performing simulation in urban area. It is because the flow structure and dispersion of air pollutants within cities are influenced by urban features such as surface roughness (Kitwiroon *et al.,* 2003). The Fifth Generation Mesoscale Model (MM5) by Pennsylvania State University / National Center for Atmospheric Research (PSU/NCAR) is for producing meteorological fields in 4D mode and the Community Multiscale Air Quality Modelling System (CMAQ) by U.S. EPA Atmospheric Science Modeling Division (U.S. EPA) for the chemical mechanism and dispersion of pollutants which is also a representative of the third generation of air quality models which include clouds, aqueous, and aerosol chemistry. Meteorological – air quality modeling systems are ensemble to include the application of both global and mesoscale meteorological models and several chemical air quality models are being actively developed. (Erisman *et al.*, 2005).

## Problem Statement

There are several studies conducted to determine the emission of $SO_2$ from Asia and South-East Asia. However, the output resolution of the emission from the studies are by region/country (Shrestha *et al.*, 1996); $1^O$ x $1^O$ (Akimoto and Narita, 1994; Engardt and Leong, 2001) and $0.5^O$ x $0.5^O$ (Siniarovina and Engardt, 2005) which are too coarse compare to the study area relatively. The high resolution emission inventories from different sources are still unavailable at time being. In order to access the air quality profile of an area, an emission inventory was needed. Currently the air quality in the Klang Valley is monitored by five

Continuous Air Quality Monitoring Station (CAQMS) under Department of Environment Malaysia. The limited air quality monitoring station network is due to the cost and maintenance. It is difficult to obtain the air quality status if the highly sensitive area or the area of interest is far away from the air quality monitoring station. Air pollution modeling could provide a better solution in determining the air quality status over a large area.

## Objective

This study will focus on the relationship between pollution emission changes and the meteorological condition thus affecting the air quality in the study area. An emission inventory from different type of sources will be established. The meteorological profile and air quality of major cities and populated area will be established in this paper. Evaluation of the simulation model will be carried out at the final stage of the study.

## Methodology

The study will involve initially the compilation of maps, digitizing the elevation data and incorporation of available soil geological map and database. The land use and land cover change of the selected study area will be established. Digital map will be gathered from Department of Survey and Map Malaysia (JUPEM) and land use maps will be gathered from Town and Country Planning Department (JPBD). These data will be used as input for the modeling process.

This study aims to cover the whole Klang Valley, comprises Kuala Lumpur and its surroundings and suburbs. Klang Valley is surrounded by hilly areas and the Port Klang coastline to the west. Klang Valley's main population centers are located at Petaling Jaya (1,480,800), Shah Alam (393,200), Klang (809,400) and Subang Jaya (546,600) and others major cities (DOSM, 2007). The tropical climate the average temperature ranges from 22$^{o}$C to 33 $^{o}$C throughout the year and the relative humidity is as high as 90%. Being located in the equatorial zone, the climate is governed by the northeast and southwest monsoons. The northeast monsoon blows from December to March and the southwest monsoon from June to September. These two main monsoon seasons are separated by two relatively short inter-monsoon seasons which usually recorded heavy rainfall. The annual rainfalls vary between 2,000 mm and 2,500 mm and the mean monthly rainfall between 133 mm and 259 mm.

## Modeling Approach

MM5 is the first processing steps to run to obtain the meteorological fields of the study area, which are for the air quality monitoring. In MM5, the regular latitude-longitude terrain elevation and vegetation of the chosen domain were horizontally interpolated or analyzed by the TERRAIN. This step requires landuse and topography data which could obtained from USGS 1 km NOAA satellite data sets and Digital Elevation Model from USGS with 30s spatial resolution respectively. While REGRID is to read archived gridded meteorological analyses and forecasts on the pressure levels and interpolate the map projection to the horizontal grid and map projection defined by MM5. The initial meteorological conditions for the specific period of time were obtained from NCEP/NOAA, USA. INTERPF performs the vertical interpolation from pressure levels to the $\sigma$-coordinate of the MM5 model. After MM5 integration, NESTDOWN can be used to interpolate model level data to a finer grid to prepare for new model integration. The outputs of the MM5 are preprocessed by MCIP as input for SMOKE and CMAQ.

SMOKE is used to produce the emissions required by CMAQ using various databases. The inventory import step reads the raw emissions data, screens, processes, and converts the data to the SMOKE intermediate inventory file. The emissions in the inventory file are subdivided to hourly emissions during temporal allocation; assigned chemical speciation factors during speciation, and assigned spatial allocation factors during gridding. The plume-rise computation estimates vertical plume rise of emissions sources and computes the fraction of emissions from the sources to go into the model layers. The results of these steps are combined in a merge step, which creates model-ready files for CMAQ.

After MCIP preprocess the data from meteorology model for CMAQ. GRIDDESC file is generated and it is used to define the modeling grid. The ICON creates binary netCFD initial condition files which are configured for a specific modeling grid and chemical parameterization for input to the CCTM. BCON prepares chemical boundary conditions for the CCTM. JPROC converts physical information about photoreactive molecules into clear-sky photolysis rate look up tables for input to the CCTM. The basic CCTM outputs generated include instantaneous and average hourly concentration files, wet and dry deposition files, and visibility estimates.

In order to evaluate the accuracy of the modeling output, verification must carry by comparing the simulated meteorological output from MM5 with the climatic condition collected from the monitoring station within the study area such as wind speed and direction, surface temperature and relative humidity. Sensitivity analysis also will be carried out with different parameterization in MM5 in order to determine the impacts of the parameterization of MM5 towards the distribution of the air pollutants. Simulated result generated from CMAQ must also need to be validated with the secondary data (Hourly $SO_2$ concentration) that collected by the air quality monitoring stations of Department of Environments in Klang Valley.

## Result & Discussion

Simulation on the meteorology condition of selected months in year 2005 has been done. The temperature profile generated from the MM5 simulation showed 0.81 correlation coefficient when compare to the actual data collected from the monitoring station by Malaysian Meteorological Department (MMD). Emission data generated from the inventory of the emission from the industrial, transportation and domestic sector were used to generate air pollution dispersion of $SO_2$ over the study area with CMAQ modeling. The daily average concentration of $SO_2$ from CMAQ simulation results indicated 0.4 correlation coefficient when compare to the daily average concentration from the air quality monitoring station onsite.

## Significant of study

Through this study, proper distributions of the land uses to strategic area are able to minimize the impact of the air pollution. Health assessment is suggested to carry out in the identified effected zone in the study area caused by the development. Predicted changes of the meteorological condition and pollution emissions may use as one of aspects that take in consideration while establishing development plan by the Town and Country Planning Department Malaysia. The established emission inventory will be resourceful for other air pollution modeling in future, since the emission inventory still unavailable in Malaysia.

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