Development of a GIS-based Air Quality Modeling System
– A Software Tool for Predicting Air Pollution Levels in Urban Areas –

Background

In recent years, cogeneration systems have been installed for commercial uses in buildings such as hotels, hospitals and office buildings to reduce energy consumption and emissions of CO_2. Most cogeneration systems operate by internal combustion, such as gas turbines, gas engines and diesel engines that burn fossil fuel; thus, most cogeneration systems exhaust gases containing NO_x emissions from rooftops of buildings in which the cogeneration systems are installed. When air-quality impact assessments for such facilities are undertaken, the building downwash effect on pollution dispersion around surrounding buildings must be considered. Some Gaussian dispersion models have been proposed that account for the building downwash effect by modifying plume rise algorithms or dispersion parameters. In these models, the dimensions of buildings around a pollution source that may affect plume dispersion need to be specified. In urban areas, however, it is difficult to specify building dimensions (widths and heights) because there are many buildings and some of them have complicated shapes.

Objectives

To develop an air dispersion modeling system which can take into account the building downwash effect by using a geographic information system (GIS) to specify building dimensions automatically;

Principal Results

1. Development of a GIS-based air quality modeling system

To determine the building dimensions, commercially available electronic residential maps containing detailed information about buildings and homes were used. These maps indicate the planar shape and number of stories of each building, as well as the names of all buildings and residential houses. The planar shapes of buildings adjacent to emission sources were transformed into rectangles that envelope all polygonal vertices, and the length and projected width of each rectangle were determined in the wind directions of 16 sectors (22.5 degree) used in Japanese standard meteorological data acquisition systems, such as AMeDAS (Automated Meteorological Data Acquisition System). The building height was calculated by multiplying the number of stories of each building by the given floor height. The dominant buildings affecting plume dispersion were selected, and their heights and projected widths in each direction were calculated using the Good Engineering Practice Stack Heights formula. Three different types of dispersion model are incorporated in the system, and input parameters such as calculation grids, source location, emission rates and building dimensions can be configured readily by using a graphical user interface (Fig.1).

2. Validation of model performance

To evaluate the performance of developed system, a series of wind tunnel experiments simulating plume dispersion around models of buildings in the city of Shinagawa, Tokyo, were carried out (Fig.2). It was found that the maximum concentrations predicted using the system are lower than those obtained in the wind tunnel experiments, particularly for wind vectors 45 through 180 degrees (Fig.3). This is probably due to the plume discharged from the stack dispersed vertically significantly due to the high-rise buildings located downwind of the source building when winds were blowing from the east side. However, the calculated maximum ground-level concentrations are within a factor of two of wind tunnel observations for most wind vectors.

Future Developments

In order to accurately predict the high concentrations that occur near the source buildings, modification of the plume rise algorithms and dispersion parameters are required.

Main Researcher: Ayumu Sato,
Research Scientist, Environmental Physics Sector, Environmental Science Research Laboratory

Reference

A. Sato and Y. Ichikawa, 2005, "A GIS-based dispersion model for predicting pollution from cogeneration systems in urban areas", Proceedings of the 7th International Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes, pp 159-162.

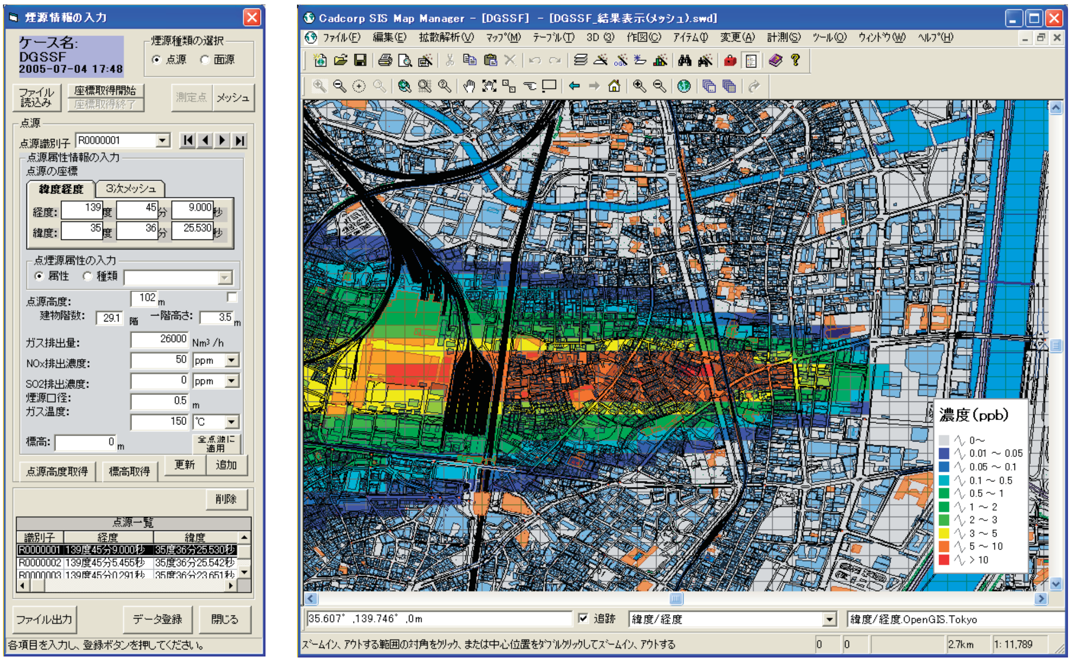

Fig.1 GIS-based Air Quality Modeling System

Input parameters, such as calculation grids, source locations, emission rates and building dimensions, can be configured readily using a graphical user interface.

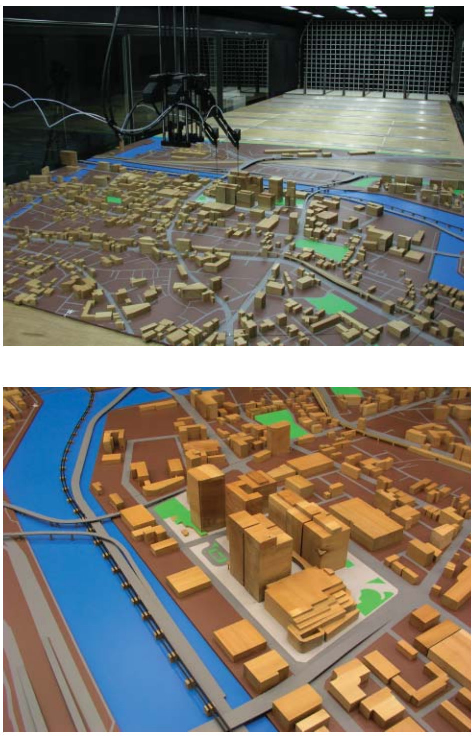

Fig.2 View of a scale model in wind tunnel

To evaluate the performance of the system, a series of windtunnel experiments simulating plume dispersion aroundbuildings in urban areas were carried out.

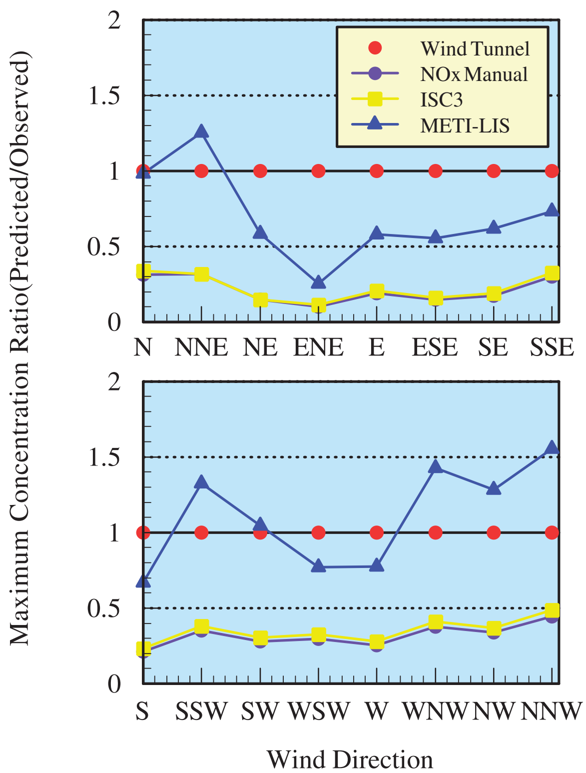

Fig.3 Maximum concentrations predicted for each wind vector

Maximum ground-level concentrations calculated using METI-LIS scheme are within a factor of two of wind tunnel observations for most wind vectors.