Studies on behavior of flow and gas dispersion around buildings in a residential area

Background

Exhaust emissions from cars, co-generation systems and heating equipment, which are strongly influenced by surrounding buildings and heating of building facades caused by direct solar isolation, disperse intricately in residential areas. In order to consider the improvement strategy of air quality in residential areas, it is important to estimate the pollutant gas dispersion considering these influences using a numerical model. Though reliable date sets obtained by both field and wind tunnel experiments help the numerical model to be developed, few experiments have been conducted for flow and gas dispersion within the urban canyons. Concerning the numerical model, applicability evaluation of the numerical model for the gas dispersion in a real residential area is needed toward the practical application.

Objectives

We implemented field and wind tunnel experiments for flow and gas dispersion in an urban canyon to demonstrate the effects of the instantaneous turbulent motions on the gas dispersion, and additionally verified the applicability of the numerical model to flow and gas dispersion in a real residential area.

Principal Results

1. Investigation of the behavior of flow and gas dispersion in the urban canyon in field and wind tunnel experiments

The concentration of the tracer gas emitted from ground surface of the canyon and wind velocities were simultaneously measured in an outdoor urban scale model (COSMO: Comprehensive outdoor scale model), which is about 1/5 the scale of typical two-story buildings in Japan. The results show that the vertical turbulent fluctuations above the canyon have strong influence on the reduction of the tracer gas concentration within the canyon (Figure 1). Additionally, the wind tunnel experiments using TWINNEL (twinned wind tunnel) at CRIEPI were conducted under the same layout of the buildings, leading to understand the instantaneous behavior of the turbulent motions within the canyon (Figure 2).

2. Applicability evaluation of the numerical model for flow and gas dispersion in a real residential area

The numerical model was applied to simulate flow and tracer gas dispersion released from the roof of the building in Komae Research Laboratory at CRIEPI in Japan, where wind tunnel experiments under the model scale ratio of 1/250 were conducted. The numerical model is based on a finite volume method with an unstructured grid system to resolve the flow structure in a complex layout of the buildings. The mean velocities, turbulent intensities and mean concentration obtained by the present model are in good agreement with those obtained by the wind tunnel experiments. The present numerical model can accurately represent the flow and concentration field in the residential area (Figure 3).

Future Developments

To estimate distributions of the pollutant concentration and air temperature in a real residential area, we are planning to improve the numerical model considering the real large-scale turbulent motions and air temperature in a meso-scale region.

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Reference

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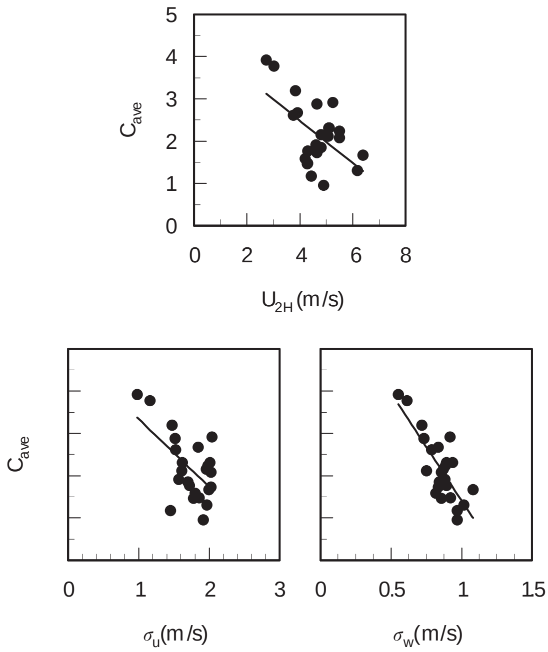

Fig.1 Velocity statistics and mean concentration.

The mean concentration inside the canyon, C_{ave}, decreases when increasing the mean velocity above canyon, U_{2H}, and the standard deviation of turbulent fluctuations, σ_u, σ_w, especially σ_w has good correlation with the mean concentration.

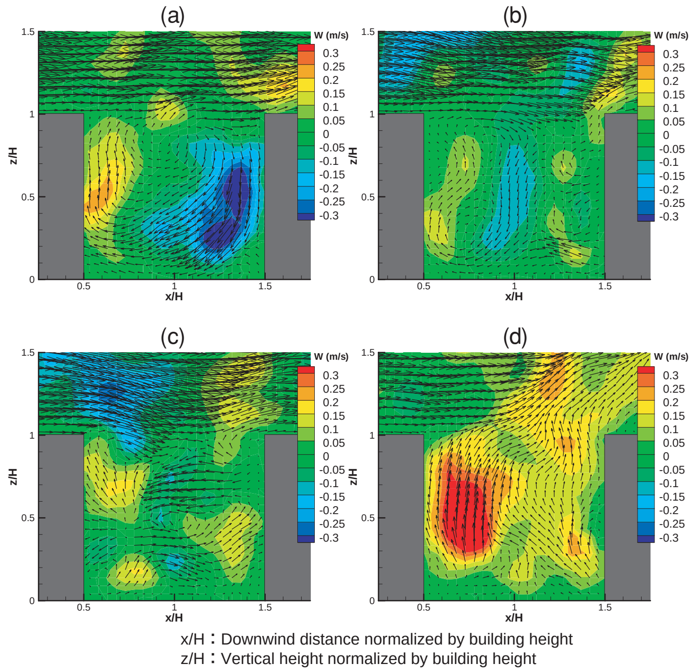

Fig.2 Instantaneous flow fields.

Instantaneous flow fields can be classified into three classes: (a) flow resembled the mean flow field, (b) (c) flow formed by the multiple small eddies, and (d) the large-scale upward wind motions within the canyon.

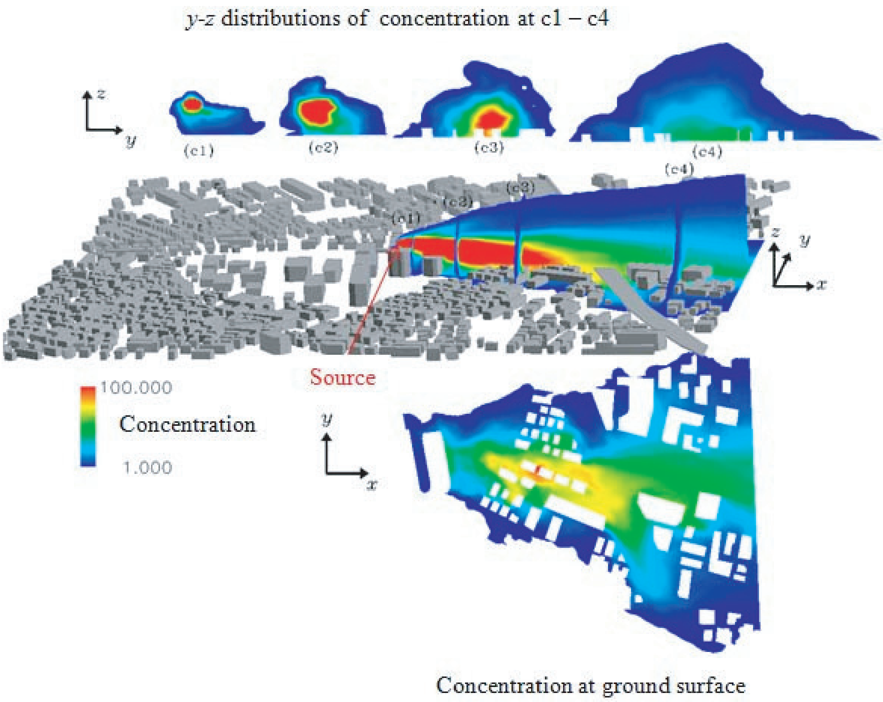

Fig.3 Mean concentrations reproduced by the numerical model.

The downward dispersion of gas emitted from the top of the roof can be accurately reproduced, and the velocities and concentrations estimated by the numerical model are in good agreement with the wind tunnel data.