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MEASUREMENT OF THE THERMAL ENVIRONMENT IN URBAN CANYONS AND PREDICTION BY CFD SIMULATION

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ABSTRACT

We analyzed the thermal environment within Kyoto city using a numerical model that considers three elements: the unsteady-state heat conduction of building walls and ground surfaces, radiation heat exchange between walls and ground surfaces, and airflow approximated by computational fluid dynamics (CFD). We found that the model accurately simulates the thermal environment accurately within wide urban canyons. However, the various canyon shapes within a city each have unique of thermal characteristics. In order to investigate the influence of canyon shape on the thermal environment, we measured air and surface temperatures in Kyoto city during the summer of 2003. We then compared model predictions with measured air and surface temperatures. The model produced an accurate simulation of the urban thermal environment.

INTRODUCTION

It is well-known that urban air temperature is increasing in cities around the world. The temperature increase is due to diminishing green areas, low wind velocity due to high building density, and the materials used to coat street surfaces. Urban planning requires an understanding of the urban thermal environment and factors that influence heat distribution in such an environment (Williamson *et al.*, 2001).

Many studies have undertaken measurement and analysis of the urban thermal environment (H. Yasui *et al.*, 2000, A. Yoshida *et al.*, 1999). However, many of these studies sought to understand the thermal environment of the city by comparison with the thermal environment of suburban areas. The various shapes of urban canyons range from wide open canyons bounded by buildings of uniform height (Figure 1), to narrow closed canyons bounded by buildings of variable height (Figure 2). It is probable that these canyon have different thermal characteristics. Then it is necesssary to grasp the thermal characteristics to make use of it for improvement of urban thermal environment.

There are also many studies that seek to simulate the urban thermal environment using numerical models. Takahashi *et al.*, (2003) analyzed the thermal environment in Kyoto city using a numerical model that considered three elements: the unsteady-state heat conduction of building walls and ground surfaces, radiation heat exchange between walls and ground surfaces, and airflow approximated by computational fluid dynamics (CFD). The model was able to accurately simulate the thermal environment in wide urban canyons, but some local parts are not accurate enough. And we didn't simulate the thermal environment within narrow urban canyons. Furthermore, there are various canyon shapes within a city and each canyon shape has a unique thermal environment. It is necessary to simulate the thermal characteristics of canyon of various shapes in order to test the accuracy of the model. And if the precision of the model can be proved, using this numerical model, the effect of changing canyon shapes can be investigated in order to improve urban thermal environment at street level.

The aims of this study are: (1) to examine the influence of canyon shape on thermal environment; (2) to test the accuracy of the numerical model by simulating the thermal environment of different canyon shapes and comparing the simulation results with measured data.

MEASUREMENT OF THERMAL ENVIRONMENT

In this section, the measurements of air temperature, ground surface temperature and wall surface temperature are described. The purpose of these measurements is to investigate the influence of canyon shape on thermal environment, to provide boudary conditions for the steady-state CFD simulation, and to provide a test of the simulation results.

Measurement procedure

The measurement site was within central Kyoto city in an area that consists mainly of medium height commercial buildings. Measurements were taken between 1000 hrs and 1600 hrs on 24 August 2003. It