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Measurement of thermal environment in Kyoto city and its prediction by CFD simulation

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Abstract

In the summer of 2002, measurements were simultaneously performed to investigate the characteristics of heat flow in urban areas at three locations in Kyoto city: (1) a commercial urban area mixed with low-rise traditional residential buildings that represents the urban area of Kyoto; (2) a university campus area with lots of green zones; and (3) a plaza covered with a concrete slab which was used as a reference point of measurement. Heat flux of boundary layer over the three locations and the surface temperatures of building walls and streets were measured to investigate the urban thermal environment. For the analysis, a new simulation code was developed by combining unsteady state heat conduction of building walls and grounds, radiation heat exchange between them, and airflow by computational fluid dynamics (CFD). By using this code, the thermal environment of the urban areas such as air temperature, humidity, wind velocity, and boundary layer heat flux was predicted and compared with the measured results. It was found that this model could predict the real thermal environment of the urban area. Using this code, the effect of additional green on roofs and grounds can be investigated in order to mitigate urban heat island and to improve urban thermal environment at the street level.

Keywords: Measurement; Heat flux; CFD; Unsteady heat conduction

1. Introduction

It is a well-known fact that the urban air temperature is gradually rising in all cities and some effective measures are needed to mitigate it. Several factors are reported to be the cause of the temperature rise, such as diminishing of green area, low wind velocity due to high building density and change of street surface coating materials. However urban planning based on the prediction of urban environment incorporating the effects of these factors is under development [1].

A lot of researches have been performed on the measurement [6] and the analysis of urban environment, however, there are few researches that compare measured and simulated heat flux over urban areas and simultaneously measured thermal environments of several areas with different topographical features. Such comparative measurement and simulation method enable the analysis of the factors that influence the urban environment. In addition there are many researches regarding urban thermal environment simulation, however, there are few researches in predicting it by combining three-dimensional CFD simulation model and unsteady state heat conduction of building walls and grounds. Moreover, few of them compared the simulated results with the measured results and verified simulation accuracy [2].

The purpose of this research is: (1) to clarify the influence of local topological features on urban temperature and humidity; (2) to compare sensible and latent heat flux characteristics of the urban areas with different amount of built and green area; and (3) to predict urban thermal environment by developing a new numerical simulation model combining air flow and temperature calculation by CFD and transient heat conduction calculation of buildings and grounds.

2. Measurement of heat flux, temperature and humidity

We measured the sensible heat flux and the latent heat flux transported from the urban surface to the upper atmosphere, and the temperature of buildings' walls and streets at three typical sites. The first site is a central part of Kyoto city (site U) which is bristling with medium height commercial buildings mainly. The second site is a university campus (site C) with much greenery such as a green court, and a hill covered with ample green, called Mt. Yoshida Yama, is closely located eastward. The third site is a city-hall plaza

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