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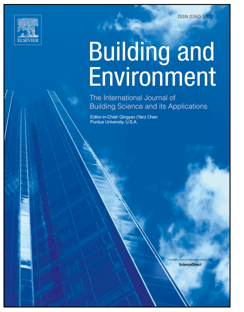

Predicting Urban Heat Island Circulation Using CFD

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Predicting Urban Heat Island Circulation Using CFD

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ABSTRACT

Most existing microscale computational fluid dynamics (CFD) models and mesoscale meteorological models cannot consider multi-scale urban wind flows, as neither can completely take into account the mesoscale and microscale physics, and their interactions. Here we suggest a CFD model which has good potential for development of the meso-micro scale models for predicting and designing multi-scale urban airflows. The principal idea is to use CFD numerical methods to solve a set of governing equations with appropriate boundary conditions that can govern both major mesoscale and microscale flow characteristics. Based on the coordinate transformation method proposed by Kristóf, Rácz and Balogh (2009), we derived a similar set of governing equations with some improvements and used an existing porous turbulence model for modeling the urban canopy layer. The approach was then successfully implemented using a commercial CFD package (Fluent) for studying urban heat island circulation (UHIC), which is considered to be one of the most difficult problems in CFD. Our predicted mean quantities agree well with existing data in the literature obtained from large eddy simulations, mesoscale models, and laboratory experiments. Our predicted results also reveal the effects of the different heat fluxes and urban height of a city on UHIC characteristics.

Keywords Meso-microscale model, mesoscale model, microscale model, CFD, urban climate, urban heat island circulation

1. INTRODUCTION

The urban climate is multi-scale in nature. The multi-scale nature of wind flows in a city may be illustrated by the phenomenon of urban heat island circulation (UHIC) (Gal and Unger, 2009), which occurs when the synoptic wind is weak. During the day, buildings are warmed by solar and other anthropogenic heat. A natural convection boundary layer develops along each building wall. These (microscale) thermal boundary layer flows merge either within or above the urban canopy layer. Multiple building plumes develop above the urban canopy layer. As there are tens or hundreds of thousands of buildings in a large city, there can be the same number of plumes, which again merge into a large urban plume. The air is lifted up due to the buoyancy effect, so the pressure is lower in the city center area, which drives the inward flows through the urban edges, and eventually develops into (mesoscale) urban heat island circulation when there is an inversion. As shown in Figure 1, each individual building plume would flow upward if the building were isolated, but in an

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