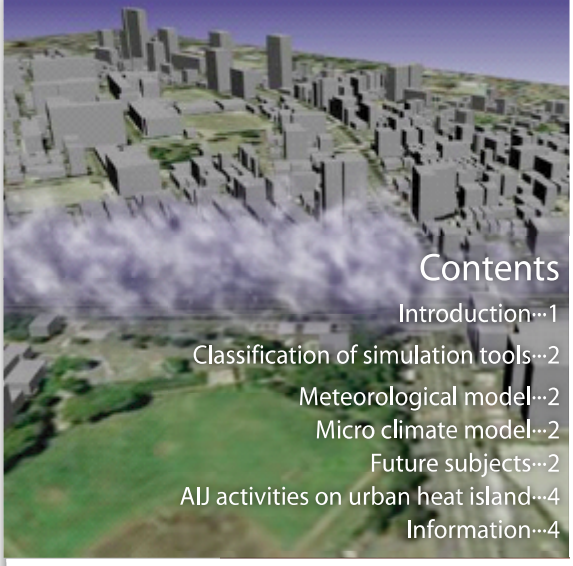


Contents

NEWSLETTER ON URBAN HEAT ISLAND COUNTERMEASURES

NOVEMBER 2007
Vol. 2

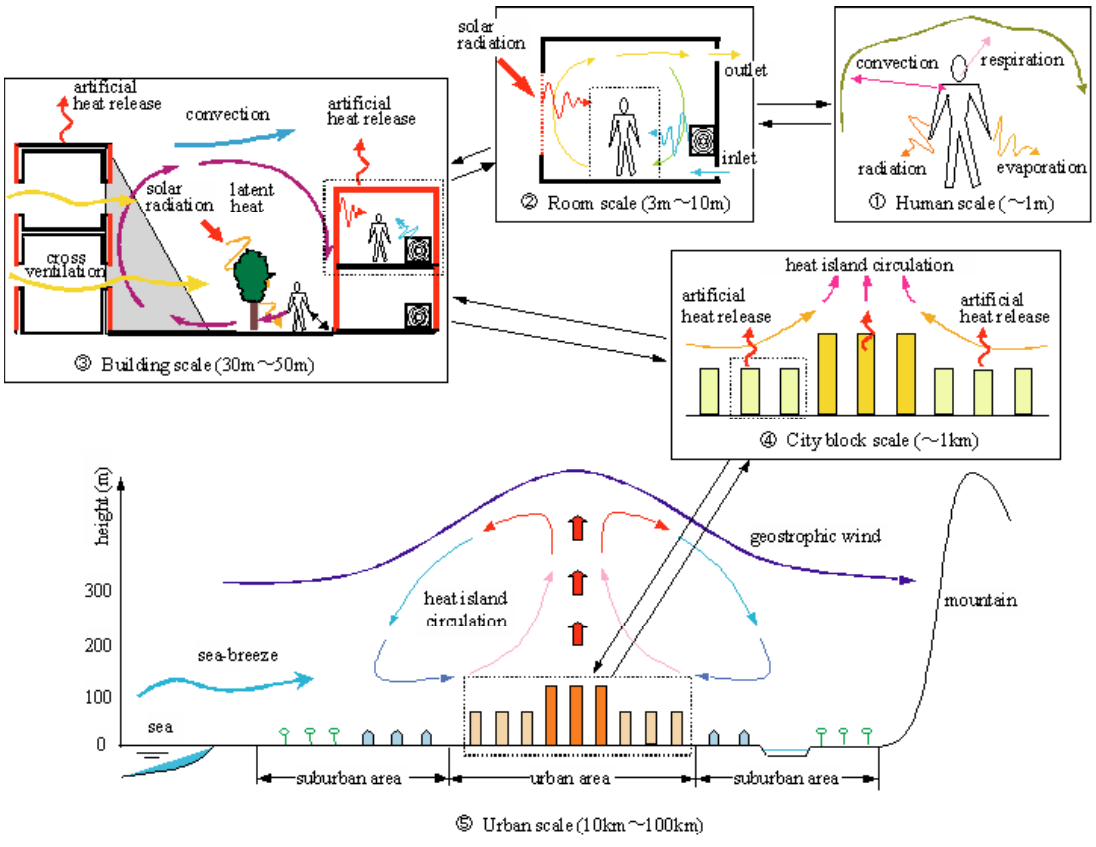
Computer Simulation Tools for Urban Heat Island

SUBCOMMITTEE ON HEAT ISLAND
COMMITTEE on the Global Environment, Architectural Institute of Japan
http://news-sv.aij.or.jp/tkankyo/s3/

Introduction

It is very important to estimate the effects of various countermeasures against urban heat islands before they are applied in practice. In order to estimate the effects quantitatively, the heat island phenomena should be simulated and the structure of the outdoor thermal environment understood. Urban heat islands are very complex and there are two principal difficulties to their comprehension, i.e. multi-scalar and multi-physical problems. Recent developments in computer technology enable the simulation of such physical phenomena. Now, computer simulation tools are widely used to comprehend urban heat phenomena and estimate the effect of various countermeasures. The urban climate is composed of phenomena on various spatial scales in and around the urban area as shown in the figure below. Thus, the various simulation tools proposed correspond respectively to these various scales.

In this manuscript, various assessment tools are introduced and classified according to their corresponding modeling scales. Special attention is given to recent progress in Japan.



Various scales of phenomena concerning urban climate

Classification of simulation tools

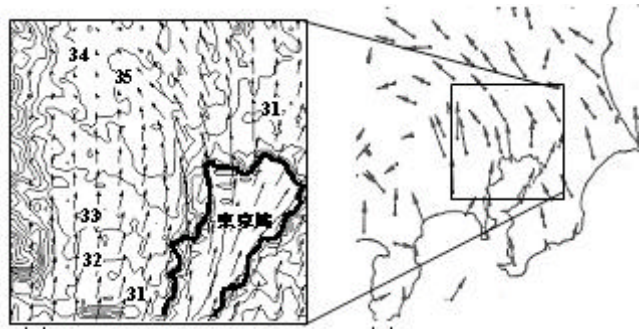
The computer-based urban climate simulation tools can be roughly classified into models which have been developed in the meteorological or geographical fields, and those from the engineering field, such as wind engineering or civil engineering. These models may be used either separately or simultaneously according to the targeted scale and the resolution level required.

Meteorological models

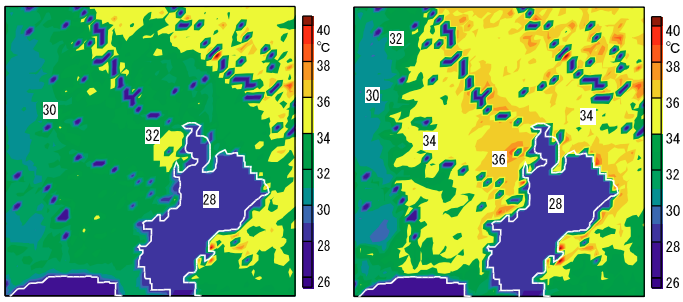
The meteorological models are further subdivided into the meso-scale meteorological model and the one dimensional urban canopy model. Originally the one-dimensional urban canopy model was developed as a surface sub-layer model for the meso-scale meteorological model. However, the one-dimensional urban canopy model is often used independently to estimate the effect of urban heat island countermeasures because it is very easy to apply. As the calculation load is very small, it can practically be applied to many case studies of various heat island mitigation measures. The above right figure shows a comparison of velocity vectors over the Kanto plain between a meso-scale model simulation and those observed. The simulation results accurately reproduce the sea breeze and show good agreement with observations. The figure second to the right compares the temperature distributions at ground level at 3:00 p.m. in early August under land use conditions from the present back to the Edo era (about 200 years ago). The current surface temperature in central Tokyo is about four degrees centigrade higher than that of the Edo era. This indicates that urbanization as evidenced by a decrease in greenery and an increase in anthropogenic heat has advanced the progress of this urban heat island. As to the meso-scale meteorological model, it is good at predicting phenomena in the order of 100-kilometer scale (meso-scale) such as land and sea breezes. However, the mesh size for the meso-scale meteorological model is at least about 1 kilometer , and is unsuitable for evaluating the pedestrian level outdoor thermal environment.

Micro climate model

On the other hand, the engineering model is usually based on a three-dimensional CFD (Computational



(1) Simulation results (2) Observation results
Velocity vectors over Kanto Plain (3:00pm Summer)
(Simulation: authors, Observation: Kuwagata et al., 1990)



(1) 1830 (2) 1995
Prediction of climatic change in Tokyo
(ground temperature at 3:00 p.m., early August)
(Mochida et al. 1999)

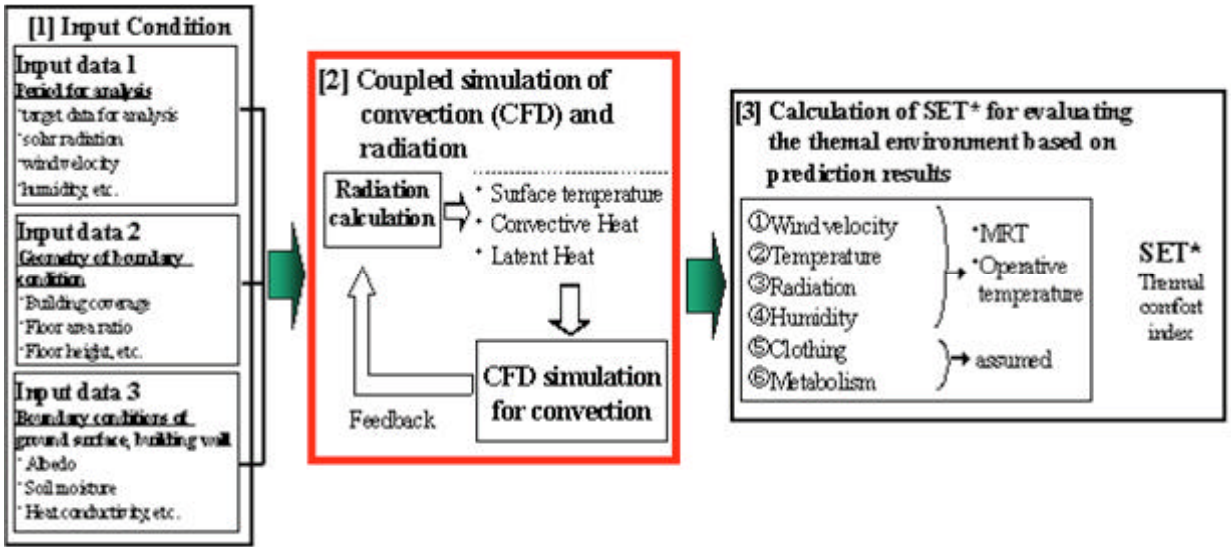
Fluid Dynamics) model, and often coupled with radiation and conduction calculations. This model is good at predicting the detailed spatial distributions of flow, temperature, and scalar fields inside a complex urban area, and is also referred to as a microclimate model.

The upper figure on the next page presents the calculation flow for the microclimate model. The human thermal sensation index, a new standard effective temperature (SET*) proposed by Gagge A.P. (1986) is also incorporated in this method.

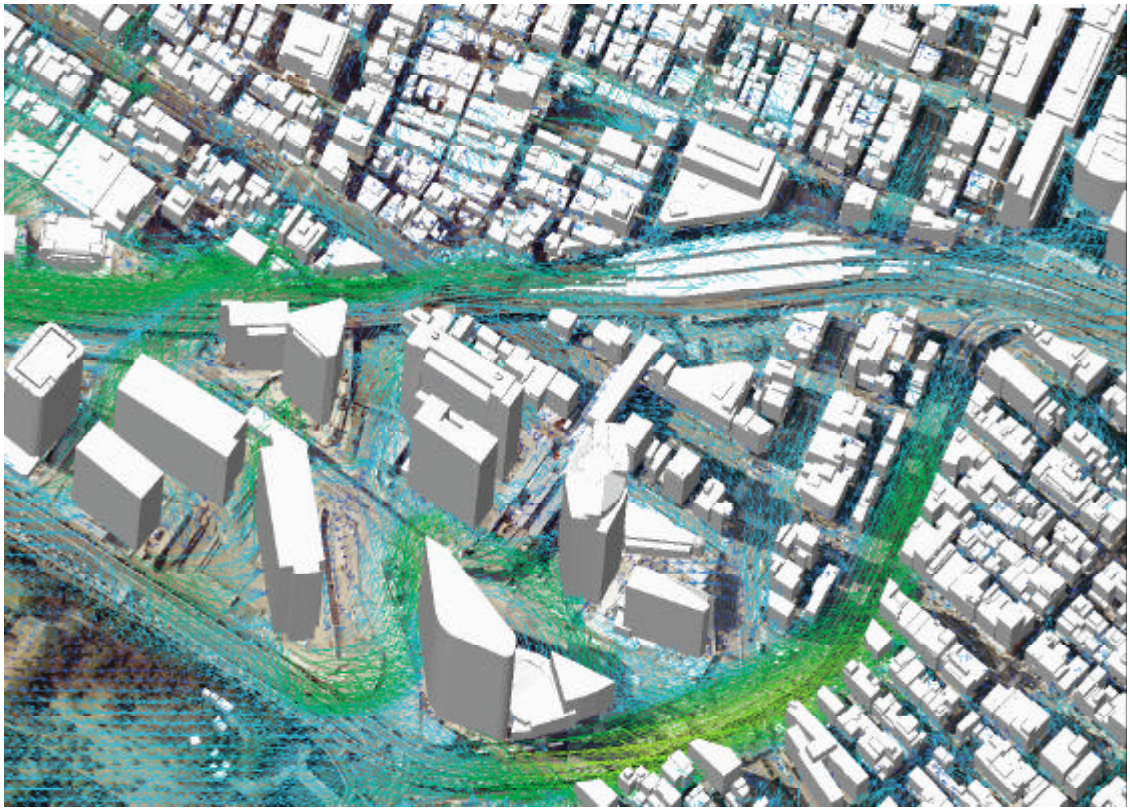
Recently, improved computer performance has enabled massive CFD calculations for urban climates over a scale of several kilometers with a relatively fine mesh resolution in the order of meters. The bottom figure on the next page shows a simulated wind field in central Tokyo on a scale of five kilometers.

Future subjects

Computer simulations provide a very powerful tool to estimate the mechanisms of urban heat islands and the effect of any countermeasures. However, some problems remain. Validations of the prediction accuracy of these methods are not sufficient. Thus,



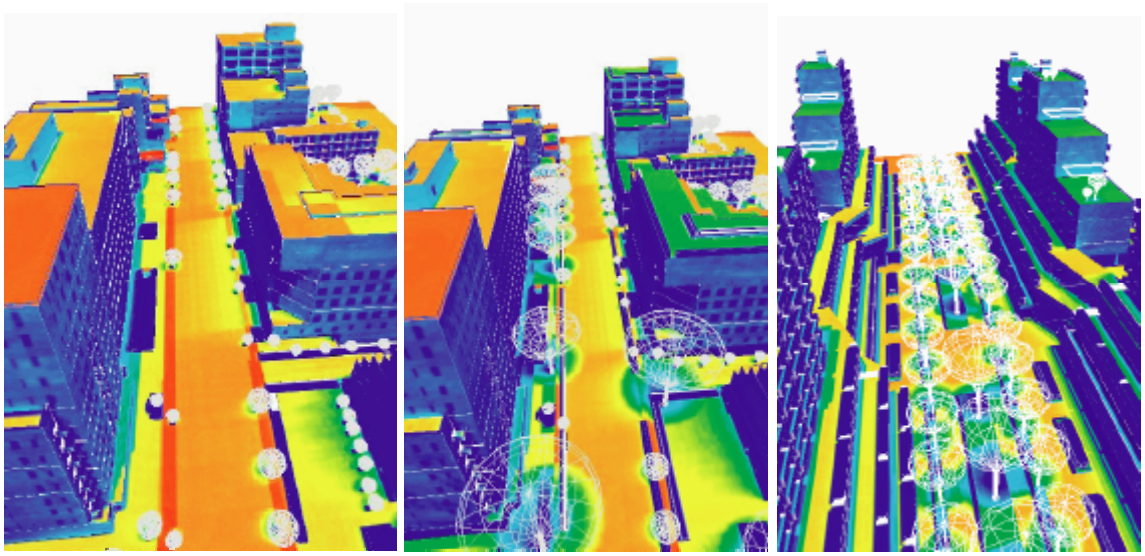
Flow of micro climate simulation



Velocity vectors within a complex urban flow field of 5 km scale
(Ashie et al. 2005)

the application limit is not clear under present conditions. Benchmark tests are required in order to understand the properties of the various models developed. Nevertheless, a detailed structure of the urban climate, which cannot be observed experimentally, can be obtained using these tools. However there is a still deep gap between the understanding of researchers and specialists of the urban climate and urban planners and policy makers. In terms of the application of this knowledge to actual urban design, it is important to make it clearly understandable with some examples. The visualization technique is one of the most powerful methods of expressing the influence of various urban heat island mitigation strategies easily and concretely for non-specialists. The upper figure on the next page shows an example of visualization of simulated results. In the next stage, these simulation tools should evolve into design tools able to integrate all processes described above for practical applications.

(Ryozo Ooka, University of Tokyo)



(1) the present (2) planted case (3) changing configuration

Visualization of surface temperature of urban structures (Hoyano et al., 2004)

AIJ activities on urban heat islands

a) AIJ published a book on urban heat islands

AIJ has recently published a book on urban heat islands. The members of the subcommittee on heat island have edited this book. It contains various topics pertaining to urban heat islands: 1. What is an urban heat island? 2. Climate and the urban environment; 3. Countermeasures against urban heat islands; 4. Promotion of mitigation against urban heat islands; and 5. How to design future cities.

Cover page of the book published by AIJ

b) Special lecture by Prof. Kuttler

The Urban Climate Modeling Work Group under this subcommittee organized a special lecture by Prof. Wilhelm Kuttler (The University of Duisburg-Essen) at the Institute of Industrial Science, the University of Tokyo on 7th November, 2007. Recent research into the urban climate conducted by the lecturer was explained, followed by a fruitful discussion.

Lecture delivered by Prof. Kuttler (Nov.7, 2007)

Information

The Seventh International Conference on Urban Climate (ICUC-7) will be held in Yokohama (Japan) on June 29 ~ July 3, 2009. Details about the ICUC-7 can be found at the following website:
http://www.ide.titech.ac.jp/~icuc7/

The 18th International Congress of Biometeorology (ICB2008) will be held in Tokyo (Japan) in September 22 - September 26 2008. The detail of ICB2008 is shown at the following website:
http://www.icb2008.com/

NEWSLETTER
ON URBAN HEAT ISLAND COUNTERMEASURES

This Volume was edited by: R. Ooka, Dr. of Eng.
University of Tokyo
contact: ooka@iis.u-tokyo.ac.jp

NOVEMBER 2007
Vol. 2

Next Issue ➳ Observational studies of the Urban Heat Island - Cooling Effect of Urban Park - as vol.3

This newsletter was sponsored by the International Exchange Fund of AIJ

Architectural Institute of Japan
5-26-20 Shiba, Minato-ku, Tokyo, 108-8414 Japan
Phone: +81-3-3456-2051
http://www.aij.or.jp/