P 343A **RISK ASSESSMENTS OF OUTDOOR HOT ENVIRONMENT USING URBAN METEOROLOGICAL NUMERICAL MODEL SYSTEM**

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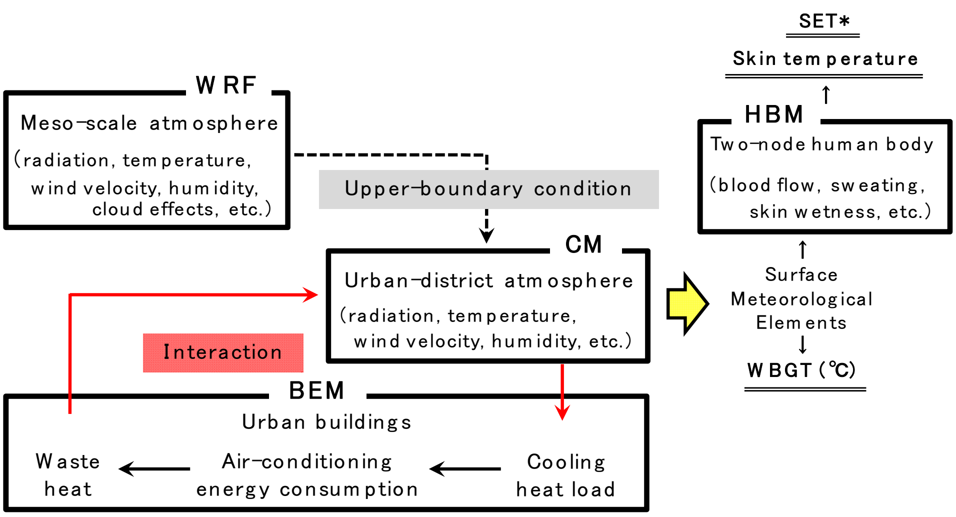
1. INTRODUCTION

In Japan, patients of heat disorder who are carried by ambulance intend to increase annually due to the surface-air temperature rise. Hence the incident prediction of heat disorder is daily public-released by the meteorological information services and the public organizations in summertime Japan. The WBGT (Wet-Bulb Globe Temperature) index (Yaglou and Minard, 1957), which is well known as a heat disorder index worldwide, is often used for the predictions. Since the heat disorder predictions and its public release are conducted for each prefecture or city of Japan, the spatial resolution of prediction is too coarse for a human activity scale within urban and residential areas. The outdoor heat disorder is considered to occur more locally. This is because a human body is usually influenced by the local scale air-temperature, humidity, wind flow, and radiation.

Therefore we will try to assess the heat disorder risk for district-scale outdoor spaces using an urban meteorological numerical model system. This model includes an urban canopy meteorology, building energy, and human body physiology; it can represent near-real human conditions (heat stress) of the urban outdoor space.



WRF : Weather Research & Forecasting Model (NCAR)
CM : Urban Canopy Model (Kondo and Ryu, 1998)
BEM : Building Energy Model (Kikegawa et al., 2001)
HBM : Human Body Model (Gagge et al., 1971)

Fig. 1 Calculation flow in our model system: WRF-CM-BEM-HBM.

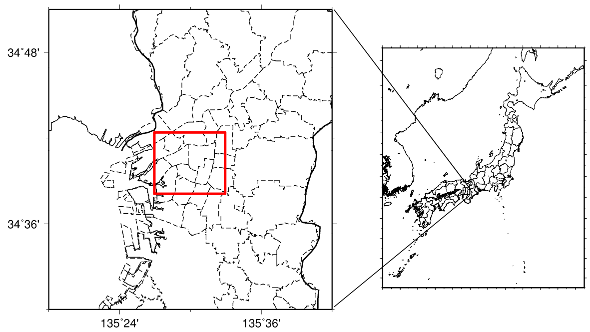


Fig. 2 Our study area: Osaka City in Japan. The red square represents a calculation domain.

2. NUMERICAL MODEL

The model system is composed of the meso-scale meteorological model (WRF), the urban canopy model (CM), the building energy model (BEM), and the human body model (HBM). The WRF(http://www.wrf-model.org/index.php),which is developed by NCAR, simulates the regional meso-scale meteorological motion. The CM, which is developed by Kondo and Liu (1998), simulates the urban canopy wind, temperature, and humidity vertically in the multi layer. The BEM, which is developed by Kikegawa et al. (2001), can calculate the building energy assumption and its waste heat by air-conditioning. Last the HBM, which is developed by Gagge et al. (1971), simulates a heat budget and physiological response of the human body. Detail descriptions of CM and BEM are referred to Kondo et al. (2005) and Kikegawa et al. (2003), respectively.

The calculation flows are depicted in Fig. 1. The simulation result of WRF is downscaled as upper boundary conditions of CM. The calculation process of CM interacts with that of BEM. Simultaneously the meteorological elements evaluated by CM are used for the calculation of HBM and WBGT index.

The CM and BEM have many parameters about the building and road materials, and building-inside activities. So we provide adequate values for the parameters (Ohashi et al., 2007). The HBM human conditions (e.g., metabolic rate, clo, and weight etc.) are given previously; in our study a man of 170-cm height, 60-kg weight, 1.0 met, and 0.6 clo is assumed for calculation.

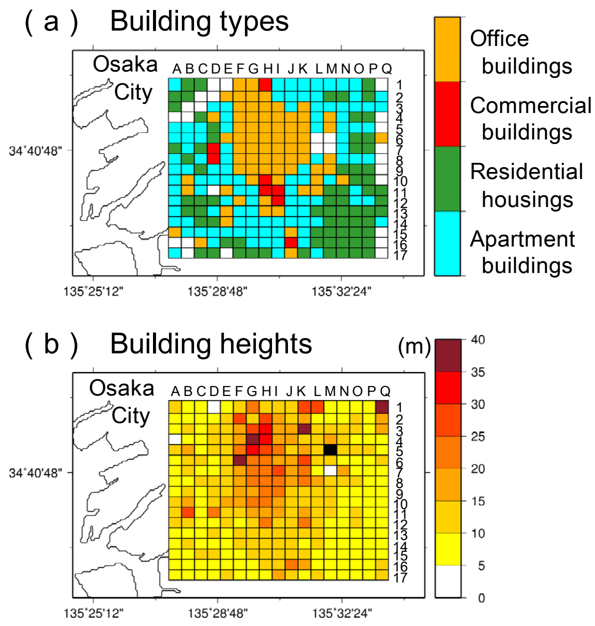


Fig. 3 Mesh maps of (a) main building types and (b) averaged building heights. A black-toned mesh in (b) indicates the maximum building height of 69.8 m of our region.

3. STUDY CASE

Our model system is utilized for Osaka City (the population of about 2,668,000) in Japan during a hot summer season. In summertime of 2007, many people are exposed to the long-term strong heat stress. Heat disorder patients of 339 people in Osaka City were carried by ambulance during the period from June to September in 2007.

Figure 2 represents a study domain of Osaka where the region has 289 (17×17) meshes in total with about 500-m spatial resolution. Eventually the WBGT index and heat disorder risk are estimated for each 500-m mesh. A calculation period is selected from July 20 to August 30 in 2007 as a Japanese typical summertime.

In Fig. 3, occupied building types within the 500-m district and averaged building heights are indicated. Using the Osaka GIS data, the building types are roughly divided into office, commercial, residential housing, and residential apartment buildings in our region. This figure shows that the office and commercial districts with taller buildings are centered of region.

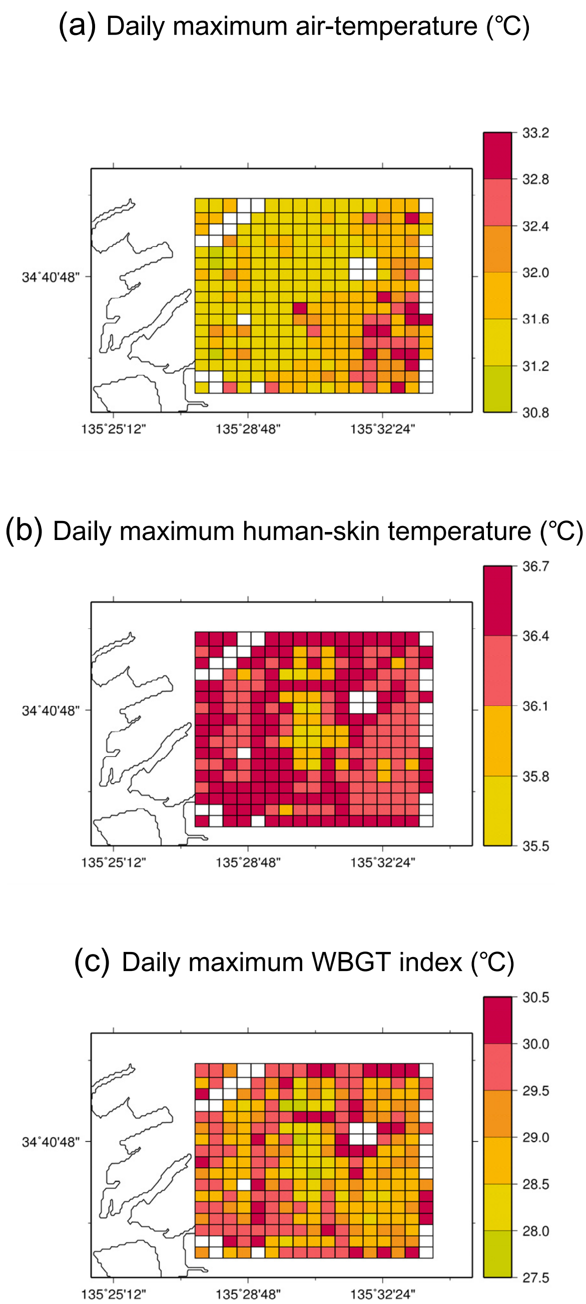


Fig. 4 Mesh maps of (a) daily maximum air-temperature, (b) daily maximum human-skin temperature, and (c) daily maximum WBGT index, averaged from July 20 to August 30.

4. RESULTS

Here the simulated results of daily maximum air-temperature, human-skin temperature, and WBGT index are indicated in Fig. 4. These values are averaged during the calculation period. The daily maximum air-temperature becomes higher with inland-ward. Its maximum difference of 2°C appears between the coast and inland. On the other hand, daily maximum human-skin temperature and WBGT index are lower in the center of calculation region, which significantly differ from the above air-temperature distribution. Especially daily maximum WBGT index appears a maximum difference of 2.5°C between the center and surroundings. This difference corresponds to change from “alert” to “severe alert” in the guide of heat disorder prevention published by Japan Sports Association and Japanese Society of Biometeorology.

It should be noticed how temperature of a human-skin rather than the atmosphere from a point of view of the heat disorder mechanism. Hence the WBGT index, which is an index of heat disorder, has a good correlation with the human-skin temperature.

5. DISCUSSION

Based on the gridded distribution of WBGT index, we try to make a risk map of the summertime heat disorder. This is a reason why the public people are easy to intuitively understand the regional heat disorder as an incident risk. Therefore we developed a risk function of heat disorder using the real data of heat-disorder patients of Osaka City. Figure 5 shows the relationship between heat disorder patients carried by ambulance and the heat disorder exposure (*HE*). The *HE* is defined by

$$HE = \int_{7\mathrm{h}}^{18\mathrm{h}} WBGT(t)dt \ . \qquad (1)$$

Here *WBGT*(*t*) represents the hourly WBGT index measured by Ministry of the Environment, Japan at the Osaka Meteorological Observatory. The data of heat disorder patients are provided by National Institute for Environmental Studies, which should be noticed as suspected of heat disorder from their symptoms. The figure reveals a clearly exponential correlation between the *HE* and heat disorder incidence (per 100,000 people). When especially *HE* exceeds around 310-320°C・h, the heat disorder incidence increases sharply. Namely people should pay

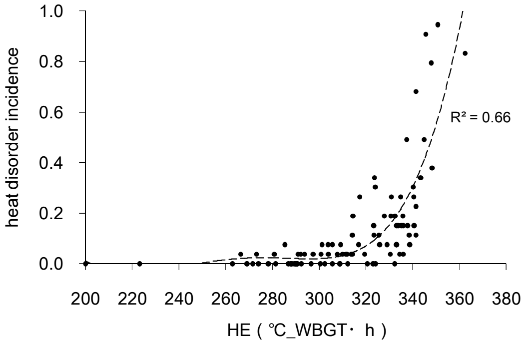


Fig. 5 Relationship between heat disorder exposure (*HE*) and heat disorder incidence (per 100,000 people) obtained from the actual data of Osaka City.

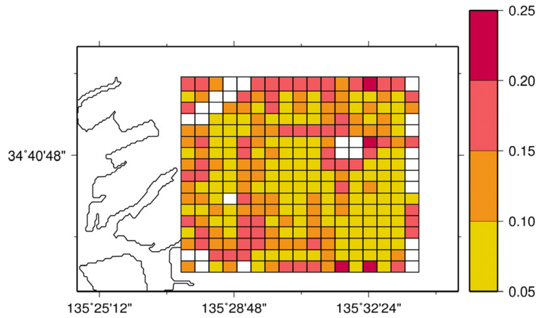


Fig. 6 Mesh map of heat disorder risk represented as incidence per 100,000 people.

attention to their own crises of heat disorder on the threshold which the WBGT value accumulated from 7 hours reaches 300°C・h.

A mesh-scale heat disorder risk with the heat disorder function (a regression curve denoted in Fig. 5) will be estimated for each model grid. Its result is shown in Fig. 6. The obtained heat disorder risk is also lower at the central area of domain like the skin temperature and WBGT index due to use of *HE*. On meshes with a high risk of the heat disorder, their risks increase by a factor of four compared with the center area of lower risk meshes. As you can notice, the values of heat disorder risk become very small entirely. This is because the heat disorder function given by Fig. 5 is made of only the patient data carried by ambulance. It is inferred from the fact that many heat disorder patients exceeding the patients carried by ambulance go to hospital themselves. Hence a regional difference in the heat disorder risk shown in Fig. 6 should be recognized as a relative difference of the risk rather than absolute risk.

6. CONCLUSIONS

We tried to simulate a regional map of the heat disorder risk by use of a meteorological numerical model system. The summertime risk map of Osaka City in Japan was able to produce a clear spatial difference of the heat disorder risk within a calculation domain. It is important for a heat disorder simulation to theoretically calculate the risk from combine a meteorological model with a human body model which can represent the thermal physiology.

Particularly, in urban outdoor environment which has strongly heterogeneous surface covering and human activity, the heat disorder prediction with fine resolution should be required as indicated in this study.

Acknowledgement

The measured WBGT data was used from the web site of Ministry of the Environment, Japan (http://www.nies.go.jp/health/HeatStroke/). Also the number of heat disorder patients was used from the web site of National Institute for Environmental Studies, Japan (http://www.nies.go.jp/health/HeatStroke/spot/index.html).

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