CFD Simulation of Summertime Air Temperature Distribution of the Twenty Kilo-meters Square Area of Center of Hong Kong

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We have performed large-scale numerical simulations using the Earth simulator for the estimation of urban heat island phenomena considering detail locations of buildings and roads by means of CFD (Computational Fluid Dynamics). In this fiscal year, twenty kilo-meters square area of center of Hong Kong was analyzed by using a horizontal grid spacing of 2 m to examine thermal construction in summer time. For the CFD simulation, building height, land use, anthropogenic heat are databased by a 2 m mesh resolution. In addition, sun shade at each mesh and each time was analyzed considering complex 3D urban forms for the calculation of heat balance of urban surfaces. Numerical results were summarized to a map showing air temperature and wind velocity fields.

Keywords: Heat island, Hong Kong, CFD, Air temperature

1. Introduction

Recently, countermeasures against the urban heat island (UHI) effect, such as reduction of anthropogenic heat release and enhancement of urban ventilation, have become increasingly important in Asian region. The evaluation of urban ventilation requires the construction of a high-resolution computational fluid dynamics (CFD) system, which takes account of complex urban morphology. The morphological complexity arises from multiscale geometry consisting of buildings, forests, and rivers superimposed on varying topography. Considering these backgrounds, we have developed a high-resolution CFD system and have performed simulations of wind and air temperature fields of Tokyo using a horizontal grid spacing of 1-5 m [1] [2].

In 2012, we simulated Hong Kong area by using the developed high-resolution CFD system on ES2. Land use, building height and topology of down town area of Hong Kong are databased and air temperature and velocity fields are simulated by 2 m mesh resolution. The simulation day is 23 July, 2006.

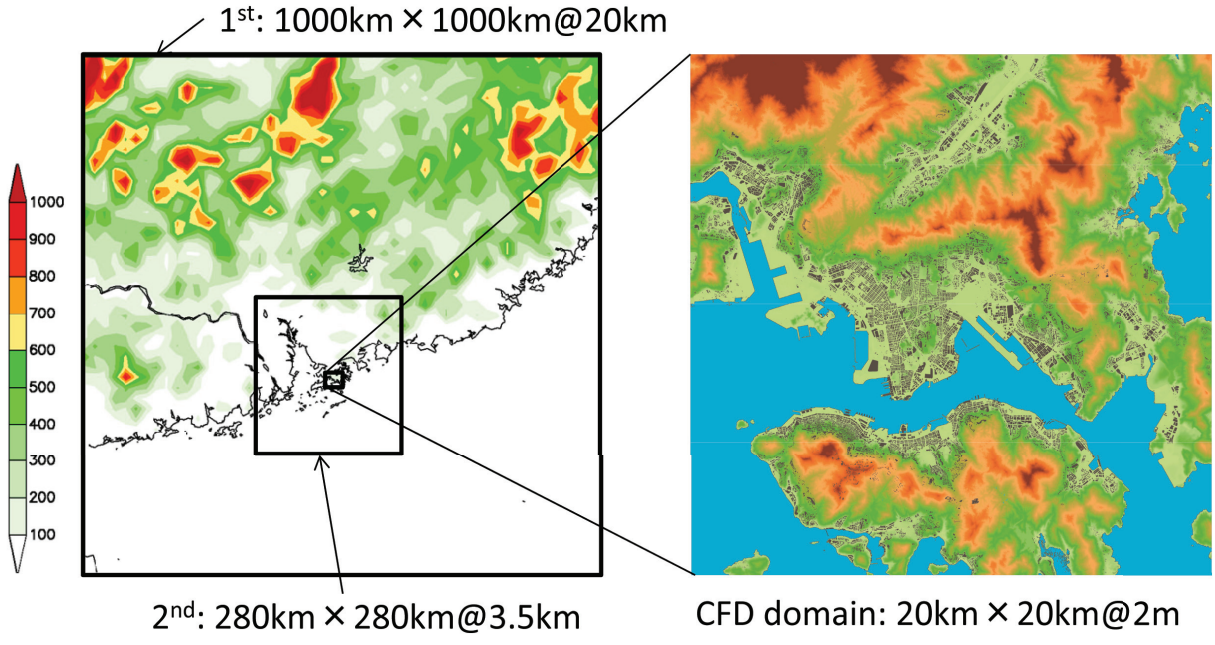

Fig. 1 Simulation domain.

2. Location of analysis

Twenty ten kilo-meters square area of Hong Kong is considered for analysis (Fig. 1, right). The computational domain extends vertically to a height of 1,500 m and is divided into grid cells that vary in height from 1 to 10 m with the smallest grid cells closest to the ground. The domain is horizontally divided into equally-sized 2-m grid cells. In order to obtain the boundary values of the CFD computational domain, meso-scale model is run prior to the CFD analysis. The model is run for two domains with one-way nesting. The length of the sides of the domain and the grid spacing of the coarse grid model are 1000 km and 20 km, respectively, and those of the fine grid model are 280 km and 3.5 km, respectively. The coarse grid model is run using initial and boundary values based on data from the NCEP/NCAR Reanalysis. The period of analysis is from 2100 HKT on 22 July, 2006 to 2400 HKT on 24 July 2006. Figure 2 shows an example of simulation results.

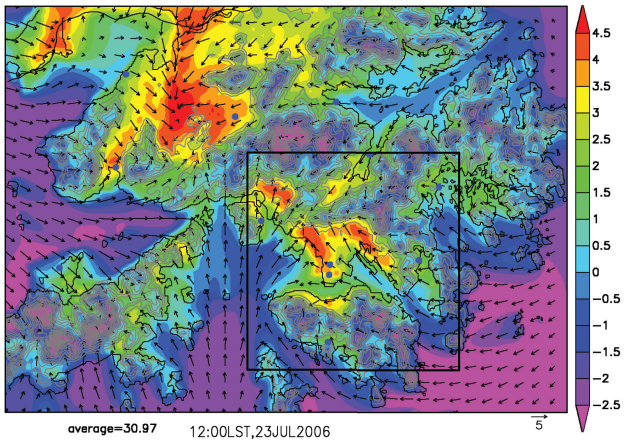

Fig. 2 Simulated air temperature and velocity distribution at 12:00 on 23 July, 2006 The CFD domain is surrounded by frame.

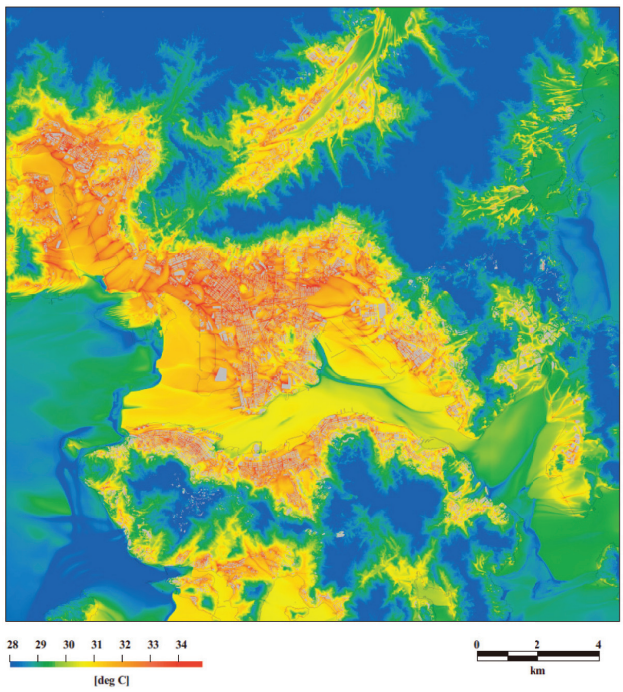

Fig. 3 Simulated air temperature distribution (HKT 14:00, July 23, 2006).

3. Input data

3.1 Elevation of land and building

GIS layers with building and podium height data and topographical data are first resized to have 2 m grid cells. Secondly, they are clipped by the 20 km × 20 km boundary and combined into a single layer.

3.2 land use

GIS layers with land-use classification codes and Normalized Difference Vegetation Index (NDVI) data are combined to produce a raster that displays six distinct classifications of land use type within the 20 km × 20 km boundary. The six classifications are a) Water, b) Grass, c) Tree, d) Road/asphalt, e) Buildable area, f) Railway.

3.3 anthropogenic heats

Three daily heat releases from residential, industrial and commercial buildings at Hong Kong are calculated by dividing the respective use energy in July 2006 (Census and Statistics Department, 2010) by the number of days in July (31 days). To the Vehicles and Trains, the daily heat releases distribution at the target area are calculated based on the traffic volumes in every 300 m × 300 m grid.

4. Results

Air temperature distribution at 14 o'clock is shown Fig. 3. High air temperatures are formed around high rise building areas. It is noticed that the elevation effect is clear around

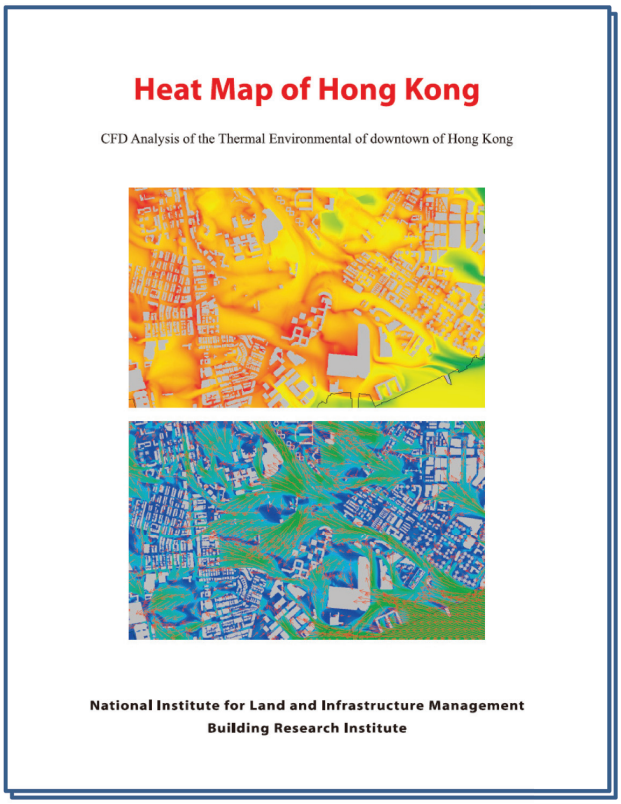

Fig. 4 Heat map of Hong Kong.

mountain area more than the former results by meso scale models [3]. Main wind direction is east, and air stream of Kowloon bay is separated to Hong Kong Island and main land.

Numerical results of air temperature and wind velocity are summarized to A0 sized color map as shown in Fig. 4. This map is folded up and used for A4 size for carrying as same as Tokyo's version [4]. We expect that the map is used as reference data of city planning for administration of Hong Kong.

Acknowledgement

Input database of numerical simulation have been produced by Edward Ng Lab, The Chinese University of Hong Kong (CUHK). The contribution of Edward Ng and Doctor Ren Chao was vital for the accomplishment of this research.

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CFD による香港 20km 四方の夏季気温分布シミュレーション

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筆者らは CFD（数値流体力学）により街路や建築物を解像可能な詳細なメッシュ分割でヒートアイランド現象を検討してきた。本報では、香港を対象にして広域 CFD 解析を実施した結果を示す。広域 CFD 解析に当たり、香港地域の建物高さ、土地利用、人工排熱等の各種データ整備、都市空間の 3 次元的な日陰形成を考慮した非定常熱伝導計算を実施した。香港地域の広域 CFD 解析は、水平 2m メッシュ、メッシュ総数 120 億で実施した。香港地域の気温、風速の解析結果は 1 枚のカラーマップに整理した。

キーワード: ヒートアイランド, 香港, CFD, 気温