ASSESSING EFFECTS OF BUILDING TEMPERATURE REDUCTION ON URBAN HEAT ISLAND

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Abstract

Assuming some measures work perfectly to maintain building temperatures constant year around, we conducted numerical simulations on how much heat island effects decreased compared with the case where no measure was taken. As expected heat domes and turbulent kinetic energy over buildings decreased significantly. However, the surface temperatures in the urban area remained high where wind speeds were small.

Key words: urban heat island, mesoscale/cfd numerical model, A2Cflow

1. INTRODUCTION

Urban areas are known to be warmer than the surrounding rural areas. The causes for the temperature increase in urban areas are by modifications of land use materials and distributions. Soil surfaces are replaced by concrete buildings and asphalt pavements that absorb and store more heat than the original soil surfaces. The stored heat energy is emitted during the night time preventing the night time temperature decrease.

Various measures were developed in order to mitigate urban heat island effects: cover the roofs and walls of buildings by plants, use reflective paints, cool walls by water curtain to name a few. One promising method is a heat pump which stores heat during the daytime or in summer and use it in night time or in winter.

Assuming some measures work perfectly to maintain building temperatures constant year around, we conducted numerical simulations on how much heat island effects decreased compared with the case where no measure was taken.

We used a three-dimensional atmospheric model A2Cflow where “A2C” stands for “Atmosphere to CFD.” A2Cflow can simulate airflows from building to terrain scales in a seamless manner by nesting computational domains. The model physics were identical for the CFD and atmospheric components since the governing equations were same (Yamada, 2004).

Affiliated with the A2Cflow is a three-dimensional transport and diffusion code “A2Ct&d” where “t&d” stands for transport and diffusion. A2Ct&d is based on a Lagrangean random walk theory (Yamada and Bunker, 1988). A2Cflow provides three-dimensional mean and turbulence distributions needed for A2Ct&d simulations.

2. SIMULATIONS

2.1. Control run

We simulated diurnal variations of air flows around a cluster of buildings, which were bound by the ocean and hills (Fig. 1). Large cities are often located in a coastal area or near complex terrain.

![Fig.1. Three dimensional image of the computational domain.](image)

Two inner domains were nested in a large domain (Fig. 2). The first domain was 6560 m x 8960 m with horizontal grid spacing of 160 m. The second domain was 1280 m x 1440 m with horizontal grid spacing of 40 m. The third domain was 360 m x 400 m with horizontal grid spacing of 10 m.

Domain 1 includes topographic features such as the ocean, coastal area, plains, and hills. Domain 2 is a transition area between Domain 1 and Domain 3. Buildings were located in Domain 3.

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The simulation area was around Kobe, Japan. Kobe is surrounded by the ocean in the south and Rokko Mountain in the north so that the sea and land breezes frequently occurred. The elevation data was extracted from the digital elevation data provided by the Japan Map Center.

Hypothetical buildings (13 in total) were placed in Domain 3 whose heights varied from 30 m to 100 m. Thermal properties of the buildings were identical for all buildings and assumed to be the same as those for concrete.

Simulations initiated at 8 a.m., July 20 (Julian Day 200) and continued for 48 hours. Initial wind directions were westerly and wind speeds in the upper levels were 3 m/s. Initial temperatures at mean sea level was 25°C. Potential temperature gradients in the vertical direction were 0.001 K/m for the first 1000 m above the ground and 0.003 K/m in the levels greater than 1000 m above the ground. The top of computational domain was 2000 m above the highest ground elevation, which was 789 m for the present study.

Figure 3 shows wind and temperature distributions in Domain 2 at 2 m above the ground at 9:20, July 20 (Julian Day 200).

Figure 4 shows the modeled temperature distributions along a vertical section in the north-south direction at 12:00, Day 200. There was temperature domes over the building cluster.

Figure 5 shows the ground temperature distributions at 12:00, Day 200. Ground temperature in the building cluster was much higher than those in the surrounding area. The main reason for the higher temperature was the reduction of wind speed.
3.2. Constant building temperature

We conducted simulations where building temperature were assumed to be constant (25 degrees C) throughout the simulation period. Other simulation conditions were identical to those for the control run.

Figure 6 shows wind and temperature distributions in Domain 2 at 2 m above the ground at 9:20, July 20 (Day 200). As expected there was no temperature hot spot in the eastern side of the building cluster compared with the counterpart of the control run (Fig. 3). Consequently wind directions in the hot spot were also different.

The modeled ground temperature distributions (not shown) at 12:00, Day 200 were almost identical to those in the control run (Fig. 5). Although temperature distributions in the layers above the ground were significantly different, ground temperature remained the same in the urban area where wind speeds were small.

3. SUMMARY

Numerical simulations were conducted to study reduction of heat island effects when building wall temperatures were kept constant. As expected heat domes over buildings disappeared. However, ground temperature remained the same in the urban area where wind speeds were small.

REFERENCE
