# Improvement of urban parameters for the single-layer UCM in the WRF model

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## 1. Introduction

Anthropogenic heat, urban fraction, and building height (roughness lenght, displacement height) are major urban parameters expressing the urban characteristics such as human activity, land use, and urban geometric structure in an urban model. In the single-layer urban canopy model (UCM) of the current Weather Research and Forecast model (WRF), urban areas are categorized into only three types of urban, defined by different sets of values of urban parameters.

To reproduce the urban effects to local climate caused by inhomogeneity in the urban area, this study modified the WRF/UCM to incorporate the gridded urban parameters into the model, and then conducted the sensitivity analyses of spatially inhomogeneous urban texture to the local climate.

## 2. Model and Experimental Design

The version used in this study was WRF version 3.3.1 (Skamarock et al., 2008). The applied schemes and model setting are listed in Table 1. The outer domain covers the most part of main island in Japan, while the inner domain covers the central part of Japan including the Tokyo metropolitan area (TMA) (Fig. 1). The grid of the inner domain has 500 x 500 grid cells with the horizontal resolution of 4 km. The simulation was conducted from July 25, 2010 to September 1, 2010, and the output only in August was used for analysis.

Table 1. Model settings

| | |
|---|---|
| Boundary data | NCEP/NCAR reanalysis I |
| Resolution | 20km, 4km (Horizontal)<br>31 levels (Vertical) |
| Land surface scheme | Noah land surface model |
| Urban scheme | Single-layer urban canopy model (Kusaka et al., 2001) |
| PBL scheme | Mellor-Yamada-Janjic TKE scheme |

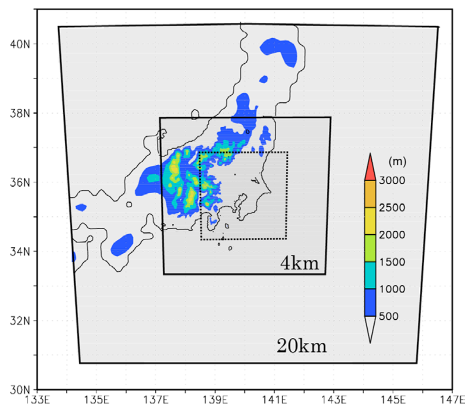


Fig 1. Model domains. The dashed square indicates the analyzed area (Tokyo metropolitan area).

Table 2. Experimental design

| Simulation | Urban fraction | AH | Roughness length (Z0C) | Displacement height (ZDC) |
|---|---|---|---|---|
| CTL_org | 0.7* | 17.5* | 0.71* | 7.185* |
| CTL_LU | 0.7* | 0 | 0.71* | 7.185* |
| EXP_LU | map | 0 | 0.71 | 7.185 |
| CTL_AH | map | 17.5* | 0.71 | 7.185 |
| EXP_AH | map | map | 0.71 | 7.185 |
| EXP_z0 | map | map | map | 7.185 |
| EXP_zd | map | map | 0.71 | map |
| EXP_all | map | map | map | map |

* only at grid cells with LU_INDEX ( the dominant land use) = urban

The four urban parameters given as the gridded data in new WRF/UCM are as follows: (1) urban fraction, (2) anthropogenic heat (AH), (3) momentum roughness length, and (4) displacement height. The urban fraction is defined as a ratio of urban area to an entire grid cell.

The gridded urban parameters used in this study are illustrated in Fig 2. The urban fraction is created using the fine land cover data (FLCD) from the Digital National Land Information (DNLI) dataset, published by the Ministry of Land, Infrastructure, Transport, and Tourism. The FLCD categorizes land use into 11 or 12 types for every 100-m square. These 11 or 12 land-use types were reclassified to eight land-use types used in USGS land-use types in the WRF model. The anthropogenic heat release is based on the AH value in August reported in NIRE (1997), which is estimated using energy consumption rates. The momentum roughness length above canyon and the displacement height are calculated according to empirical equations set up based on a number of large eddy simulations in the Tokyo metropolitan area (Kanda et al., 2012).

To evaluate the impacts of the gridded data to urban climate, the sensitivity analyses are conducted. The experimental

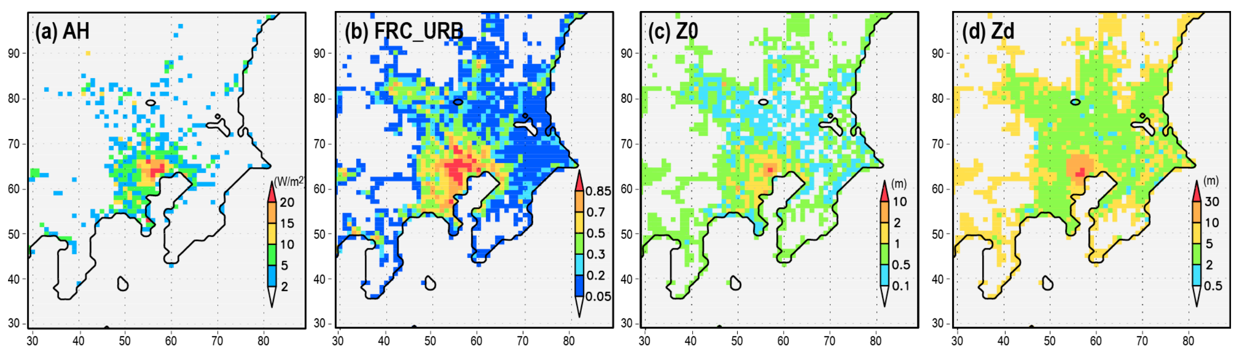


Fig 2. Distributions of (a) the anthropogenic heat flux, (b) urban ratios, (c) the roughness length, and (d) the displacement height.

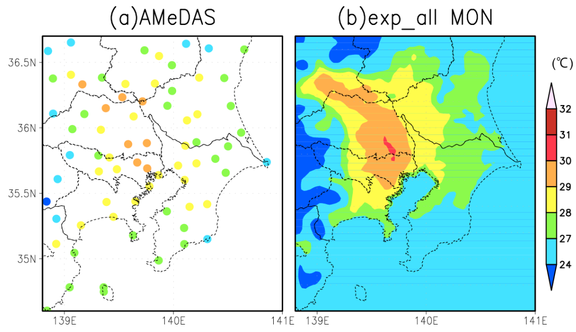


Fig 3. Monthly surface air temperature of (a) observation and (b) model.

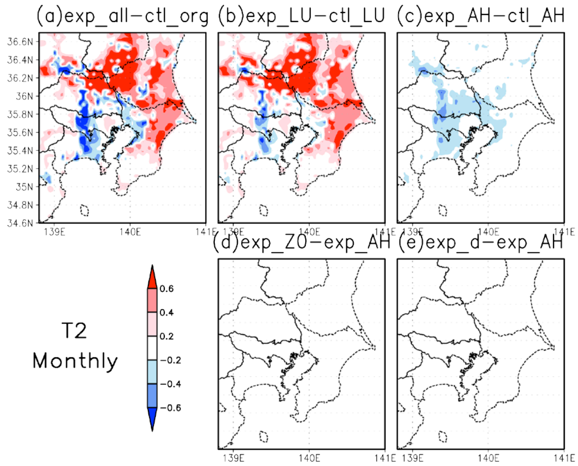


Fig 4. Difference of surface air temperature due to difference between the constant value and the gridded data in: (a) four urban parameters, (b) the urban fraction, (c) the anthropogenic heat, (d) the roughness length, and (e) displacement height.

design was shown in Table 2. The fixed value in Table 2 means the urban parameter is spatially homogenous, namely it is provided as constant value. On the other hand, "map" means the urban parameter is given the gridded data.

## 3. Results

### 3.1 Sensitivity analysis of gridded urban parameters

The model output from new WRF/UCM is compared with observation to evaluate the model performance. Figure 3a shows the observed monthly surface air temperature. The monthly surface air temperature in August exceeds 29 deg. in the central part of TMA. The model results can capture well the observation, although the simulated temperature is slightly overestimated in the center part of TMA and coastal areas. The model results can also reproduce the observed characteristics of surface wind speed and precipitation (not shown).

The impacts of the gridded data of each urban parameter on surface air temperature are indicated in Fig 4. Figure 4b shows the surface air temperature differences between EXP_LU and CTL_LU, while Fig 4c is that

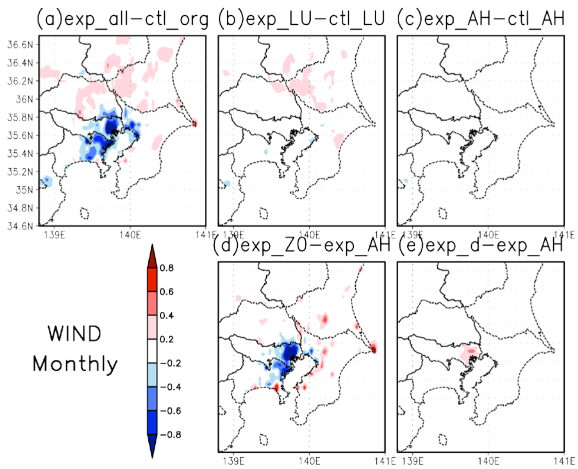


Fig 5. Difference of surface wind speed due to difference between the constant value and the gridded data in: (a) four urban parameters, (b) the urban fraction, (c) the anthropogenic heat, (d) the roughness length, and (e) displacement height.

between EXP_AH and CTL_AH. The surface air temperature is strongly affected by the land use and anthropogenic heat. The difference of about 20% in urban fraction corresponds to the difference of about 0.6 deg.

in surface air temperature. On the other hand, the differences of roughness length and displacement height show the temperature change less than 0.2 deg..

The wind speed is susceptible to roughness length. The difference is more than 0.6 m/s in the central area (Fig 5).

### 3.2 Diurnal variation of sensitivities of gridded urban parameters

Hourly variation of responses to surface air temperature is shown in Fig 6. The difference between the simulations of the new WRF (EXP_all) and the original WRF (CTL_org) is large during the nighttime from 17LT to 04LT. The main cause is the difference in the value of urban fraction. This

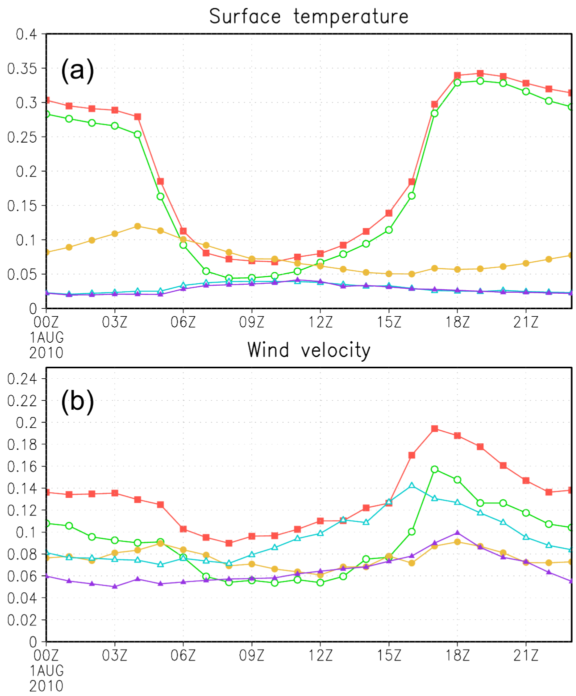


Fig 6. Diurnal variations of the differences of (a) surface air temperature and (b) surface wind speed due to difference between the constant value and the gridded data on: (a) four urban parameters, (b) the urban fraction, (c) the anthropogenic heat, (d) the roughness length, and (e) displacement height.

is because the difference in surface air temperature between the urban area and other land-use areas, such as grassland, irrigated cropland, and pasture, is dominant in the nighttime.


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