

## 358: Urban Climate Projection in Tokyo for the 2050's August under the RCP4.5 Scenario

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### Abstract

This study presents the projected urban climate of Tokyo for the 2050's August under the RCP4.5 scenario. To accurately evaluate the urban climate, the simulations use the improved WRF model with 4-km grid increment coupled to the single-layer urban canopy model (UCM). Dynamical downscaling approach is used with a CMIP-5 GCM (MIROC5) in future projection. The projected 10-year mean temperature increase in the Tokyo metropolitan is 2~3°C for the 2050's August compared the 1990s. This temperature difference is comparable to the mean temperature anomaly for abnormally hot summer in current climate. The result provides an estimate of heat stress for the Tokyo residents in warming climate. Additional experiments indicate that the compact city urban planning scenario can reduce the August mean temperature of surrounding residential areas by 0.2°C, whereas the distributed city scenario can increase the temperature of surrounding residential areas by 0.5°C. Uncertainty due to urban planning scenario is much smaller than that due to emission scenario or GCM and urbanization has less impact on the temperature increase due to global climate change in the future, but the urban planning in the future should be not ignored in the dynamical downscaling for the future-climate projection.

Keywords: urban climate projection, dynamical downscaling, RCP4.5, WRF

### 1. Introduction

Urban climate projection is needed for mitigation of the heat island effect. Very recently, Kusaka et al. (2012a) provided a projection of urban climate in Tokyo metropolis in Japan for the 2070's August using dynamical downscaling from three CMIP3 GCMs (MIROC3.2-Medres, MRI-CGCM2.3.2, CSIRO-Mk3.0). The simulations were conducted by the Weather Research and Forecast model with 4-km grid increment coupled to the single-layer urban canopy model (WRF\_UCM, Kusaka et al. 2001, 2012b). However, Kusaka (2012a) used only one climate change scenario (A1B from IPCC 4<sup>th</sup> assessment), and urban landscape was assumed to remain as that of today's (status-quo). Further, projection was targeted only for 2070's August. The present study presents urban climate projection for the 2050's Augusts in the Tokyo metropolis in Japan. Projection is conducted using dynamical downscaling approach with the WRF\_UCM from a CMIP5-GCM (MIROC5) under the RCP4.5 Scenario. Furthermore, three different urban scenarios are considered, (i) status-quo city, (ii) compact city, and (iii) distributed city, as developed by Yamagata et al. (2010).

### 2. Method

#### 2.1 Dynamical Downscaling

First, a hindcast experiment is conducted in order to assess the capacity of the new WRF model, which is improved by Adachi et al. (2012). Next, climate change experiments are performed with dynamical downscale for 2050's August. The future climate forcing is provided from a CMIP5-GCM, MIROC5 with IPCC RCP4.5 scenario.

#### 2.2 WRF UCM

The standard UCM in WRF model is the single-layer urban canopy model developed by Kusaka et al. (2001), Kusaka and Kimura (2004a, b). In the standard UCM, urban areas are categorized into only three types of urban landscape types, which are defined by different values of urban parameters (Skamarock et al., 2008; Chen et al. 2011, Kusaka et al. 2012a). The current study employs an improved version of WRF (Adachi et al. 2012), which is capable of treating horizontal distribution of urban parameters thus can express spatially inhomogeneous urban texture.

#### 2.3 Urban Scenario in the 2050's

Urban climate depends on global-scale climate variation and urban landscape. From this reason,

different urban scenarios shall be considered for future projection. Therefore, this study employs three urban scenarios developed by Yamagata et al. (2010) and uses these scenarios in dynamical downscaling from a CMIP5 GCM, MIROC5. Here, the urban scenarios are characterized by different anthropogenic heat, land use, and building height (Figure 1).

### 3. Results

#### 3.1 Performance of the dynamical downscaling with the WRF model

First, dynamical downscaling experiment from the NCEP re-analysis data is performed as a verification test of the WRF model improved by Adachi et al. (2012). The WRF model well reproduces the observed horizontal distribution of the monthly mean surface air temperature in August in 2004: the urban areas are warmer than their surroundings, and the temperature in Tokyo is the highest in the Kanto plain. Similar result is obtained when other reanalysis data (i.e., JRA25 and NCEP final analysis) is used as boundary conditions.

#### 3.2 Urban climate projection in the 2050's August in Tokyo

Second, dynamical downscaling experiment from a CMIP5-GCM (MIROC5) for the present- and future-urban-climate projections is conducted. In the status-quo scenario, the projected 10-year mean temperatures in the 2050's August over the Tokyo metropolitan area are 2~3°C higher than that in the 1990s (Figure 2). This result indicates that abnormal summer in current climate condition may become normal in future climate, as the temperature anomaly for abnormally hot summer in current climate is also about 2 °C.

In the compact city scenario, the projected temperature rise is reduced by ~0.2 °C compared to the status-quo scenario. However, the spread-city scenario raises the temperature by 0.2 °C in the wide area surrounding central Tokyo (Figure 3). The temperature rise in the spread scenario is as large as 0.5 °C. This result indicates that urban planning may partially mitigate the temperature rise induced by global scale warming. This simulation assumes no change in population and the electric energy consumption regardless of the urban scenario. Therefore, if energy-saving and natural landscaping policies are implemented, further reduction of temperature rise may be expected.

### 5. Conclusion

This study presents the projected urban climate of Tokyo for the 2050's August under the RCP4.5 scenario. To accurately evaluate the urban climate, the simulations use the improved WRF model with 4-km grid increment coupled to the single-layer urban canopy model (UCM). To project future urban climate, the simulations apply dynamical downscaling from a CMIP-5 GCM (MIROC5). Summary of results are as follows.

1) The projected 10-year mean temperatures in the 2050's August over the Tokyo metropolitan area are 2~3°C higher than that in the 2000s, the anomaly is comparable the abnormally hot summer in current climate.

2) Additional experiments indicate that the compact city urban planning scenario can reduce the August mean temperature by 0.2 °C, whereas the distributed city scenario can increase the temperature by 0.5 °C.

3) Uncertainty due to urban planning scenario is much smaller than that due to emission scenario or GCM. Also, urbanization has less impact on the temperature increase due to global climate change in the future. However, the urban planning scenario in the future should be not ignored in the climate projection research.

### 6. Acknowledgements

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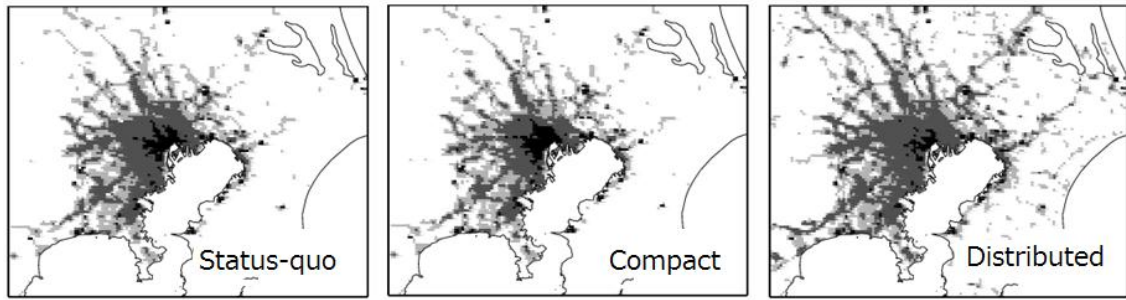


Fig 1. Anthropogenic heat map in the 2050's August under the status-quo, compact, and distributed urban scenario.

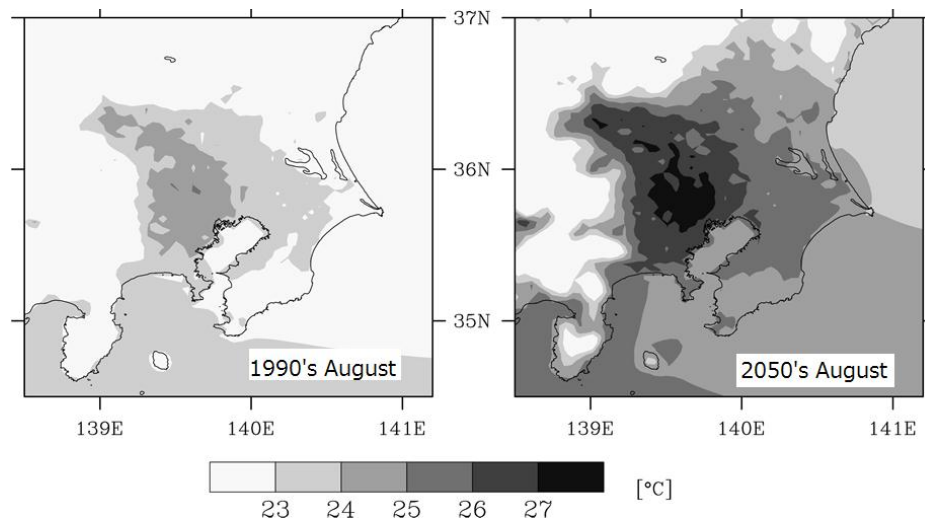


Fig 2. Projected surface air temperature in 1990's and 2050's August. The results are from the dynamical downscaling with the WRF model from a CMIP5-GCM (MIROC5).

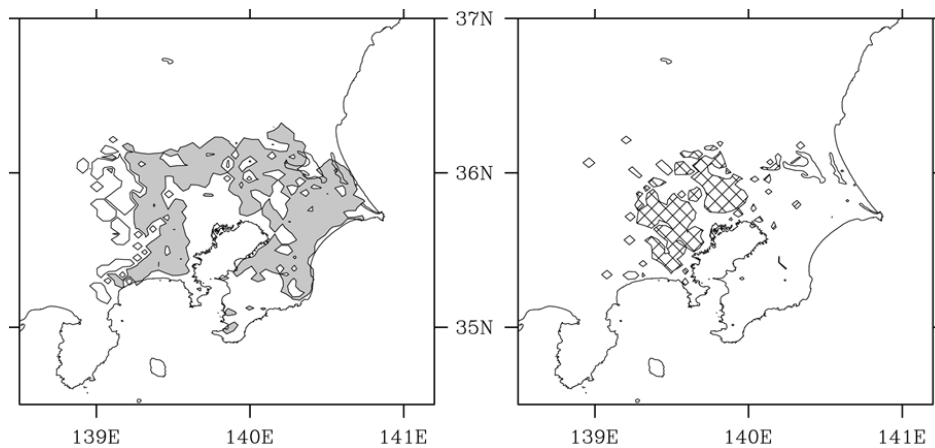


Fig 3. Projected impact of urban scenario in future climate (anomaly from status-quo scenario) for spread city (left) and compact city (right) scenarios. Grey shading indicates positive 0.2 °C anomaly, and hatched (with crossed-lines) area indicates negative 0.2 °C anomaly.