Dynamical Downscaling of Global Climate Change for Urbanizing Kanto Plain

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Abstract

This study estimates the local climate change around the Tokyo Metropolitan area by a new dynamical downscaling method, i.e., the pseudo global warming method, which allows to reduce the model bias of the CGCM projection. First, the results of hindcast are compared with the observed temperature. Then the dynamical downscaling is carried out using the boundary conditions given by the CGCM projection of the future climate assuming IPCC SRES-A1B scenario for the emission of the greenhouse gases. Results show that the uncertainty of the temperature projection caused by GCMs is very large. The range of temperature change by global warming is larger than the temperature increase caused by change in land-use.

Key words: global warming, downscaling, regional climate model

1. INTRODUCTION

By the global warming caused by increase of the greenhouse effect gas will further enhance the heat discomfort of the citizen living in urban heat islands. Mitigation of the urban heat island will be more necessary. However, the heat contrast between urban and rural may change by the global climate change. This study intends to quantitative estimation of the urban heat island effects and warming by the increase of greenhouse gas around Tokyo metropolitan area by a dynamical downscaling method using a regional climate model.

2. METHOD AND MODEL DESCRIPTION

The numerical model for downscaling is TERC-RAMS (Inoue and Kimura, 2007), which is a modified version of the Regional Atmospheric Modeling System (RAMS). Parameterization of urban surface is given by a single layer urban canopy model presented by Kusaka and Kimura (2004). The horizontal grid interval is 3 km in the fine grid system (77 X 72 grid points), which is nested in the coarse grid system that covers central Japan with 15 km resolution. Six numerical experiments are carried out including a hindcast run and four downscaling runs. These are listed in Table 1, where CTL indicates the hindcast run for August 2006 assuming reanalysis data JRA25/JCDAS for boundary conditions and the actual land-use based upon the Fine Land Cover Data (FLCD) provided by Ministry of Land, Infrastructure, Transport and Tourism. In the run LAND, land-use are modified after a simple assumption that the decadal increment of the total urban area in the Kanto Plain will be constant and is equal to a half of that between 1987 and 1997. Figure 1a indicates distribution of the rate of urban area in 1997, while 1b shows assumed rate in 2070s. Runs BCCR, CCCMA, MIROC and MRI shown in Table 1 are downscaling runs that estimate the regional climate in 2070s based on the coarse grid projections given by four GCMs assuming SRES A1B emission scenario. Names of runs are given by Model IDs of GCMs defined in IPCC report (AR4, Chap.8). In these downscaling runs, land-use is assumed to be the same as the present.

A new downscaling method, Pseudo Global Warming Downscale (PGW-DS) was adopted (Kimura and Kitoh 2007, Sato et al., 2007, Kawase et al. 2009). The PGW-DS is almost the same as the conventional dynamical downscaling method but the boundary conditions is obtained by the reanalysis data adding the monthly mean difference between the future and present climates simulated by CGCMs.

Table 1. Descriptions of numerical experiments.

Numerical experiments for Aug. 2006

CTL	Hindcast using reanalysis
LAND	Same as CTL, but modified land-use

Downscaling of projected climate in 2070s by four GCMs

BCCR	BCCR-BCM2.0
CCCMA	CGCM3.1(T63)
MIROC	MIROC3.2(hires)
MRI	MRI-CGCM2.3.2

3. RESULTS

Mean screen height temperature was overestimated up to 1.0 C at Otemachi, Kumagaya and most other stations during daytime, while the shapes of Probability Density Function (PDF) of hourly temperature and the diurnal variation were simulated well. The maximum observed temperature was 27.5 C at Otemachi, while simulated one was 28.5 C. More comparison with observation is reported by a separate report by Adachi and Kimura (2009).

Figure 2a shows horizontal distribution of monthly mean screen height temperature in August 2006 given by CTL, while 2b indicates the same figure but obtained by run MRI, i,e., the downscaled temperature in 2070s using the CGCM projection by MRI-CGCM. Temperature in the central part of Tokyo (Otemachi) is about 28.5 C in the CTL, but it was estimated to be over 31 C in 2070s based upon MRI. Temperature contrast between the central part of Tokyo and rural areas tends to be enhanced. Figure 2c indicates monthly temperature of the run LAND. Temperature clearly increased in the most part of Kanto Plain, particularly in the northeastern part of the Plain. However, the temperature difference between CTL and LAND is much smaller than the difference between CTL and MRI that means change caused by the global climate change.

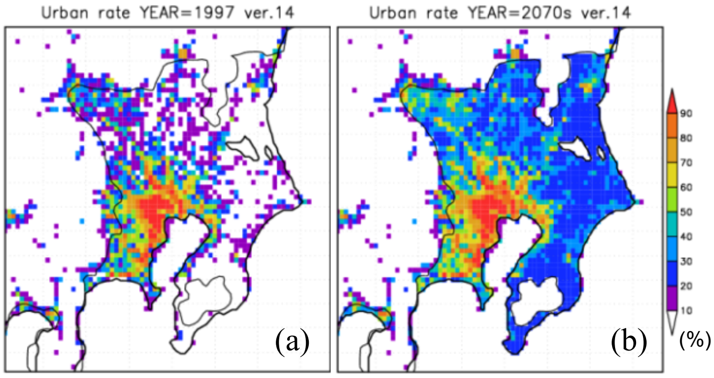

Figure 1. Distribution of the ratio of urban area (a) in 1997, (b) in 2070s.

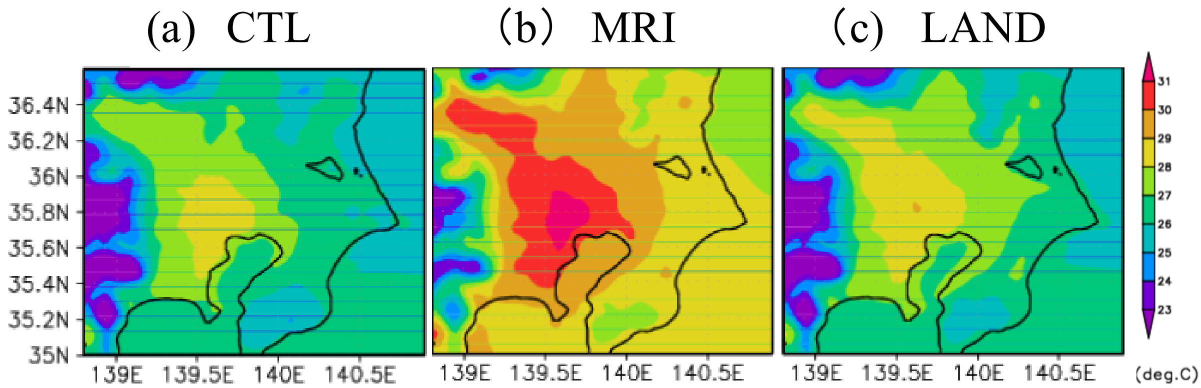

Figure 2. Horizontal distribution of monthly mean screen height temperature of (a) CTL, (b) MRI, and (c) LAND.

4. DISUCUSSION

Temperature change until 2070s strongly depends on the GCM which gives boundary condition of the regional climate models. Figure 3 indicates Probability Density Functions (PDFs) of hourly surface temperature at Kumagaya in August 2006. Black line and blue line indicate PDFs of surface temperature given by observation and CTL, respectively. Simulated present PDF given by CTL agrees well to that of observation. Red line indicates the mean of four PDFs given by downscaling temperature from four CGCMs. The red PDF entirely shifted to higher temperature. Particularly the maximum temperature increases by nearly 8 C and reaches to the extreme value of 42 C. Four thin lines indicate individual PDFs estimated by each CGCMs. These lines widely disperse showing that the uncertainty of the projection is quite large. The

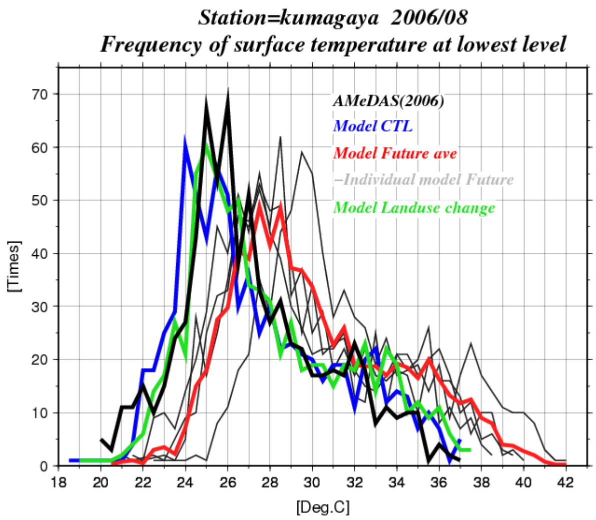

Figure 3. Probability Density Functions (PDFs) of hourly surface temperature at kumagaya.

temperature change is much larger than the estimated change in temperature caused by future change in land-use, which is shown by the difference between blue line (CNTL) and green line (LAND).

5. CONCLUSION

Dynamical downscaling is carried out using the boundary conditions given by four CGCM projections of the future climate assuming IPCC SRES-A1B scenario. The intensities of the regional scale warming at the surface level are individually estimated for the increase of the greenhouse gases and for the change in land-use. Results show that the uncertainty of the temperature projection caused by dependency of GCMs is very large and the range is larger than the estimated temperature increase caused by future change in land-use.

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