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Numerical Studies on Temperature Change and Urbanization in Recent 30 years in Kanto Plain

Sachiho Adachi*, Fujio Kimura* **
*University of Tsukuba, Ibaraki, Japan
**Advanced Atmosphere-Ocean-Land Modeling Program, Research Institute for Global Change, Japan Agency for Marine-Earth Science and Technology, Kanagawa, Japan

Abstract

By in situ observation, surface temperature increased by nearly 1 C during recent 30 years in Kanto Plain. At the same time, urban areas keep to extend. Observed warming in the Kanto Plain is affected by the global climate change as well as the further expansion of the urban areas. This study evaluates both effects quantitatively using a numerical model. The increase in urban area during the past 10 years contributed about 30% of warming in the inland areas, while it was only 10% in the southern part of Kanto Plain. The remains are caused by change in the synoptic scale climate.

Key words: urbanization, climate change, numerical simulation

1. INTRODUCTION

Several previous papers discussed the effect of land-use change on the warming trend of surface temperature, which is observed through the world (Lim et al. 2005; Parker 2006). The effects of land-use change on the local temperature cannot ignore at least in urban and surrounding areas. Particularly, there are many populous regions in Japan, where artificial alteration of land use may strongly affect local-scale climate (e.g., Fujibe 2008). Heat stress for citizen in urban area is predicted to greatly increase in future because of both effects of the urban heat island and the global warming. The quantitative projection of the future climate change will be necessary in regional scale. Downscaling method is one of useful methods to achieve the request.

This study focuses on Kanto area, which is the most populous region in Japan. Purpose is to quantitatively estimate the contribution of land-use change and global climate change to the past temperature change in Kanto area in the period from 1987 to 1997.

2. DESCRIPTION OF NUMERICAL EXPERIMENTS

Numerical simulations were conducted for 4 cases listed in Table 1. Simulation period is 14 years and is divided into two seven-years periods, which are centered at 1987 and 1997 when land-use data are available, are defined as the first half and the second half periods, respectively. Run M80L97 is same as CTL87, but for the land-use data of 1997. The comparison between two allows to estimate the effect of land-use change during this 10 years. The initial and boundary conditions for P80L87 were given by the pseudo climate data, which were obtained by 6-hourly reanalysis data adding the difference between the first half and the second half periods. The comparison between P80L87 and CTL87 are expected to show the effect of climate change in global scale. These two effect, one by land-use change and another by global climate change, are quantitatively compared with the surface temperature change observed during 1987 to 1997.

TERC-RAMS (Inoue and Kimura, 2007) was adopted for the numerical experiments, and boundary conditions were given by 6-hourly JRA25 reanalysis/JCDAS (hereafter JRA25) with 1.25x1.25 horizontal resolution including variables of RH (relative humidity), SST (sea surface temperature), T (temperature), U (x-component of velocity), V (y-component), and Z (elevation). Simulation was executed in two nesting regions; the outer region was covered by 40 x 40 grids with 15 km horizontal interval, while the inner region was covered by 62 x 62 grids with 3 km horizontal interval. Each run was integrated from 09 JST on 26th July to 09 JST on 1st September, and the products only during August were analyzed.

Table 1. Descriptions of numerical experiments.

Run		Boundary condition	Land-use
CTL87	Hindcast for first half	First half	1987
CTL97	Hindcast for second half	Second half	1997
M80L97	Sensitivity to land-use	First half	1997
P80L87	Sensitivity to climate	First half + Climate difference	1987

Distribution of land-use was based on the fine land cover data (FLCD) in 1987 and 1997, provided by Ministry of Land, Infrastructure, Transport and Tourism. The land-use was categorized in urban and grassland, and rate of urban area was defined as the rate of "building area" classified in FLCD to the total grid area. Figures 1a and 1b show the distribution of urban rate in 1987 and 1997, and Figure 1c indicates the difference between two. Most region increased urban rate excluding the south of Bouso peninsula and north of Ibaraki prefecture (hereafter Pf). Particularly, the increasing tendency is notable in south of Saitama Pf and interior and plane region of Kanagawa Pf. Maximum of the urban rate change was around 30%. While the development of urban stagnated in the central Tokyo, because space had already saturated as of 1987.

Artificial heat release given in the model has a diurnal cycle; two maxima in morning and evening, while a minimum at 3 am, and assumed to be 25 W/m^2 in average at a grid of 100% urban rate.

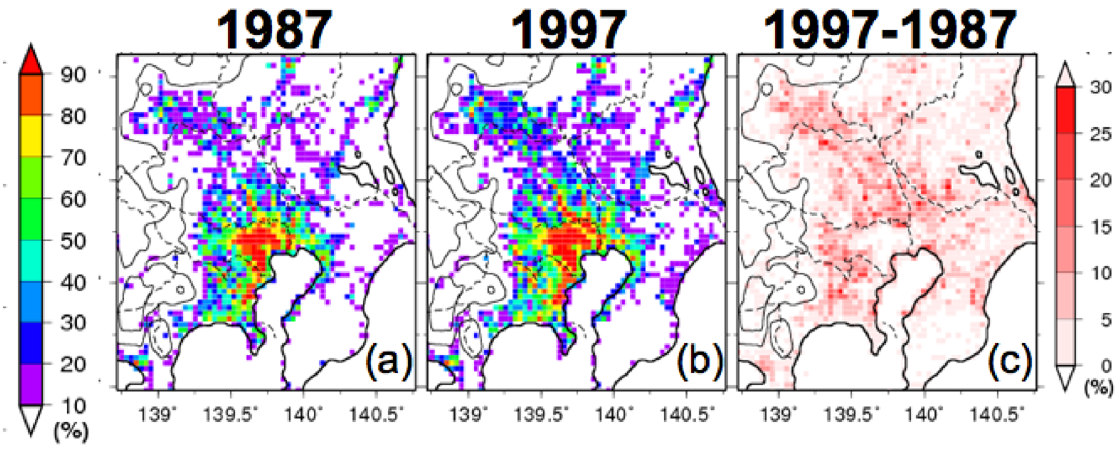

Figure 1. Urban rate in (a) 1987 and (b) 1997 and (c) the difference of the rate between 1987 and 1997.

3. MODEL RESULTS

This paper discusses the simulated result only for during night (02-04JST). Simulated surface temperature and precipitation were compared with AMeDAS observation whose elevation is lower than 100m above sea level and located in the nested model area. The deviation of surface temperature from observation is less than 0.5 C except for 1987 in the first half period, while temperature in 1997 in the second half year has cold bias of about 2 C. Simulated precipitation shows underestimation compared to observation in every year except for 1994 and 2000. Precipitation amount is about a half of that of observation. However, horizontal distribution agrees well to the observation (not shown).

Figure 2a shows the difference in surface temperature between M80L97 and CTL87 at 02-04JST. The boundary conditions of these experiments are same except for land-use. The temperature increasing area corresponds well to the area in which land-use prominently changed. The warming reaches to 0.2 to 0.3 C along the Takasaki railway line around Gunma and Saitama Pf. and Tama area. While the temperature change is small in the coastal areas, even if land-use change is remarkable. Distribution of temperature change associated with

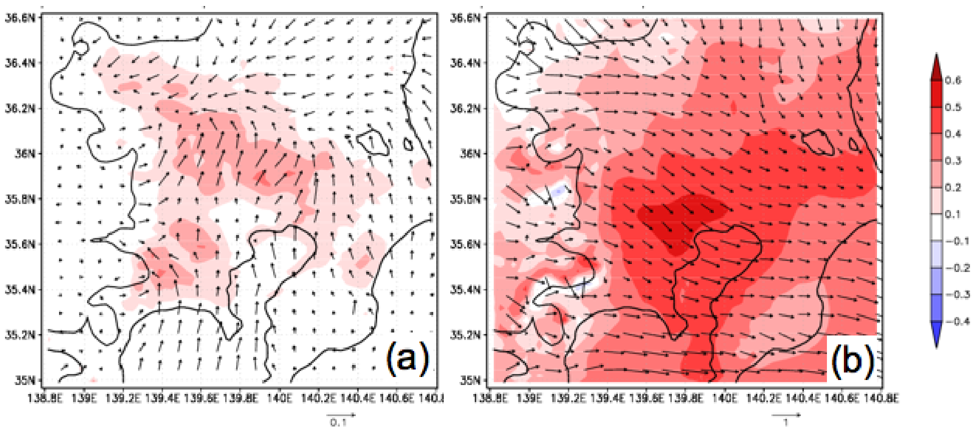

Figure 2. Difference in surface temperature at 02-04 JST (a) between M80L97 and CTL87 and (b) between P80L97 and CTL87.

synoptic climate change is shown in Figure 2b. The warming is large in the southern part. The area larger than 0.4 C is extended around Tokyo bay.

Estimated temperature changes between the first half and the second half periods are compared to observation. Temperature anomaly ΔT is defined as a deviation of AMeDAS surface temperature from the temperature at 850hPa observed by the operational radio soundings at Tateno, in order to reduce interannual variation. The bars shown in figure 3 indicate the difference of ΔT between the first half period and the second half period. Light gray bars show the prefecture average of difference of ΔT calculated from observation, while black bars denote the effect of land-use change estimated from the difference between M80L97-CTL87. White bars mean synoptic climate change (global warming effects). Total of the black and white bars are the difference of ΔT between two periods estimated by the model. The solid lines shows the contribution rate of land-use change in the change of ΔT between the first half and the second half period. The black bars in figure 3a were estimated by the direct downscaling method (CTL97-CTL87), while ones in figure 3b are by the pseudo climate downscaling method (P80L87-CTL87).

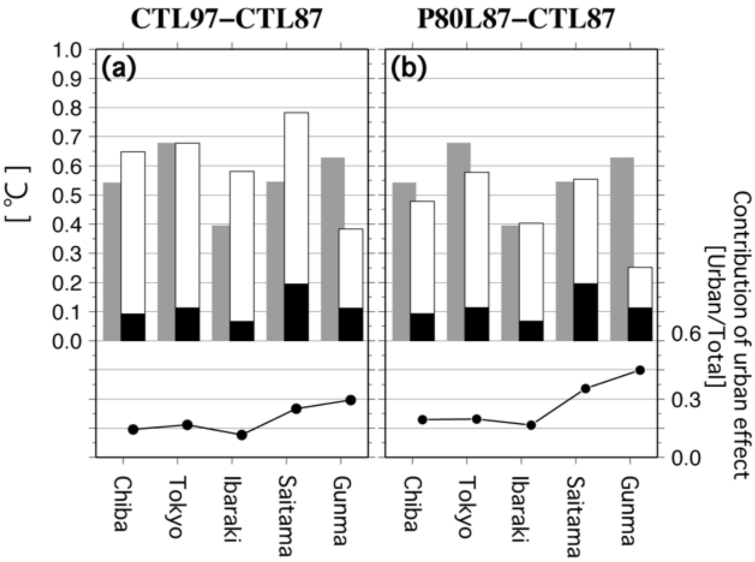

Figure 3. Difference of temperature anomaly (ΔT) between 1987 and 1997 by (a) the direct downscaling method and (b) the pseudo downscaling method.

Figure 3a indicates increase of temperature anomaly ΔT is large in Saitama, Tokyo and Chiba Pf, while it is somewhat smaller in Ibaraki and Gunma Pf. The change component of urban ratio is larger in inland areas such as Gunma and Saitama, but smaller in Chiba, Ibaraki, and Tokyo. Temperature increase caused by change in synoptic scale climate is large in the southern Kanto Plain, being nearly 0.5 C. The contribution by change in urban rate is about 30% in the inland areas, while it is only 10% in the southern part of Kanto Plain. The components in temperature increasing caused by synoptic scale climate change, which is estimated by the pseudo climate change experiment, are agree well to those of the direct downscaling although the amplitude is slightly smaller. The pseudo global warming method can be apply to the downscaling of future climate change.

4. CONCLUSION

Assuming JRA25/JCDAS for the initial/boundary conditions, downscaling of surface temperature during night was carried out by two different methods. In addition to above, by some sensitivity experiments, the contributions of the change in land-use and the synoptic scale climate change were estimated in temperature change observed during past ten years. We successfully simulated change in nighttime surface temperature and found that the contribution by change in urban rate was about 30% in the inland areas, while it is only 10% in the southern part of Kanto Plain. The remains are caused by change in the synoptic scale climate. The pseudo global warming method was able to simulate climate of the second half period, although the amplitude of warming was underestimated compared to that of the direct downscale method.

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