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SPATIAL DISTRIBUTION OF SUMMER TEMPERATURE IN TOKYO WARDS -OBSERVATION RESULTS OF METROS-

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Abstract The urban heat island phenomena in summer over Tokyo Wards was studied by using the data obtained from METROS (Metropolitan Environmental Temperature and Rainfall Observation System), which is the high density heat island phenomena observation network. The observational results clarified the detailed spatial distributions of temperature never known before. Concerning the spatial distribution of daily maximum temperature, the region with a relatively high temperature extends from the central Tokyo district toward the northern and northwestern area. On the other hand, relatively high values in the daily minimum temperature are distributed around the coastal area of Tokyo Bay including the central Tokyo district. Since the central Tokyo district has significantly high temperatures both in the daytime and in the nighttime, and also raises the temperature in the adjacent north and northeast area, it is necessary to take countermeasures preferentially to this district.

Key words: heat island phenomena, Tokyo Wards, air temperature, days of torrid night, time proportion of hours which exceeded 30°C

1. Introduction

The high temperature with intensified heat island phenomena causes various negative impacts, such as the increase of heat stroke patients, aggravation of air pollution, increase of local severe rain, increase of energy consumption, and so on (Ministry of the Environment 2005). On July 20, 2004, an extraordinarily high temperature of 39.5°C was recorded at Otemachi in Tokyo. Public concern about the heat island phenomena has been growing year by year. The Tokyo Metropolitan Research Institute for Environmental Protection (MRIEP) has tackled the heat island issues for supporting the planning of countermeasures (Ito *et al.* 1994; Mikami *et al.* 1997a, 1997b; Ando *et al.*2003; Mikami *et al.* 2004; Yokoyama *et al.* 2005). Then it became clear that detailed observation data were necessary for the investigations of mechanism and cause of heat island phenomena. However, since there are not enough meteorological stations by the Japan Meteorological Agency in the Tokyo area for the detailed analysis, the MRIEP started the spatiotemporally high-density meteorological observation system in cooperation with Tokyo Metropolitan University (TMU) from the summer of 2002. It is called METROS (Metropolitan

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Environmental Temperature and Rainfall Observation System).

In this paper, the three-year observation results of METROS will be reported.

2. Observation Methods

The automatic recording thermometers (temperature and humidity logger No. 3641 made by Hioki electrical machinery Co., Ltd.) were installed into the instrument shelters of 100 elementary schools with about 2.5 km spatial resolution in Tokyo 23 wards in July 2002 (METROS100). The meteorological instruments for wind direction and velocity, air temperature, air humidity, precipitation and atmospheric pressure were also established on the rooftop of 20 buildings in 23 wards. The interval of these measurements was set up at 10 minutes. Then the data were automatically transmitted to the MRIEP and TMU (METROS20). The details of the METROS are reported by Ando *et al.* (2003). In order to recognize the spatial structure of temperature, some contour maps were drawn by using these datasets.

3. Results and Discussion

Spatial distributions of mean daily maximum temperature in summer for three years

The spatial distributions of mean daily maximum temperature in summer for three years are shown in Fig. 1. Though the values of air temperature are obviously different in each year, the spatial structures are similar among three years. The region with high temperature extends from the central Tokyo district toward the northern and northwestern parts of wards area. On the other hand, low air temperatures appear along the Tokyo Bay shore region except for Minato Ward, especially, remarkably low in Edogawa ward.

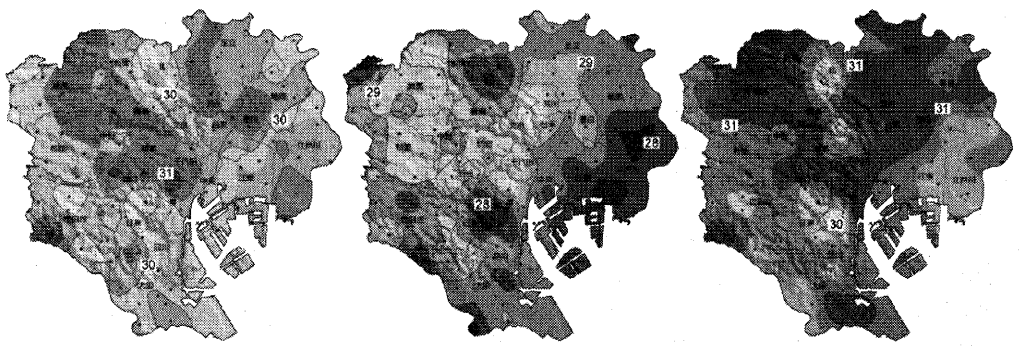


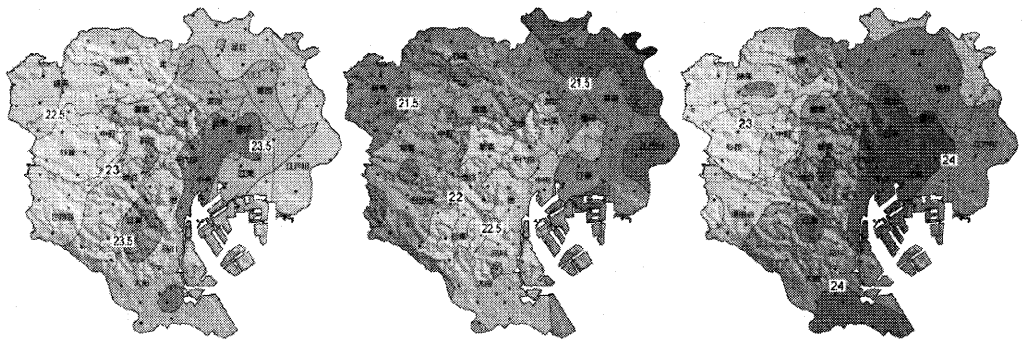
Fig. 1 Spatial distributions of mean daily maximum air temperature (°C)in summer (from July 20 to September 30 in each year).

The northern and northwestern wards, where are expected to be cooled by the sea breeze from Tokyo Bay in the daytime, experience significantly high temperature. This suggests that these

areas are heated by the wind through the central Tokyo district, or the cooling effect of sea breeze is very low. In addition, the ascending current of heat island circulation in the central Tokyo district is considered to prevent the sea breeze from entering into the inland (Japan Meteorological Agency 2006). On the other hand, it seems to become low temperature by the cool sea breeze in the coastal region of Tokyo Bay.

Spatial distributions of mean daily minimum temperature in summer for the three years

The spatial distributions of mean daily minimum temperature in summer for the three years are shown in Fig. 2. As well as the case of maximum temperature, the absolute values of temperature in each year are different. However, the spatial structures are similar among three years. The region with a relatively high temperature expands in the Tokyo Bay shore region including the central Tokyo district. There are clear and closed isothermal lines around the central Tokyo, and this result is consistent with that of the past research, which showed that the heat island phenomena appeared clearly in the minimum temperature distribution than in the maximum temperature distribution (Ito *et al.* 1994; Mikami 2003).



<2002> <2003> <2004>

Fig. 2 Spatial distribution of mean daily minimum air temperature (°C) in summer (from July 20 to September 30 in each year).

Spatial distributions of proportion of hours above 30°C

Though there are many indices for expressing the high temperature in the daytime, such as a daily maximum temperature, tropical day (daily maximum temperature exceeding 30°C), etc., these do not always indicate the impact of heat on our health. Ono (2004) demonstrated that the carrier number of heat stroke patient rapidly increased above 30°C in the daytime. Therefore, this temperature is considered to be good indicator and the total hours above 30°C seem to well express the influence on health in the daytime. The spatial distributions of proportion of hours above 30°C are shown in Fig. 3. The region with high proportion tends to extend from the central Tokyo district to the northern and northwestern wards. However it expands further east rather than the corresponding area with relatively high temperature in Fig. 1. It is necessary to pay more attention to the heat stroke in these regions than in other region.

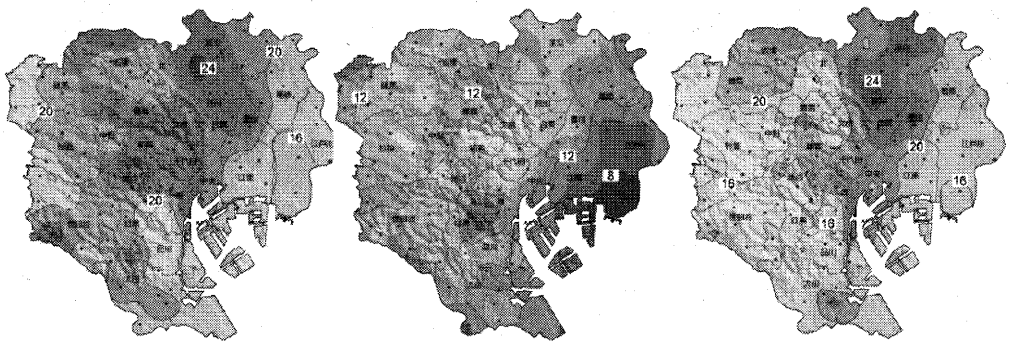


Fig. 3 Spatial distributions of proportion of hours above 30°C (%) to all time in summer (from July 20 to September 30)

The spatial distribution of the days of torrid night

The torrid night (daily minimum temperature exceeding 25°C) is related not only with the sleeplessness but also with the heat stroke (Ministry of the Environment 2005). Figure 4 shows the spatial distributions of the number of torrid nights in summer for the three years. The regions with a large number of torrid night days exist in central Tokyo district and Tokyo Bay shore regions except for Edogawa and Koto wards. The number of torrid night days seems to be relatively few in the northwest area.

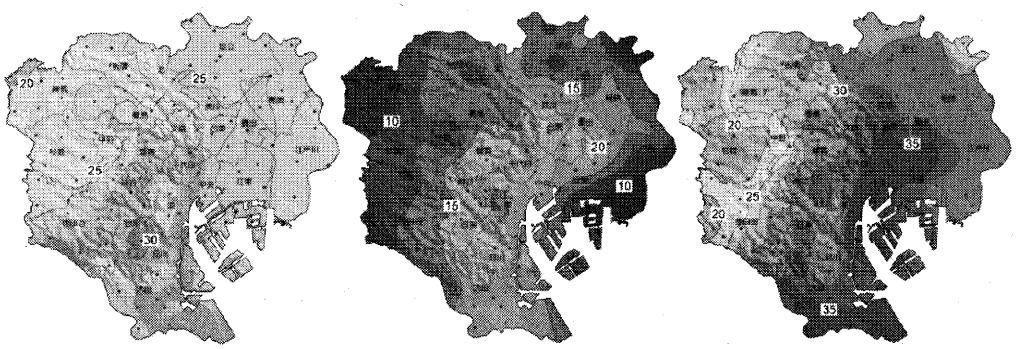


Fig. 4 Spatial distributions of torrid night days in summer (from July 20 to September 30).

4. Conclusions

As a result of high-density meteorological observation by METROS, the actual condition of heat island phenomena in 23 wards was illustrated in detail. The main results are as follows.

(1) For daily maximum temperature, the region with relatively high temperature extends from the central Tokyo district to the northern and northwestern wards.

(2) Relatively high temperature in daily minimum temperature was distributed over the Tokyo Bay shore including the central Tokyo district.
(3) The spatial distribution of number of hours above 30°C is comparatively similar to that of daily maximum temperature. However, the region with the high proportion of hours above 30°C was located further east in comparison with the warmer area as to daily maximum temperature.
(4) Since the central Tokyo district has significantly high temperatures both in the daytime and in the nighttime, and also raises the temperature in the adjacent north and northeast area, it is necessary to take countermeasures preferentially to this district.

References

Ando, H., Shioda, T., Morishima, W., Kojima, S., Ishii, K., Izumi, T., and Mikami, T. 2003. Spatial structure of summer temperatures over the urban area of Tokyo in 2002. *Annual Report of the Tokyo Met. Res. Inst. for Env. Protection 2003*: 81-87.**

Ito, M., Udagawa, M., and Mikami, T. 1994. Study on the distribution of the temperature in Tokyo. *Annual report of the Tokyo Met. Res. Inst. for Env. Protection 1994*: 35-46.**

Japan Meteorological Agency 2006. *Hitoairando Kanshi Houkoku, Heisei-17nen Kaki, Kanto Chihou (The Heat Island Monitoring Report, 2005 Summertime, Kanto District)*. Tokyo: Japan Meteorological Agency.*

Mikami, T., Wakabayashi, M., Udagawa, M., and Ito, M. 1997a. Urban heat island phenomena in Tokyo: Part1. - Reproducibility simulation of present conditions by numerical model-. *Annual Report of the Tokyo Met. Res. Inst. for Env. Protection 1997:* 38-48.**

Mikami, T., Wakabayashi, M., Udagawa, M., and Ito, M. 1997b. Urban heat island phenomena in Tokyo: Part2. - Measures for reducing heat island intensity and their effects -. *Annual Report of the Tokyo Met. Res. Inst. for Env. Protection 1997*: 49-56.**

Mikami, T. 2003. Actual condition of urban heat islands in Japan. *Environmental Information Science* **32**: 32-36.**

Mikami, T., Ando, H., Yokoyama, H., Yamaguchi, T., Ishii, K., Shioda, T., Morishima, W., Kojima, S., and Izumi, T. 2004. Spatiotemporal variation of summer urben heat islands in Tokyo. *Annual Report of the Tokyo Met. Res. Inst. for Env. Protection 2004*: 11-17.*

Ministry of the Environment 2005. *Heisei-16nendo Hitoairando Genshou niyoru Kankyou Eikyou nikansuru Chousa Kentou Gyomu Hokokusho (2004 Research and Examination Statement of Service Book on the Environmental Effect by Heat Island Phenomena)*. Tokyo: Ministry of the Environment.*

Ono, M. 2004. *Chikyu Ondanka to Kenkou (Global Warming and Health)*. Available online: http://www.nies.go.jp/impact/, 2007/10/31.*

Yokoyama, H., Ando, H., Yamaguchi, T., Ichino, M., Akiyama, Y., Ishii, K., and Mikami T. 2005. Realities of summer urban heat island in Tokyo wards - observation results of METROS since 2002 to 2004 -. *Annual Report of the Tokyo Met. Res. Inst. for Env. Protection 2005*: 3-9.**

(*: in Japanese, **: in Japanese with English abstract)