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Changes in Temperatures in Okayama Area Compared with Different Urbanization Areas, Japan

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ABSTRACT

To investigate the changes in temperatures in Okayama area compared with different levels of three urbanization areas such as Tsuyama, Tokyo areas and Hachijo island in Japan. Data of temperatures in Okayama (1891-2009), Tsuyama (1943-2009), Tokyo areas (1876-2009) and Hachijo Island (1907-2009) in Japan was obtained from Japan Meteorological Agency. Changes in temperatures in 4 areas in Japan were analyzed and compared. By using data from 1943 to 2009, some parameters of temperatures were significantly correlated with years. The change in parameters of temperatures in Hachijo Island was calmest among 4 areas. The changes in mean temperature in August and in a year in Okayama area for 50 years were the highest (August: 1.55˚C, Year: 2.05˚C) among 4 areas. In addition, correlation coefficient rate between years and the number of days over 35˚C in August in Okayama area was highest (r = 0.407, p = 0.0037). Parameters of temperatures were gradually increased with years in Okayama area, especially in recent years. However, those associations were not clearly noted in Hachijo Island. In conclusion, global warming in Okayama might be accelerated more rapidly than that in Tokyo area in recent 50 years.

Keywords: Temperature, Global Warming, Urbanization, Okayama Area

1. Introduction

Global warming has become a serious issue for human beings. The Fourth report of the Intergovernmental Panel on Climate Change (IPCC) at 2007 on climate change has forecast that global warming will have a major impact on health conditions [1]. Global average temperatures are projected to increase between 1.8 and 4.0 °C by the end of 21st century [1]. Heat waves such as Shanghai in 1998 and Paris in 2003 may be representative of the increases in short-term climate change events [2-5]. It has also reported that the levels of atmospheric CO_2 concentrations are increasing since the last century [6,7]. In addition, global warming has accelerated, and changes in temperatures were remarkably noted since the 1980s, resulting in increased numbers of heat related disorder in summer [8,9].

Most cities show a large heat island phenomenon, registering 5-11˚C warmer than surrounding rural areas [10]. On local and regional scales, changes in land cover can sometimes exacerbate the effect of greenhouse-gas-induced warming, or even exert the largest impact on climatic conditions.

We have also previously reported that higher temperatures were closely linked to higher ambulance transports in Okayama area, Japan [11]. However, accurate analysis of warming, whether temperature is actually increasing in Okayama area and what affects this will have, remain to be investigated.

The aim of this study was to investigate the current status of global warming in Okayama. In addition, we compared various parameters of temperatures between various areas from the viewpoint of the heat island effects.

2. Methods

2.1. Study Area

Okayama area in Okayama Prefecture is on the southern

shore of Honshu Island. The population of 700 000 people is situated on Okayama area. Currently several public offices of Chugoku district are located in Okayama area. Although the surrounds of Okayama area had been used primarily as paddy fields for agriculture, recently they have undergone rapid changes, developing into residential and/or commercial areas (**Figure 1**).

We selected three areas, Tokyo as the city part area, and Tsuyama or Hachijo Island as the provinces, for the analysis in comparison with Okayama city, Japan.

Tsuyama area in Okayama prefecture is on the central of Chugoku area, Japan. The population of 110 000 people is situated on the Tsuyama area. Tsuyama area had been used primarily as paddy fields for agriculture compared to Okayama area (**Figure 1**).

Tokyo area is the largest metropolitan area in Japan and its population is about 13.0 million. Tokyo central (8.8 million population, 621 km^2) is located in the center of the metropolitan area, and is mostly urbanized in Japan (**Figure 1**).

Hachijo Island (65.52 km^2) is located at the south from Tokyo area (287 km) and the population of 9 000 people is situated on the Hachijo Island. Island is affected by the Kuroshio Current (in an oceanic climate zone) (**Figure 1**).

2.2. Temperatures

Daily, monthly and annual temperatures in Okayama, Tsuyama, Tokyo area and Hachijo Island in Japan for the required periods were obtained from Japan Meteorological Agency (http://www.data.jma.go.jp/obd/stats/etrn/index.php, accessed 27 Jan, 2010). Mean temperature in Au-
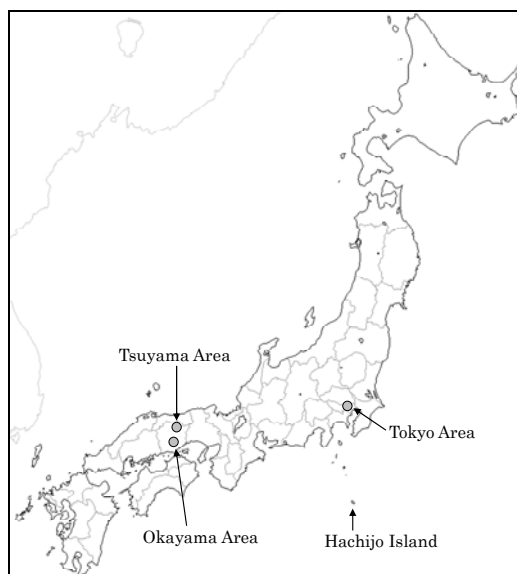
Figure 1. Four study areas in Japan. (Craft Map: http://www.craftmap.box-i.net/map.php, accessed 6 Aug, 2010).

gust, mean temperature in a year, mean of the highest temperatures in August, mean of the highest temperatures in a year, mean of the lowest temperatures in August and mean of the lowest temperatures in a year (Okayama area: 1891~2009, Tsuyama area: 1943~2009, Tokyo area: 1876~2009, Hachijo Island: 1907~2009). The number of days over the level of various temperatures in August was also used for analysis (1961~2009).

2.3. Statistical Analysis

Pearson's correlation analysis by using Statistical Package of SPSS 12.0J for Windows was performed to examine the significance of the linear relationship among continuous variables: $p < 0.05$ was considered to be statistically significant. In addition, joinpoint regression program (National Cancer Institute Joinpoint regression program, version 3.4.3, http://srab.cancer.gov/joinpoint/, accessed 18 August, 2010) was also used to investigated the where the different lines of temperatures are connected together.

3. Results

Simple correlation analysis by Pearson's correlation between years and parameters of temperatures in 4 areas is summarized in **Table 1**. All parameters of temperatures in Okayama area (1891~2009) were significantly correlated with years. Tokyo area (1876~2009) also showed significant relationship between various parameters of temperatures and years (**Table 1**). In Tsuyama area, some parameters of temperatures *i.e.* mean temperature in a year, mean of the highest temperatures in a year and mean of the lowest temperatures in a year was significantly correlated with years.

To adjust the observation period, by using data from 1943 to 2009, we also analyzed the relationship between various parameters of temperatures and years in 4 areas (**Table 2**). In Okayama area, all parameters except mean of the highest temperatures in August, were also correlated with years. Mean temperature in a year, mean of the highest temperatures in a year and mean of the lowest temperatures in a year were significantly correlated with years in Tsuyama and Tokyo areas. Mean of the lowest temperatures in August in Tokyo areas was also correlated with years. However, no parameters were correlated with years in Hachijo Island.

Correlation coefficients between various parameters of temperatures and years in Okayama area were the highest among 4 areas. From single regression line, positive change in mean temperature for 50 years was corresponded to 2.05°C in Okayama area, Japan (**Table 2**). However, the change in temperatures was the lowest in Hachijo Island among 4 areas. In addition, using single regression line in **Tables 1** and **2**, positive changes in temperatures

for 50 years in **Table 2** were higher than those in **Table 1** in Okayama area. Therefore, positive changes in temperatures for 50 years were accelerated in Okayama area. In Tokyo areas, positive changes in mean temperature in a year and mean of the lowest temperatures in a year were also accelerated. However, other parameters in Tokyo areas and Hachijo Island were not accelerated. In addition, using joinpoint regression program, we analyzed the point of change in mean temperature in 4 different areas. The point of change in mean temperatures in Tokyo was 1921, that in Okayama was 1973 (**Figure 2**) and that in Tsuyama was 1984. However, the point of change in mean temperature in Hachijo Island was not noted.

Finally, the relationship between the number of days of over various temperatures which seem to be related to heat disorder is pointed out and years was also evaluated (**Table 3**). The number of days of over 33˚C and 35˚C in Okayama area was significantly correlated with years. Especially correlation coefficient between the number of days of over 35˚C and years in Okayama area was the highest ($r = 0.407$, $p = 0.0037$) (**Figure 3**).

Table 1. Simple correlation analysis between years and parameters of temperature in four areas.

	r	p	Single regression line	Changes in temperatures (˚C) for 50 years
Okayama prefecture				
Okayama area (from 1891 to 2009)				
Mean temperature in August	0.416	**< 0.0001**	$y = 0.012x + 3.139$	0.60
Mean temperature in a year	0.648	**< 0.0001**	$y = 0.015x - 14.969$	0.75
Mean of the highest temperatures in August	0.328	**0.0003**	$y = 0.012x + 8.965$	0.60
Mean of the highest temperatures in a year	0.668	**< 0.0001**	$y = 0.012x - 4.023$	0.60
Mean of the lowest temperatures in August	0.518	**< 0.0001**	$y = 0.015x - 6.511$	0.75
Mean of the lowest temperatures in a year	0.580	**< 0.0001**	$y = 0.018x - 24.349$	0.90
Tsuyama area (from 1943 to 2009)				
Mean temperature in August	0.130	0.2939	$y = 0.006x + 14.814$	0.30
Mean temperature in a year	0.458	**< 0.0001**	$y = 0.014x - 13.598$	0.70
Mean of the highest temperatures in August	0.043	0.7299	$y = 0.003x + 25.890$	0.15
Mean of the highest temperatures in a year	0.447	**0.0001**	$y = 0.014x - 8.107$	0.70
Mean of the lowest temperatures in August	0.132	0.2866	$y = 0.005x + 11.671$	0.25
Mean of the lowest temperatures in a year	0.443	**0.0002**	$y = 0.014x - 18.968$	0.70
Tokyo prefecture				
Tokyo area (from 1876 to 2009)				
Mean temperature in August	0.556	**< 0.0001**	$y = 0.018x - 8.853$	0.90
Mean temperature in a year	0.887	**< 0.0001**	$y = 0.025x - 32.904$	1.25
Mean of the highest temperatures in August	0.353	**< 0.0001**	$y = 0.013x + 0.6077$	0.65
Mean of the highest temperatures in a year	0.728	**< 0.0001**	$y = 0.015x - 9.010$	0.75
Mean of the lowest temperatures in August	0.714	**< 0.0001**	$y = 0.025x - 24.606$	1.25
Mean of the lowest temperatures in a year	0.917	**< 0.0001**	$y = 0.033x - 53.700$	1.65
Hachijo island (from 1907 to 2009)				
Mean temperature in August	0.285	**0.0036**	$y = 0.006x + 15.136$	0.30
Mean temperature in a year	0.350	**0.0003**	$y = 0.005x + 7.624$	0.25
Mean of the highest temperature in August	0.249	**0.1111**	$y = 0.007x + 15.819$	0.35
Mean of the highest temperature in a year	0.290	**0.0029**	$y = 0.004x + 12.482$	0.20
Mean of the lowest temperature in August	0.364	**0.0002**	$y = 0.008x + 8.178$	0.40
Mean of the lowest temperature in a year	0.416	**< 0.0001**	$y = 0.008x + 0.379$	0.40

Table 2. Simple correlation analysis between years and parameters of temperatures in four areas from 1943 to 2009.

|	r	p	Single regression line	Changes in temperatures (°C) for 50 years
Okayama prefecture				
Okayama area				
Mean temperature in August	0.554	**< 0.0001**	$y = 0.031x - 33.852$	1.55
Mean temperature in a year	0.833	**< 0.0001**	$y = 0.041x - 65.744$	2.05
Mean of the highest temperatures in August	0.223	0.0701	$y = 0.014x + 4.996$	0.70
Mean of the highest temperatures in a year	0.558	**< 0.0001**	$y = 0.018x - 14.764$	0.90
Mean of the lowest temperatures in August	0.619	**< 0.0001**	$y = 0.035x - 45.840$	1.75
Mean of the lowest temperatures in a year	0.811	**< 0.0001**	$y = 0.053x - 93.859$	2.65
Tsuyama area				
Mean temperature in August	0.130	0.2939	$y = 0.006x + 14.814$	0.30
Mean temperature in a year	0.458	**< 0.0001**	$y = 0.014x - 13.598$	0.70
Mean of the highest temperatures in August	0.043	0.7299	$y = 0.003x + 25.890$	0.15
Mean of the highest temperatures in a year	0.447	**0.0001**	$y = 0.014x - 8.107$	0.70
Mean of the lowest temperatures in August	0.132	0.2866	$y = 0.005x + 11.671$	0.25
Mean of the lowest temperatures in a year	0.443	**0.0002**	$y = 0.014x - 18.968$	0.70
Tokyo prefecture				
Tokyo area				
Mean temperature in August	0.233	0.0581	$y = 0.013x + 0.841$	0.65
Mean temperature in a year	0.825	**< 0.0001**	$y = 0.035x - 52.678$	1.75
Mean of the highest temperatures in August	0.016	0.8956	$y = 0.001x + 33.094$	−0.05
Mean of the highest temperatures in a year	0.426	**0.0003**	$y = 0.013x - 5.960$	0.65
Mean of the lowest temperatures in August	0.396	**0.0009**	$y = 0.022x - 18.966$	1.10
Mean of the lowest temperatures in a year	0.889	**< 0.0001**	$y = 0.048x - 82.257$	2.40
Hachijo island				
Mean temperature in August	0.008	0.9505	$y = 0.002x + 26.121$	0.01
Mean temperature in a year	0.194	0.1152	$y = 0.005x + 9.067$	0.25
Mean of the highest temperature in August	−0.130	0.2938	$y = 0.004x + 38.272$	−0.20
Mean of the highest temperature in a year	0.073	0.5565	$y = 0.002x + 17.722$	0.10
Mean of the lowest temperature in August	0.113	0.3625	$y = 0.004x + 17.188$	0.20
Mean of the lowest temperature in a year	0.153	0.2175	$y = 0.004x + 7.593$	0.20
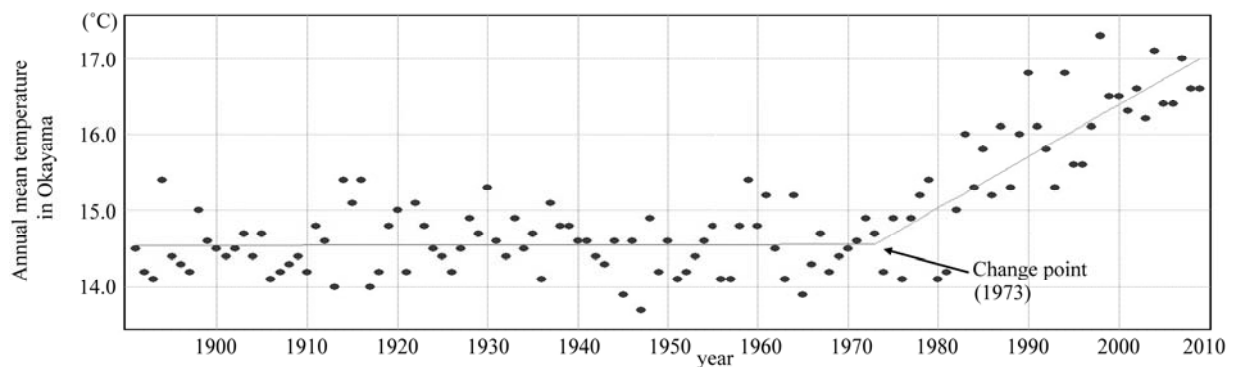
Figure 2. Change point of annual mean temperatures in Okayama, Japan (1891~2009).

Table 3. Simple correlation analysis between years and number of days over various temperatures in August from 1961 to 2009.

	Okayama area		Tsuyama area		Tokyo area		Hachijo island	
	r	p	r	p	r	p	r	p
Number of days over 30˚C	0.071	0.6301	0.053	0.7169	0.016	0.9113	0.118	0.4213
Number of days over 31˚C	0.073	0.6184	0.004	0.9799	0.074	0.6127	0.107	0.4628
Number of days over 32˚C	0.173	0.2346	0.086	0.5552	0.023	0.8731	0.085	0.5637
Number of days over 33˚C	0.343	**0.0159**	0.069	0.6384	0.077	0.5968	0.058	0.6905
Number of days over 34˚C	0.266	0.0643	0.101	0.4917	0.130	0.3748		
Number of days over 35˚C	0.407	**0.0037**	0.000	0.9978	0.125	0.3929		

4. Discussion

We firstly investigated the changes in parameters of temperatures among 4 different urbanization areas such as Okayama, Tsuyama, Tokyo areas and Hachijo Island, Japan. Parameters of temperatures were gradually increased with years in Okayama area, especially in recent years. In addition, the change point of 1973 in mean temperature may be reflected that heat island effect in Okayama area was remarkably accelerated.

According to the research of Osaka in Japan, the mean warming rate in Osaka surface air temperature is about 2.0˚C over the period from 1883 to 2006, at least half of which can be attributed to the urban heat island effects [12]. However, this surface air temperature warming was not as strong as the ground warming recorded in the subsurface temperature profiles. Therefore, the anthropo- genic thermal impacts on the subsurface can be more persistent and profound than the impacts on the atmosphere.

Taniguchi *et al*. reported that subsurface environmental indicators were evaluated from three points of view *i.e.* human activities, climate change, and character of urbanization and social policies. Heat island effect due to urbanization creates subsurface thermal contamination in many cities [13]. Average subsurface temperature profiles in four Asian cities (Tokyo, Osaka, Seoul and Bangkok) were compared and analyzed to evaluate the effects of surface warming [14]. The magnitude of surface warming is evaluated to be the largest in Tokyo (2.8 ˚C), followed by Seoul, Osaka and Bangkok. And this observation showed mean depth of deviation from the regional geothermal gradient in each urban area may be a useful indicator of the history of urbanization. The combination of the heat island effect due to urbanization and global warming on subsurface temperatures also relates to global ground water quality issues. This relationship holds because increased subsurface temper- atures alter the ground water system chemically and microbiologically [15].
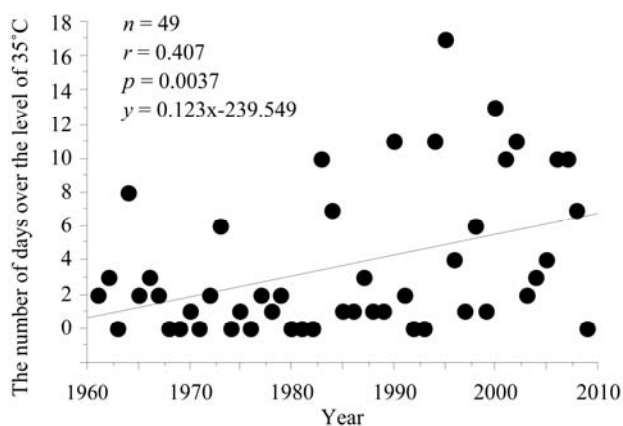

Figure 3. Simple correlation analysis between the number of days over 35˚C and years in Okayama area, Japan (1961~2009).

In some previous reports, the relation between high temperatures and heat stroke in Japan [16-18]. Nakai *et al*. investigated heat-related deaths in Japan from 1968 through 1994 and heat-related deaths were most prone to occur on days with a peak daily temperature above 38˚C [16]. In addition, they reported that incidence of heat-related deaths showed and exponential dependence on the number of hot days [16]. Piver *et al*. reported that heat stroke was associated with prolonged exposures to higher air temperatures that usually occur in the summer months of July and August in 1980-1995 in Tokyo. Residents in Tokyo were also often exposed simultaneously to high concentrations of air pollutants [17]. Qui *et al*. reported that an unusual hot spell in 1999 was followed by a high mortality rate in Hokkaido, Japan [18]. We have also previously showed that higher temperatures were closely linked to ambulance transports in Okayama area, Japan [11].

In this study, we compared points of change in mean temperature among 4 areas, and we found that point of

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change in mean temperature in Tokyo was 1921, that in Okayama was 1973 and that in Tsuyama was in 1984. Therefore, it seems reasonable to suggest that simply dealing with heat island effect in Okayama area *i.e.* innovation of the thermal energy metabolism in cities and individual coping with high temperatures is urgently required in Okayama as well as Tokyo area, Japan. In addition, the point of change in mean temperature may be good parameter of urbanization in Japan.

Potential limitation still remains in this study. The changes in parameters of temperatures, which were noted in 4 areas, may not apply for all areas in Japan. Therefore, we could not accurately evaluate the changes in temperatures in Japan. Further studies are required to prove the changes in temperatures and heat island effect in Japan.

In conclusion, the mean temperature in Okayama area is rising intentionally higher than that in Tokyo area, especially in recent years. The number of days of over 33˚C and 35˚C in only Okayama area was significantly correlated with years.

5. Acknowledgements

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