Evaluation Method of Heat Island Intensity for Coastal Urban Area

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ABSTRACT

This study describes the characteristics of the heat island in coastal cities with monthly mean air temperature in August (2000-2004), sea water temperature in summer period (2000-2004) and the number of population (2000). From the correlation between air temperature of small-scale cities and sea water temperature, a regression expression was found. With this expression, the impact of urbanization was calculated in the subject area. After having analyzed the influence of sea water temperature on air temperature, I have come to the conclusion that a different type of operation is needed for these coastal cities to get right and reasonable environmental information.

Introduction

This study describes the characteristics of the heat island in coastal cities. The degree of a heat island is expressed as heat island intensity (a difference in air temperature between urban and rural). Oke (1973) has shown this index is related to city size. Fukuoka (1983) and Park (1987) demonstrated that population correlates with heat island intensity. On the other hand, I should recall that, in a coastal area, seawater temperature has an influence upon landward air temperature. To evaluate an impact of urbanization on the environment accurately, or to calculate better heat island intensity of coastal cities, we should take account of this influence of seawater temperature. In this article, I suggest a new vision for heat island intensity of cities which located in a coastal area.

Methods

Subject area is the Seto Inland Sea (area: 881.5km2, average depth: 37.3 meters) and its surrounding 41 cities (Table 1, Figure 1). I make a comparison between air temperature and seawater temperature using the following two databases. To make a further consideration related with impact of population, the national census data of 2000 was used.

Table 1: Subject cities in the coastal area and their properties

Rank of poplation	**Name**	**Population** 2003	**Latitude** [decimal degrees]	**Longitude** [decimal degrees]	**Elevation** [meters]
1	Osaka	2,598,774	34.68167	135.51833	23
2	Kobe	1,493,398	34.69667	135.21167	5
3	Hiroshima	1,126,239	34.39833	132.46167	4
4	Sakai	792,018	34.54167	135.50833	30
5	Himeji	478,309	34.83833	134.67000	38
6	Matsuyama	473,379	33.84333	132.77667	32
7	Wakayama	386,551	34.22833	135.16333	14
8	Fukuyama	378,789	34.44667	133.24667	2
9	Takamatsu	332,865	34.31667	134.05333	9
10	Akashi	293,117	34.68667	134.87667	3
11	Shimonoseki	252,389	33.94833	130.92500	3
12	Kure	203,159	34.24000	132.55000	4
13	Niihama	125,537	33.96000	133.28167	6
14	Imabari	117,930	34.07667	132.99000	2
15	Houfu	117,724	34.03000	131.53500	6
16	Iwakuni	105,762	34.15500	132.17833	70
17	Yukuhashi	69,737	33.71167	130.97500	7
18	Tamano	69,567	34.48667	133.95000	2
19	Nakatsu	67,083	3.58500	131.18500	11
20	Kasaoka	59,300	34.50167	133.49500	0
21	Kudamatsu	53,101	34.02167	131.87333	52
22	Kumatori	42,914	34.38667	135.34833	68
23	Sumoto	41,158	34.33833	134.90500	109
24	Mishima	36,832	33.98333	133.56167	27
25	Yanai	33,597	33.95833	132.11333	3
26	Takehara	31,935	34.33000	132.98167	5
27	Otake	31,405	34.22167	132.22000	1
28	Innoshima	28,187	34.29833	133.15667	17
29	Tadotsu	23,657	34.27500	133.75167	4
30	Mushiage	19,501	34.68167	134.20667	10
31	Bungo Takada	18,506	33.57000	131.59000	5
32	Kunimi	13,785	33.67500	131.43333	14
33	Tambara	13,644	33.91167	133.06667	13
34	Utsumi	12,614	34.47167	134.27500	20
35	Nagahama	9,266	33.61667	132.48000	4
36	Gunge	9,233	34.46667	134.84833	5
37	Ieshima	8,978	34.67167	134.52167	88
38	Hikita	8,635	34.21333	134.40667	12
39	Agenoshou	5,902	33.90333	132.29167	5
40	Omishima	4,232	34.24833	132.99333	2
41	Kubi	2,956	34.18167	132.83000	4

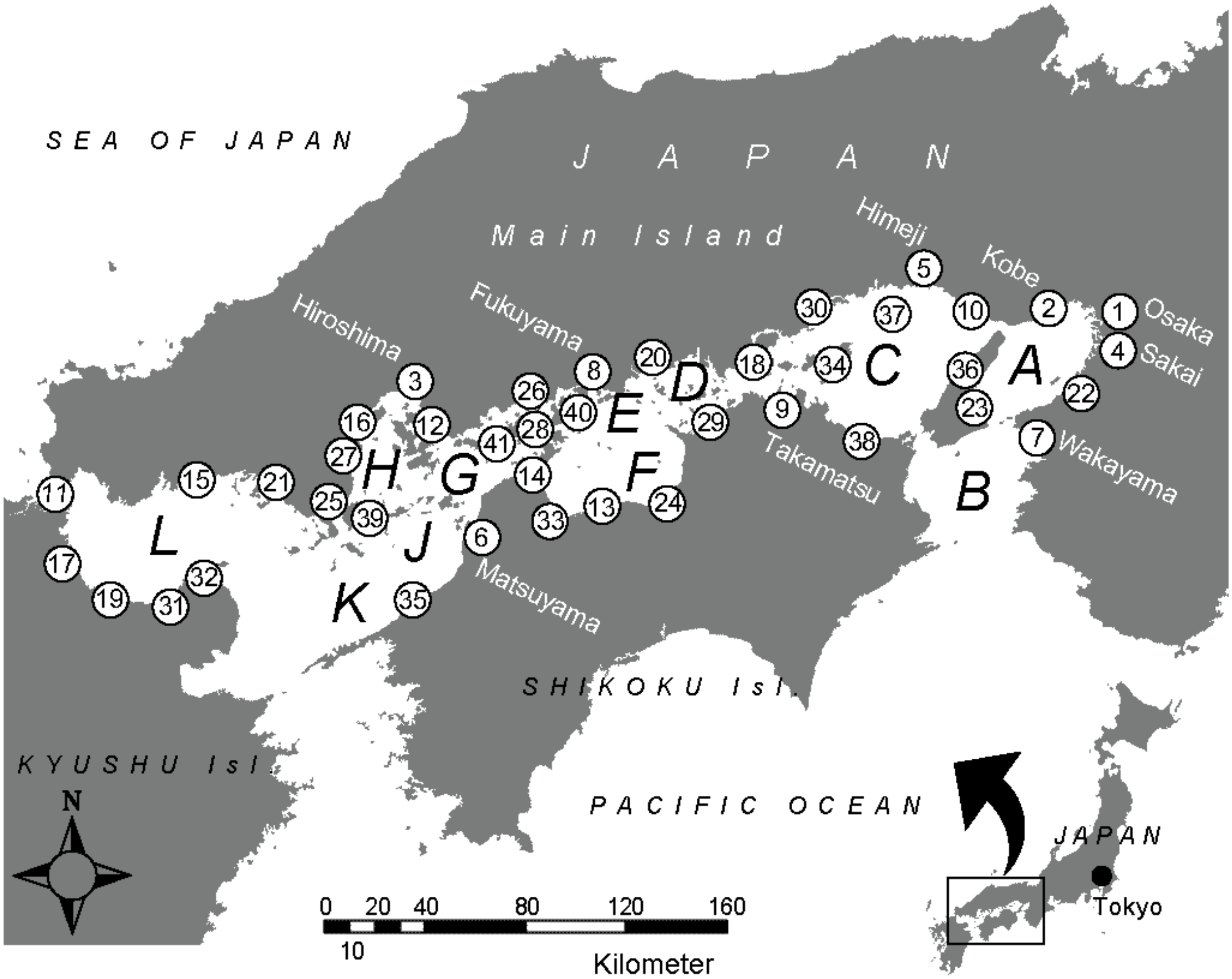

Figure 1: Subject area

(1) Air temperature

The subject cities are located around the Seto Inland Sea, where 41 meteorological telemeters (Automated Meteorological Data Acquisition System; AMeDAS) observe air temperatures. Here, air temperatures measured around the Seto Inland Sea are monthly mean average, monthly mean maximum and monthly mean minimum air temperatures in August (2000-2004 average).

(2) Seawater temperature

Eight garbage ships which belong to Regional Development Bureaus, Ministry of Land, Infrastructure, Transport and Tourism have been measuring the sea water quality in every quarter of a year since 1982. In the summer period, they have measured in July and August. The locations for these measurements are fixed among every investigation. The number of measurement points increased from 179 (2000) to 226 (2003). The seawater temperatures are observed at 2 meters under the sea-level depth.

Results

(1) Seawater temperature in summer

Figure 2 shows the distribution of upper seawater temperatures in summer, 2000-2004 (average).

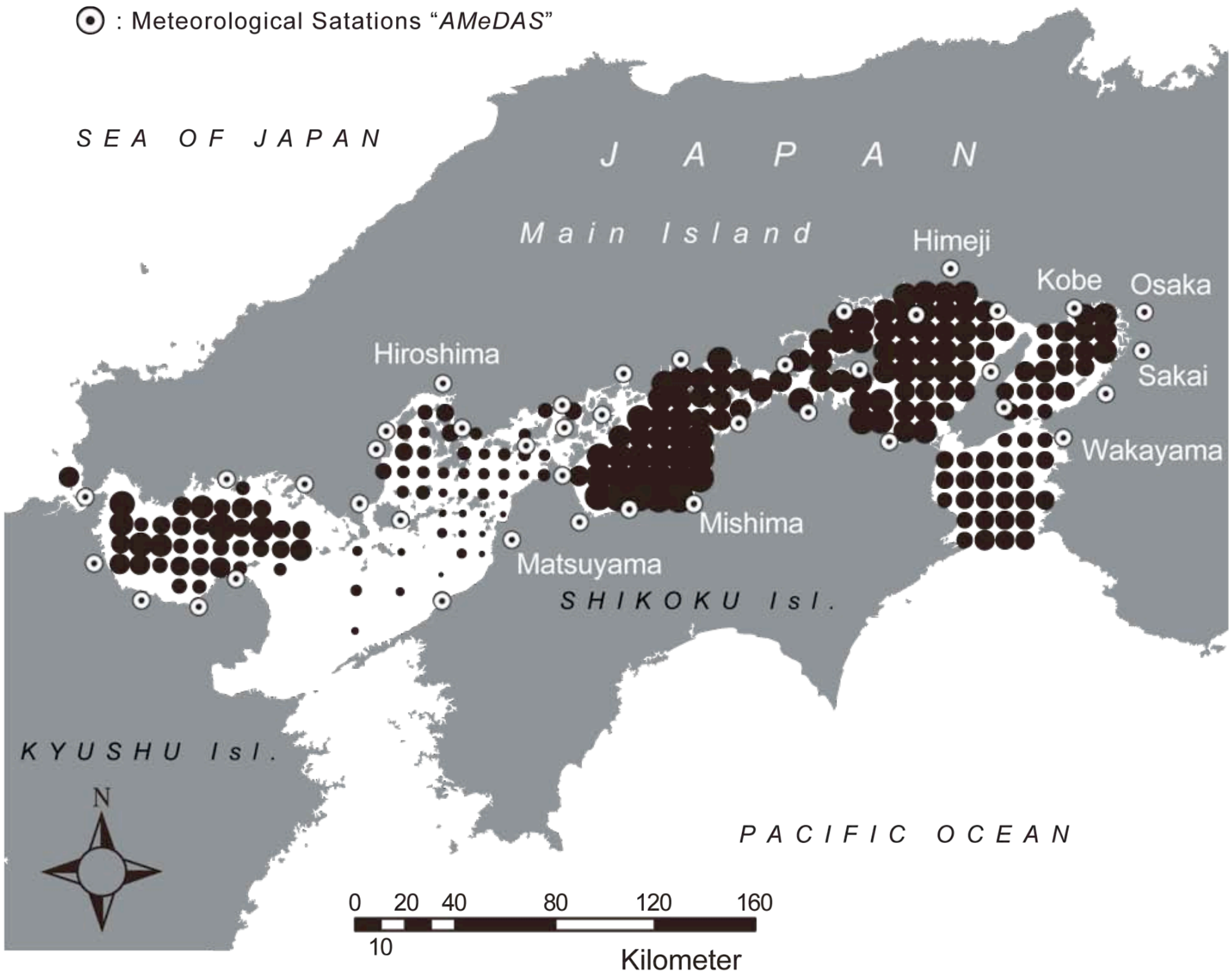

Figure 2: Distribution of seawater temperature

The Seto Inland Sea is divided into eleven parts (see figure 1). Table 2 shows Average, maximum and minimum seawater temperatures in the summer season in the period from 2000 to 2004 in each part of the Seto Inland Sea.

The average seawater temperature was 26.7 degrees centigrade in this period. The highest temperature was 30.0 degrees centigrade recorded in the Osaka Bay ("A" in fig. 1), while the lowest was 22.1 degrees centigrade observed in the northern part of Iyo Nada ("J" in fig. 1). The highest average seawater temperature was observed in Hiuchi Nada ("F" in fig. 1).

Table 2: Seawater temperatures statistics in each part of the Seto Inland Sea

Index	Code	Name of subject cities	Sea water temperature in Summer		
			AVE	MAX	MIN
A	OSK	Osaka Bay	26.5	30.0	24.6
B	KIS	Kii Suido	26.1	27.8	24.6
C	HAR	Harima Nada	27.1	29.4	25.3
D	BS2	Bisan Seto East	27.5	29.2	26.1
E	BS1	Bisan Seto West	27.4	29.5	25.8
F	HIU	Hiuchi Nada	28.0	29.9	24.8
G	AKI	Aki Nada	25.1	27.1	23.8
H	HRS	Hiroshima Bay	25.5	28.1	23.5
J	IY1	Iyo Nada South	24.4	25.2	23.0
K	IY2	Iyo Nada North	23.9	25.1	22.1
L	SUO	Suo Nada	27.5	28.7	25.3

Table 3: Monthly mean air temperatures and seawater temperatures in neighborhood in summer in the period 2000-2004

Rank of population	Name of subject cities	Monthly mean air temperature, August			Mean Seawater temperature, Summer
		Average	Maximum	Minimum	
1	Osaka	28.4	33.0	25.1	27.5
2	Kobe	28.0	31.4	25.4	27.0
3	Hiroshima	27.9	32.1	24.3	26.0
4	Sakai	27.6	32.4	23.5	27.4
5	Himeji	27.1	31.7	23.2	27.5
6	Matsuyama	27.3	31.6	23.8	23.4
7	Wakayama	27.8	32.1	24.3	26.0
8	Fukuyama	27.2	32.0	23.1	27.9
9	Takamatsu	27.4	31.7	23.6	27.6
10	Akashi	27.6	30.7	24.9	27.0
11	Shimonoseki	27.1	30.3	24.8	27.2
12	Kure	27.2	30.8	24.3	26.3
13	Niihama	27.6	31.2	24.4	28.6
14	Imabari	27.0	31.2	23.6	26.7
15	Houfu	26.9	30.5	23.7	26.1
16	Iwakuni	26.2	30.6	22.5	25.7
17	Yukuhashi	26.5	30.2	23.2	26.8
18	Tamano	27.6	30.9	24.9	27.3
19	Nakatsu	26.9	31.1	23.4	26.4
20	Kasaoka	27.7	32.0	23.9	27.4
21	Kudamatsu	26.3	30.6	22.9	26.1
22	Kumatori	26.8	30.6	23.3	26.5
23	Sumoto	26.3	30.3	23.5	26.0
24	Mishima	27.3	30.8	24.1	28.5
25	Yanai	26.8	30.7	23.6	24.5
26	Takehara	26.1	28.9	23.6	25.9
27	Otake	27.2	31.3	23.7	26.0
28	Innoshima	27.0	30.6	23.7	26.7
29	Tadotsu	27.7	32.0	24.2	27.1

30	Mushiage	26.8	30.8	23.5	27.9
31	Bungo Takada	26.7	30.6	23.4	25.4
32	Kunimi	26.5	30.3	23.3	25.5
33	Tambara	26.7	30.4	23.4	28.2
34	Utsumi	26.6	31.1	23.2	27.3
35	Nagahama	25.8	29.0	23.2	23.1
36	Gunge	27.1	30.9	23.8	26.7
37	Ieshima	26.5	30.2	24.0	27.3
38	Hikita	26.6	31.1	23.2	27.4
39	Agenoshou	26.2	29.9	23.1	23.8
40	Omishima	26.7	30.9	23.6	25.6
41	Kubi	26.6	30.9	23.2	25.1

(2) Air temperature in the coastal area

The observed monthly mean air temperatures in August in the period 2000 - 2004 are shown in table 3. The seawater temperatures observed in neighborhood of the 41 meteorological observatories were also shown in table 3. With these data, I make scatter plot diagrams with air temperatures and seawater temperatures. (Figure 2 (a)-(c)) In these figures, the sizes of plotted circles illustrate the population of each telemeter. To each scatter plot diagram was added a regression line by the method of least squares, expression and regression coefficient. It must be noted that this population does not always reflect the surrounding conditions of meteorological telemeters.

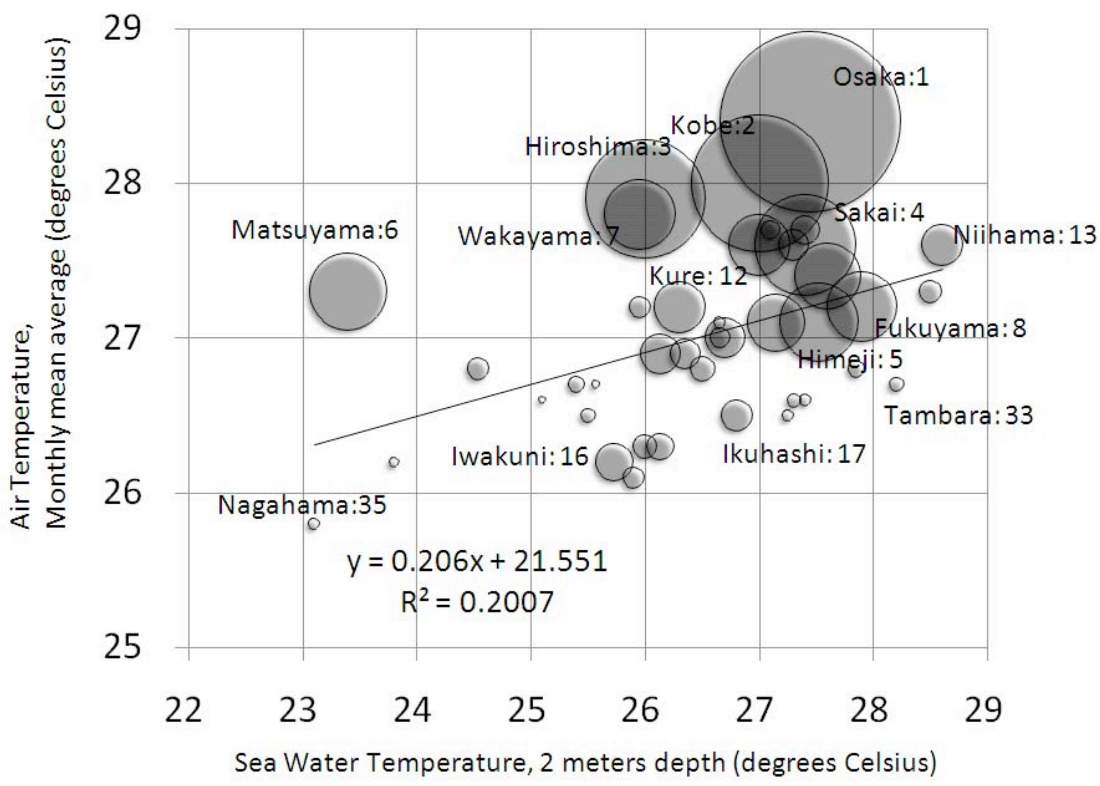

Figure 2 (a): Relation between seawater temperatures and monthly mean air temperatures. August, 2000-2004

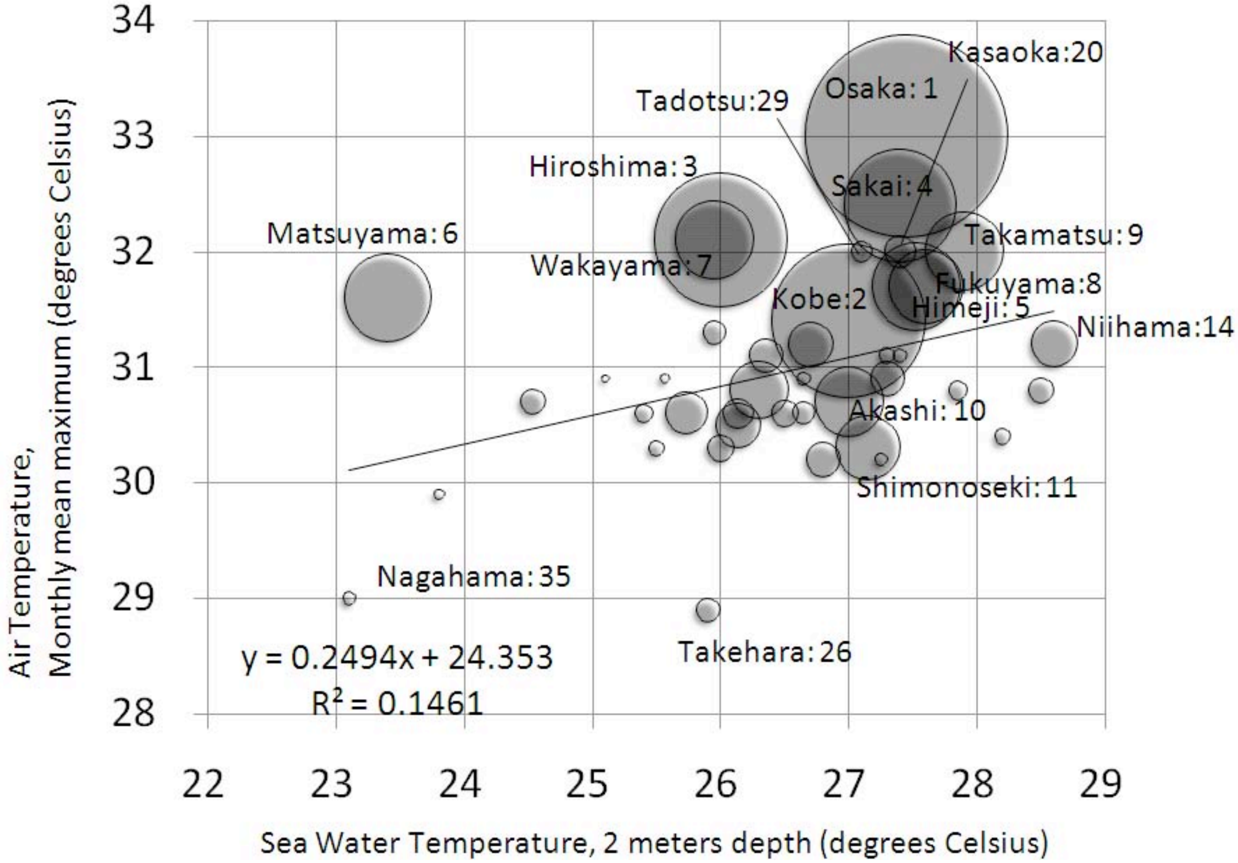

Figure 2 (b): Relation between seawater temperatures and monthly mean maximum air temperatures, August, 2000-2004

Fig. 2 thus shows monthly mean average, high and low air temperatures in August (2000-2004) and mean seawater temperatures in summer (2 meters under sea level, average 2000-2004).

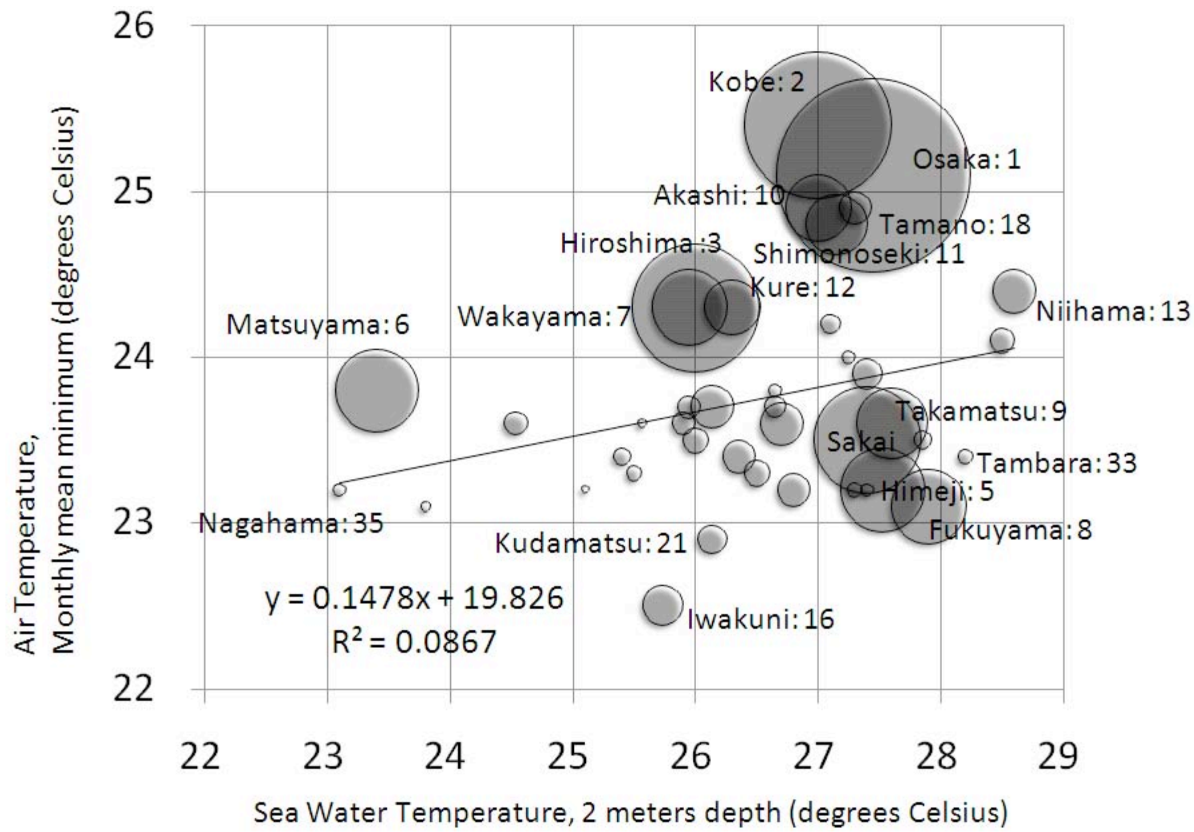

Figure 2 (c): Relation between seawater temperatures and monthly mean minimum air temperatures, August, 2000-2004

Discussion

Generally speaking, determinants of air temperatures are geographical factors such as land coverage, land use or topography except for climatological conditions. In case of coastal land, influences of the sea body are included in the determining factors.

With this operation, the correlation coefficient rose to 0.36. This result is in agreement with preceding studies (e.g. Oke, 1973). Furthermore, in a coastal region, influence of seawater temperature is added to determinants of air temperature. The result is a fitting a set of data points of small cities with a linear function by the method of least squares. In this article, this regression line is assumed as a relation expression between air temperature and seawater temperature in case of no impact of urbanization. I estimated air temperature with this relation using seawater temperature for 41 subject points. Figure 3 shows differential in degree Celsius between estimated air temperature and observed monthly mean average value. Here, the x-axis shows population in a logarithmic scale.

This scatter plot demonstrates 0.39 as a correlation coefficient. This result indicates a not large correlation. It should be remarked, however, that this simple analysis used autonomous population data, which may not illustrate surrounding urban conditions of telemeters, and did not use topographic information.

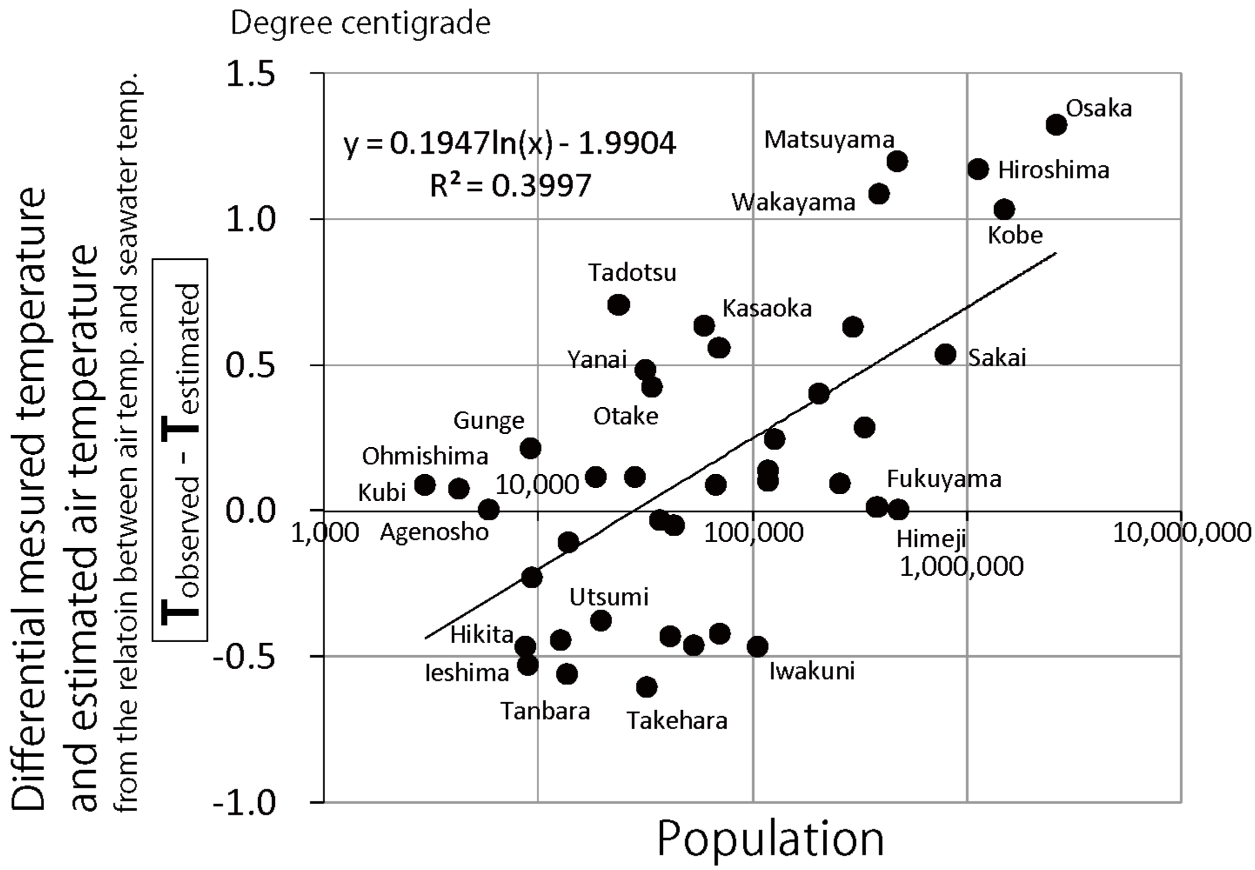

Figure 3: Scatter plot diagram of differential between estimated air temperature and the observed air temperature

In conclusion, circumstances of urban heat island in coastal region should include the influence of seawater temperature. Seawater temperature is a basic thermal or climatological condition for each coastal city. To calculate an urban heat island intensity, the selection where is rural or urban is important, but sometimes this operation may be difficult (e.g. Osaka or Kobe). The method of a relation expression between air temperature and seawater temperature may be used as a substitute for the urban heat island intensity.

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