An Analysis of the Heat Island Phenomenon by Using Arc GIS 9

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Abstract

This study is the result that developed the thermal environment map, which shows the characteristics of the thermal environment in Osaka. At first, the infrared radiation sensor, which was installed in an aircraft, measured the land-surface temperatures in Osaka, 1000km^2 area. Next, the image data that showed the distribution of the land-surface temperatures was analyzed by using Geographic Information System, Arc GIS9. In addition, the characteristics of the thermal environment in the region were clarified by the heat island factors, artificial heat release, land-cover and meteorological conditions.

1. Introduction

As heat island phenomenon has become a serious problem in big cities of Japan, improvement of land-surface and decrease in artificial heat-release are requested. It is necessary for the promotion of measures against heat island that the distribution of land-surface temperatures is clarified and that the suitable measures for regions are selected. However, the actual conditions of land-surface temperature distribution and the characteristics of the thermal load are not yet clarified.

This study was conducted as part of the promotion project for concentrated conduct of the heat island control measures, and the infrared radiation sensor (TABI) installed in an aircraft measured the land-surface temperature within the range of 1000km^2. Then, the Thermal Environment Map was prepared by the analysis of the heat island factors that are not only land-surface temperature, but also artificial heat-release, land-cover, shape of buildings, and so on.

2. Measurement of Land-surface Temperature

2.1 Aerial Measurement

The land-surface temperature covering the priority measures regions shown in “Osaka Prefecture Heat Island Measures Promotion Plan (June, 2004)” was measured with the infrared radiation sensor (TABI) carried by an aircraft. The measurement was taken at nighttime, based on the target set by Osaka Prefecture to reduce the days of 25℃ or more at nighttime, and to decrease the temperature at nighttime. The measurement range is shown in figure 1. The specification of sensor and measurement condition is shown in table 1.

Fig. 1 Measurement Range in Osaka Prefecture

Table. 1 Specification of Sensor and Measurement Condition

Item	Contents
Resolution / FOV (Field of View)	0.1℃ / 48°
Measurement Wavelength / Temperature Range	8 ~ 12 μ m / -20 ~ 110℃
Measurement Day	August 3 and 4, 2005
Measurement Area	About 1000km^2
Measurement Altitude / Resolution	2875m / 8m
Measurement Overlap	40%

21 courses in the direction of north and south were set as the measurement course. The measurement was taken separately in two days from west to east. Then, the course (Course name: X1) in the direction from the west to the east was set because it was necessary to correct the difference of temperature caused by time lag of the measurement.

2.2 Correction between Courses and Atmospheric Correction

The value measured with the aircraft has the error according to time lag of measurement and according to influence of the infrared radiation that is absorbed and scattered in the atmosphere. Therefore, the correction between courses and atmospheric correction were made.

At first, in the correction between courses, the overlap area between course X1 and course in direction of north and south was extracted, and the average of the temperature differences in the overlap area was calculated. Next, the average value was added to or subtracted from the measurement-data of course in the direction of north and south. So, the land surface-temperature in all areas was corrected based on the X1 course temperature data measured at 9:00 pm, August 3. Amount of the correction for each course is shown in table 2. Applying the technique that our company has developed made an atmospheric correction. (T, Nonaka *et al.*, 2005)

Table. 2 Correction Amount of the North-south Course

[Unit : ℃]

Course No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Amount of Correction	−0.39	−0.90	−0.45	−0.50	−0.10	0.50	0.68	0.27	0.31	0.50	0.30	0.33	0.52	0.32	0.11	−0.17	−0.71	−0.55	−0.50	−0.20	0.10

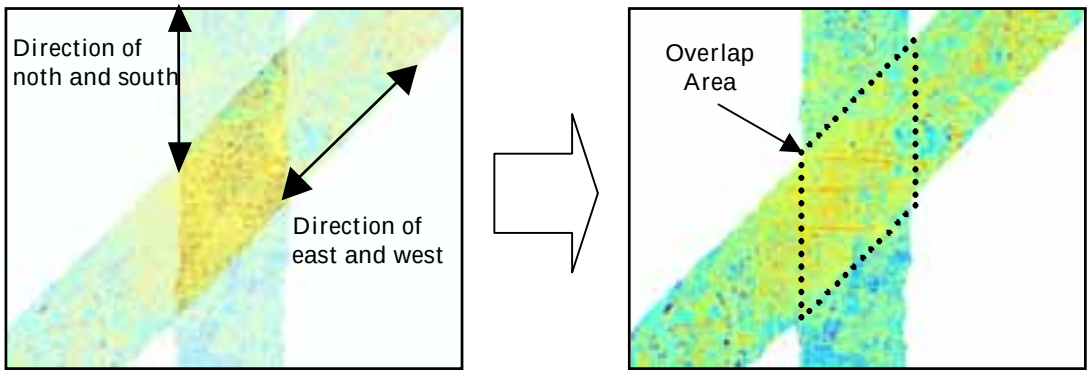


Fig. 2 Image of Correction between Courses

2.3 Measurement Result of Land-surface Temperature

Figure 3 shows the measurement result of land-surface temperature. It was clarified that the land-surface temperature was higher at the central part of Osaka where thermal load was high in daytime. In addition, it was clarified that land-surface temperature in the east and southern region where the residence had clustered was high.

It was confirmed that the difference between the measurement data and the field observation value was about 1℃ to 3℃.

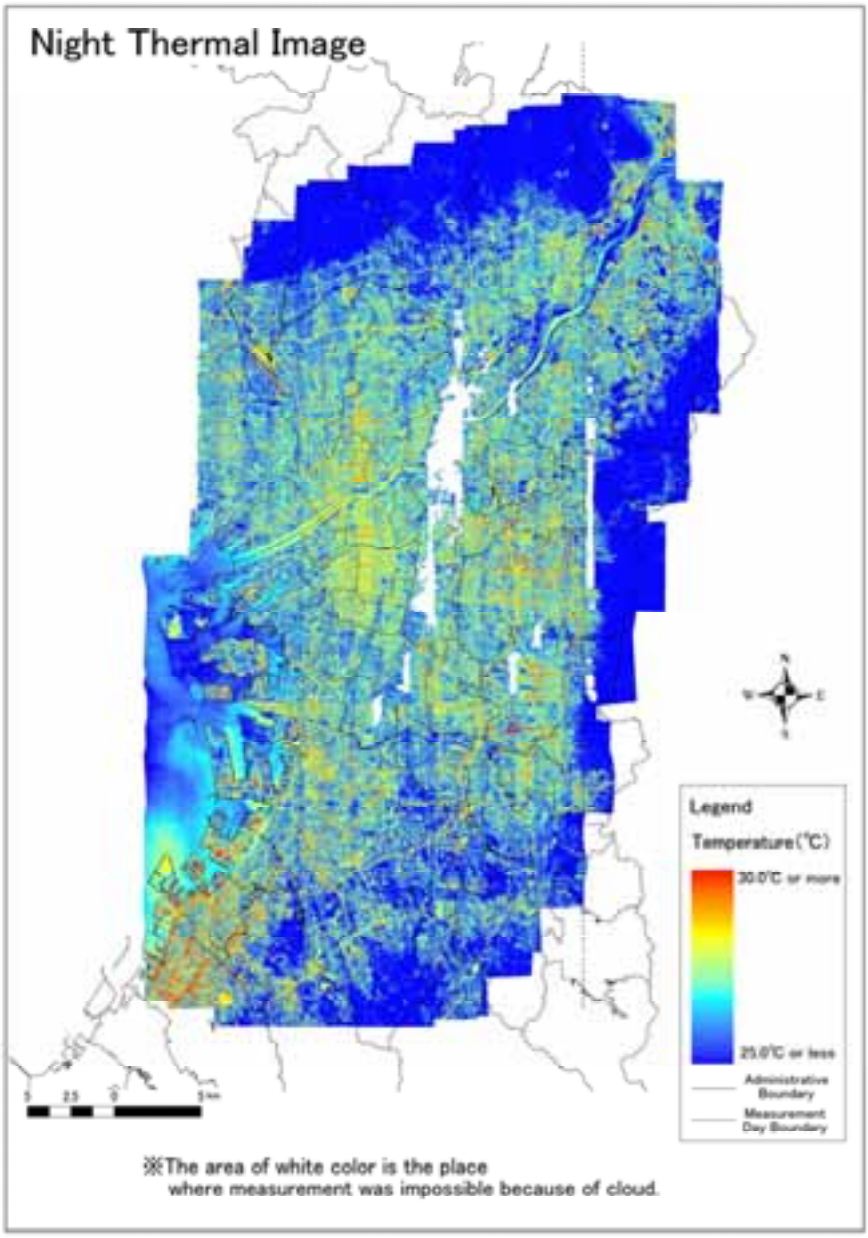


Fig. 3 Measurement Result of Land-surface Temperature

2.4 The Use of Arc GIS 9

In the atmospheric correction, a great deal of thermal image data was processed. Processing by the function of Arc GIS 9 was performed, and efficiency improvement and the speed-up of the work were brought. Figure 4 shows the process.

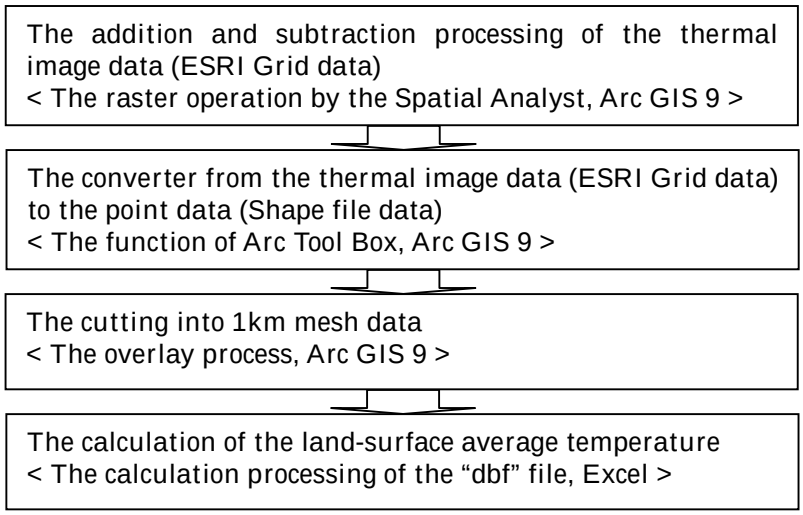


Fig. 4 Processing Flow of the Thermal Image

3. Creating of Thermal Environment Map

3.1 Extraction of the Thermal Load Characteristic

The 1km mesh data shown in table 4 was provided for the purpose of clarifying the characteristic of the thermal load. Table 4 shows the main heat island factors, artificial heat-release, land-cover, shape of building, and use of building. The thermal load characteristic was extracted by applying these data to principal components analysis (PCA). Table 5 shows the result of principal components analysis.

Table. 3 Used Data of 1km Mesh

Heat Island Factors	Used Data	Reference Materials
Artificial Heat Release	Amount of artificial heat release (Sensible heat) (cal/km^2/s)	Osaka Univ. Mizuno office.
Land Cover	Average of land surface temperature (℃)	City planning field survey of Osaka Prefecture & Osaka City
	Parks and green tracts area (m^2)	
	Waters area (m^2)	
	Unutilized lands (m^2)	
	Road area (m^2)	
	Agricultural lands area (m^2)	
	Forests area (m^2)	
Shape of Building	Building Area (m^2)	
	Average number of building stories	
Use of Building	Residential floor space (m^2)	
	Commerce and business floor space (m^2)	

Table. 4 Result of principal components analysis (PCA)

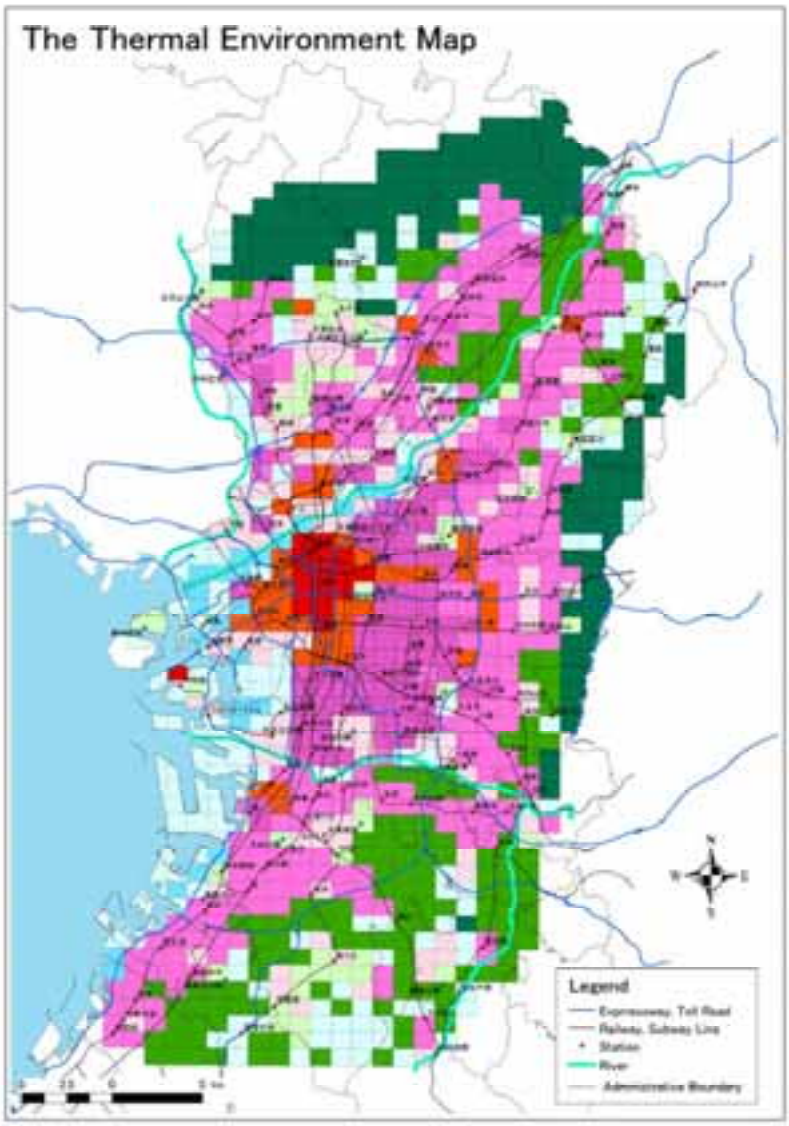
Factors	1st principal component	2nd principal component	3rd principal component	4th principal component	5th principal component
Building Area	**0.898**	−0.274	0.027	0.022	−0.113
Parks and green tracts area	0.176	0.396	0.036	**−0.458**	0.475
Forests area	**−0.646**	0.160	**−0.540**	0.061	−0.185
Residential floor space	**0.848**	−0.335	−0.096	−0.167	−0.060
Commerce and business floor space	**0.615**	0.449	−0.381	0.316	−0.014
Waters area	0.030	0.426	**0.525**	0.251	0.141
Unutilized lands	−0.040	0.446	0.307	**−0.480**	−0.193
Road area	**0.903**	−0.133	0.006	0.053	0.051
Agricultural lands area (	−0.360	−0.238	0.135	0.449	**0.532**
Average number of building stories	**0.666**	**0.522**	−0.302	0.017	0.061
Amount of Artificial heat release, 3:00am (Industry)	**0.850**	−0.265	−0.154	−0.132	−0.049
Amount of Artificial heat release, 3:00am (Industry)	0.062	0.175	0.409	0.287	**−0.607**
Amount of Artificial heat release, 3:00am (Industry)	**0.660**	0.353	−0.110	0.307	0.068
Average of land surface temperature	**0.743**	−0.053	0.480	0.020	0.115
Contribution	**39.0**	**10.9**	**9.7**	**7.4**	**7.2**
Cumulative Contribution	**39.0**	**49.9**	**59.6**	**67.0**	**74.2**

As a result of the principal component analysis, five kinds of principal component that reached the cumulative contribution of 70% or more were extracted. 1st principal component and 2nd principal component show the characteristic that thermal load increases, and 3rd principal component, 4th principal component and 5th principal component show the characteristic that thermal load decreases. These principal components characterized each 1km mesh.

3.2 The Thermal Environment Map

Classifying of the thermal load characteristic by applying these principal components to cluster analysis, created the Thermal Environment Map shown in figure 5.

It grasped that the thermal load characteristic was similar to the urban structure of Osaka prefecture. Then, it clarified that the thermal load became smaller from the center part in Osaka where commerce and business was clustered to the suburbs residential area where extended along railway. The Thermal Environment Map shows following four groups. (Group-1: The area where thermal load level is high /Group-2: The area where thermal load level is high next to Group-1 /Group-3 and Group-4: The area where thermal load level is low)



Group-1 Commercial and Business Cluster Area
- The area where commerce and business have clustered

Group-2 Residential Area
- The area where commercial and business area has mixed with residential area
- The area where residence has clustered
- The area where residence has extended
- The area where residential area has mixed with parks and green tracts area

Group-3 The area where a lot of waters and green tracts exist
- The area where a lot of waters exist
- The area where a lot of unutilized lands exist
- The area where a lot of parks and green tracts exist

Group-4 The area where a lot of agricultural lands and forests exist
- The area where a lot of agricultural lands exist
- The area where a lot of forests exist

Fig. 5 The Thermal Environment Map

4. Assignment

This study clarified the realities of land-surface temperature in the range of 1000km^2, in Osaka prefecture. Then, the Thermal Environment Map was prepared to illustrate the thermal load characteristics in the region. From now on, it is necessary to execute the suitable heat island measures against the characteristic in the region based on these results. Furthermore, promotion of measures against heat island issue requires not only the leadership by the administration but also new framework of partnership of Industry-Government-Academy.

5. Conclusion

In our daily life, we cannot live in disregard of the global environment. The environment is the mirror of human beings, reflecting us in it, as human being and the environment are inseparable. Now we need to change our lifestyle. What is more important is to keep a strong idea in our mind that “Through the individual change, one by one, we should achieve the environmental revolution and global revolution.”

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Reference

T, Nonaka., H, Okada., A, Ozawa., & T, Sasagawa. (2005). Measurement of Land-surface temperature by the infrared radiation sensor (TABI) installed in an aircraft, Japan Society of Photogrammetry and Remote Sensing, Discussion Paper, 161-162, (in Japanese)

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