PREDICTION OF AIR TEMPERATURE DISTRIBUTION IN URBANIZED AREA OF TOKYO, JAPAN USING AIRBORNE THEMAL IMAGES

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1. INTRODUCTION

This study presents a method used for predicting the air temperature distribution in an urbanized area from the surface temperature of trees.

A strong trend of urbanization can be observed whole over the world (United Nations Centre for Human Settlement, 1996). It is well known and documented that urbanization can have significant effects on local weather and climate (Landsberg, 1981). One of these effects is the urban heat island, for which the temperatures of the central urban locations are several degrees higher than those of nearby rural areas of similar elevation. The urban heat island effect has been the subject of numerous studies in recent decades and is exhibited by many major cities around the world.

In order to establish a countermeasure against the urban heat island, it is necessary to understand the feature of the thermal environment, especially, the distribution of air temperature. It is, however, difficult to know the distribution of air temperature for large area through the field measurements. The method to provide the information on the distribution of air temperature for a large area or region would need to be developed for the establishment of sound environmental planning to improve the thermal condition in cities.

It is well stated and reported that the surface temperature of tree is strongly correlated with the ambient air temperature. Using this feature, Murakami (2009) generated air temperature distribution map for a local small city in Japan. The study, however, was implemented in the region where the influences of long wave radiation from the surrounding buildings on the surface temperature of trees could be omitted. In this study, the objective was set to examine the possibility to apply the method developed in Murakami (2009) to highly urbanized area, to acquire the air temperature map of Tokyo through the proposed method, and to discuss the thermal environment of Tokyo using the map.

2. DATA USED IN THE STUDY

Since it is difficult to set the observation time for remote sensing using satellite sensor, we used airborne sensor for the study. The airborne sensor used in the study was TABI-320. This sensor is a sensitive thermal broadband imager and can distinguish temperature differences as small as one-tenth of a degree. TABI-320 incorporates

GPS/INS (Global Positioning Systems/Inertial Navigation Systems). Table 1 shows the specifications of the sensor and the outline of acquired data. The remote sensing data were obtained under clear sky conditions. A series of field measurement on the surface temperature on the ground at the same observation times were conducted, then the remote sensing data were converted to surface temperature using the result of field measurement.

Table 1. The specification of sensor and data

Sensor	TABI-320
FOV	48 degree
IFOV	2.87 mrad
Spectral range	8,000 - 12,000nm
NE ⊿t	0.1 degree
Ground resolution	3.4 m

Date	2004/8/9	19:08
	2004/8/9	20:54
	2004/8/9	22:17
	2004/8/14	12:18

Information about building shapes, uses and materials were collected using scaled (1:2500) GIS data, which was constructed by Tokyo Metropolitan Office.

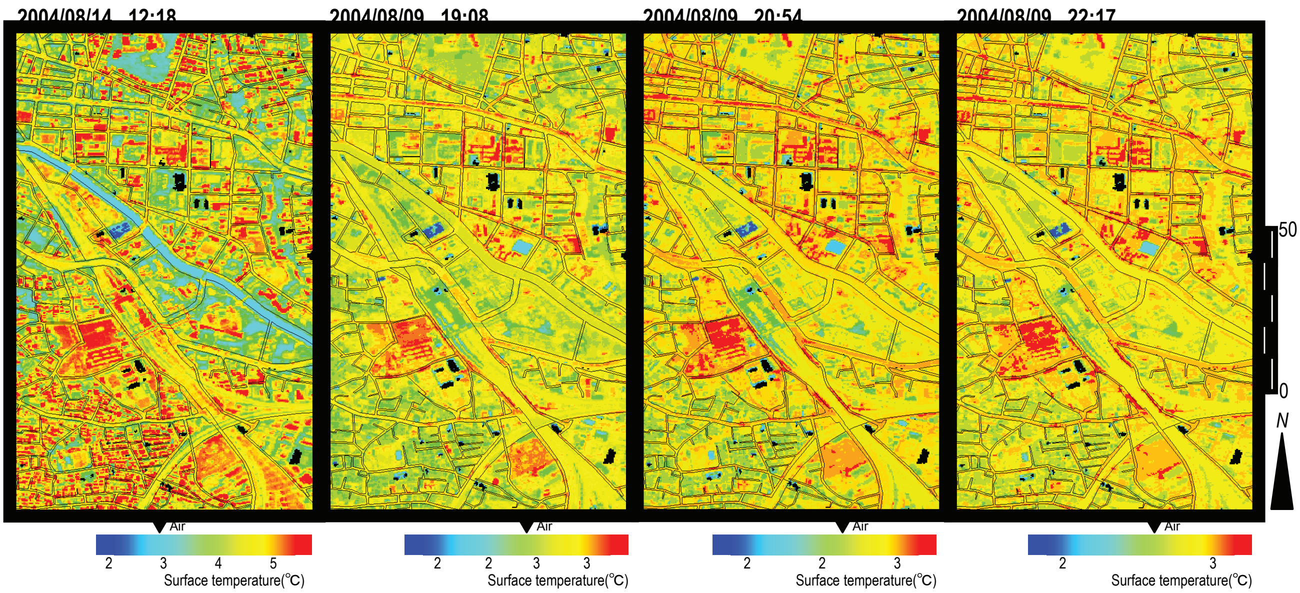

Fig. 1 samples of surface temperature map of Tokyo

3. ACQUIRING AIR TEMPERATURE MAP

Surface energy balance equation on trees can be described as;

$$-\lambda \frac{\partial T}{\partial x} = a_{su}(I_{DR} + \phi_{sky} I_{SR} + I_{RR}) + L$$
$$+ \varepsilon_s \sum_{i=1}^{n} \varepsilon_i \phi_i \sigma T^4 - \varepsilon_s \sigma T_s^4 + H + LE$$

λ: Thermal conductivity (W/mK), T: Temperature (K), x: distance (m), a_{su}: Solar reflectance, I_{DR}: Direct radiation (W/m^2), ϕ : view factor (sky: sky factor), I_{SR}: Diffuse radiation (W/m^2), I_{RR}: Reflected radiation (W/m^2), L: Atmosperic radiation (W/m^2), ε: Emissivity, σ: Stefan-Boltzmann constant (w/m^{2}K^4), inferior a: air, s: surface, H: Sensible heat flux (W/m^2), LE: Latent heat flux (W/m^2)

If the trees were not surrounded by other objectives such as tall buildings, the surface temperatures of treetop during the nighttime would be varied by atmospheric radiation and sensible heat flux. Therefore, the surface temperatures of treetop can't score higher than air temperature.

Although the objectives surrounding tree would influence the surface temperature of tree top, if the sky view factor of tree top is quite low, the influence could be omitted. Through a field investigation on the change of surface temperature of trees and thermal environment surrounding the trees, the threshold of sky view factor was examined. Besides, the result of field survey indicated that heat capacity of leaves was quite small and the surface temperature on the trees can be considered to increase close to the ambient air temperature even with low wind velocity.

NDVI was calculated using the remote sensing data taken in daytime and tree crown area was extracted. Field investigation was implemented to determine the point of tree top on the extracted tree crown area.

The points were taken and the surface temperature of tree top for each point was extracted. The surface temperatures were plotted on the map, then, interpolation was implemented using the values to acquire the air temperature distribution map.

4. THERMAL ENVIRONMENT OF THE TOKYO URBANIZED AREA

The acquired air temperature map indicated that the air temperature around the main artery scores higher than the air temperature inside the blocks. Besides, the area with higher air temperatures spread over the central area's boundary leeward. This means that the air warmed up in the central urbanized area is conveyed by wind leeward.

In this study, the relationship between the treetop's surface temperature and the ambient air temperature was examined and a method to make air temperature map was developed. The method was applied using airborne TIR data for Tokyo, Japan. And the state of the heat island of Tokyo was discussed by the proposed method using remotely sensed data acquired in different times. The result indicated that the air warmed up in the central area were conveyed leeward by the wind.

5. REFERENCES

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