Characterization of Urban Heat Radiation Flux Using Remote Sensing Imagery

Masanobu Nakamura*
Yujiro Hirano*
Shiro Ochi*
Yoshifumi Yasuoka*

*Yasuoka Laboratory Institute of Industrial Science University of Tokyo
Address: 4-6-1 Komaba, Meguro-ku, Tokyo 1 53-8505 Japan
Tel & Fax: +81-3-5452-6417
E-mail: masanobu@iis.u-tokyo.ac.jp

KEY WORDS; thermal stress, surface temperature, and air temperature, heat island

Abstract.
The warming trends in urban area, so called "Heat Island" effect, are growing all over the world and make the urban living condition and environment aggravate. It is important to study this phenomenon and understand the mechanism for the city planning. However, there are few researches from the viewpoint of quantity. Making a distribution map of thermal stress with high spatial resolution has a possibility to make an urban life more comfortable. Terra/ASTER-TIR, the sensor that applied in this study, is the first sensor that has multi spectrum in infrared band, so surface temperature can bemeasured with high accuracy and high resolution. The purpose of this study is to make distribution maps of surface temperature and air temperature those are ones of the most important information for making the thermal stress map. The study area is urban area within 30km from the center of Tokyo, Japan.

1.Introduction

1.1 Background

The phenomenon that the temperature of urban area rises year by year as represented by heat island is now one of the biggest problems for us, just as global warming is fatal. The cause of such a phenomenon is distributed in two major components. One factor is the change of land cover. Vegetation and water area that play an important role in alleviating the rise of air temperature are decreasing and artificial land covers that have high heat capacity are increasing like asphalt and concrete. Another factor is the increase of artificial heat emission. Especially the emission from automobile and artificial cooling has been increasing recently. Now, there are lots of studies dealing with these topics, but the studies from the viewpoint of quantity are not enough.

To make a heat radiation map is considered very useful in order to make the urban life more comfortable. But for making such a distribution map only from the ground truth data, plenty of data must be gathered and it must cost very much. And even if it is possible, the spatial resolution of map is not so good. By applying the method developed in our study to make surface temperatures map from remote sensing data, high-resolution distribution map can be made. ASTER/TIR can detect surface temperature with high accuracy, because it has multi spectrum in infrared band. So surface temperature and emissivity can be measuredseparately. Therefore, applying ASTER-TIR is considered ver y useful.

The thermal stress from land surface is distributed in to two components, surface emission (long wave) and sensible heat. The surface emission is given by using radiance of ASTER/TIR images on the ground that radiance acquired from remote sensing images consists of surface radiance for the most part. On the contrary, the calculation of sensible heat is complicated. In general, the formula to give the sensible heat (V) is as follows.

$$V = \alpha_c(\theta_o - \theta_a)$$

Where: α_c =Convective heat transfer rate, θ_o =Surface temperature, θ_a =Air temperature

(α_c is mainly determined by land covering and wind velocity)

It is known that the sensible heat is in proportion to the difference between surface temperature and air temperature. Therefore, to make distribution maps of surface temperature and air temperature are indispensable for sensible heat. In addition, making these maps is considered significant in calculating the latent heat, which controls the rise of temperature.

1.2 Objective

In this paper, we focused on the mapping of surface temperature and air temperature with medium resolution sensors which can be applied to make a distribution map of surface emission and sensible heat. The spatial resolution of ASTER/TIR is 90m, so the distribution of air temperature should be given with nearly same resolution.

2. Data and test sight

2.1 Study area

The study area covering 30km×30km (one granule of Terra/ASTER) is in the city of Tokyo, at 35-36° N and 139-140° E, and characterized by average temperature ranging from 5°C in winter to 29°C in summer of 2001. This sight is determined because this area is heavily affected by heat and there are a lot of ground truth data. Heat island phenomenon in this area is often reported to all over the world.

The circumstances of Tokyo are as follows. Accumulated hours when the temperature scored higher than 30°C in a year is increasing year by year, except for some years(Fig.1-a). The count of sultry night a year is correspondingly increasing (Fig1-b).

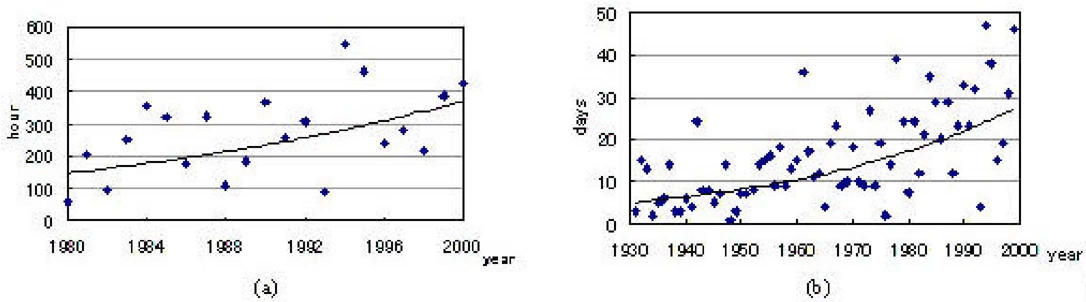


Fig 1 Heat environment of Tokyo (a) accumulated hours when temperature scored higher than 30° (b) accumulated days of sultry night)

2.2 Data set

The satellite data of Terra/ASTER from January 2000 to September 2002 were used. ASTER/TIR can detect surface temperature with high accuracy (Kato et al. 2002). Ground truth data such as air temperature, wind velocity, humidity can be obtained from the Metrological Office.

Table 1 ASTER/TIR

Number	wave length	rez of weve length
Band10	8.125-8.475μm	0.35μm
Band11	8.475-8.825μm	0.35μm
Band12	8.925-9.275μm	0.35μm
Band13	10.25-10.95μm	0.70μm
Band14	10.95-11.65μm	0.70μm

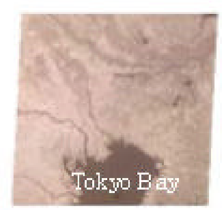


Fig 2 TIR image of study area

3.Methodology

3.1 Surface temperature

The infrared sensors are available in other sensors like Terra/MODIS or Landsat/ETM+. But those sensors have a common problem: E-T separation. It means that the equation expressed as below has two variables, temperature and emissivity, and it is considered complex to solve it.

$$T = \frac{hc/k}{\lambda \ln\left(\frac{2hc^2}{(L_\lambda/\varepsilon_\lambda)\lambda^5}+1\right)}$$

Where: T = Surface temperature, h = Planck constant, k = Boltzmann constant, λ = wavelength, L_λ = spectral radiance, ε_λ = spectral emissivity

In this study ASTER/TIR is considered appropriate to make a surface temperature map, because it has multi spectrum in infrared band, so surface temperature and emissivity can be solved independently.

Figure3 (a) is the data of daytime-10 August 2002. The range of land surface temperature is from 25°C to 45 ℃ mostly. High temperature area is located in northern-east of this picture, (Saitama prefecture). At night scene figure3 (b), high temperature area emerges in the center of Tokyo, that is to say, heat island phenomenon occurs. The range of land surface temperature is from 20°C to 26°C mostly, and the difference between land and sea is not prominent. The circled areas in figure3 (b) are Ikebukuro, Shinjuku, and Shibuya from up to down. These are the main areas in Tokyo. Some area of the land has noise because of clouds.

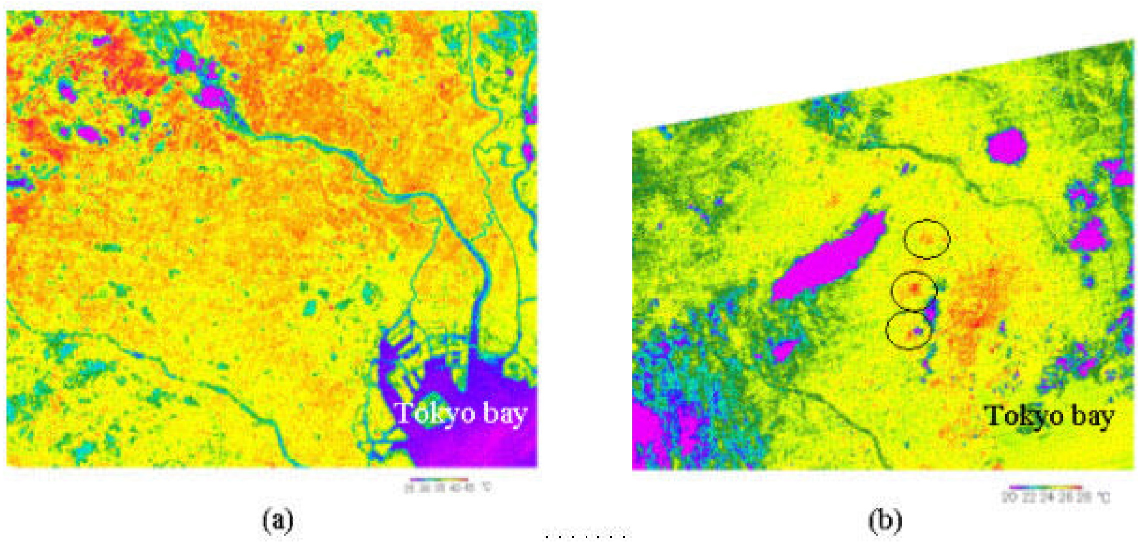
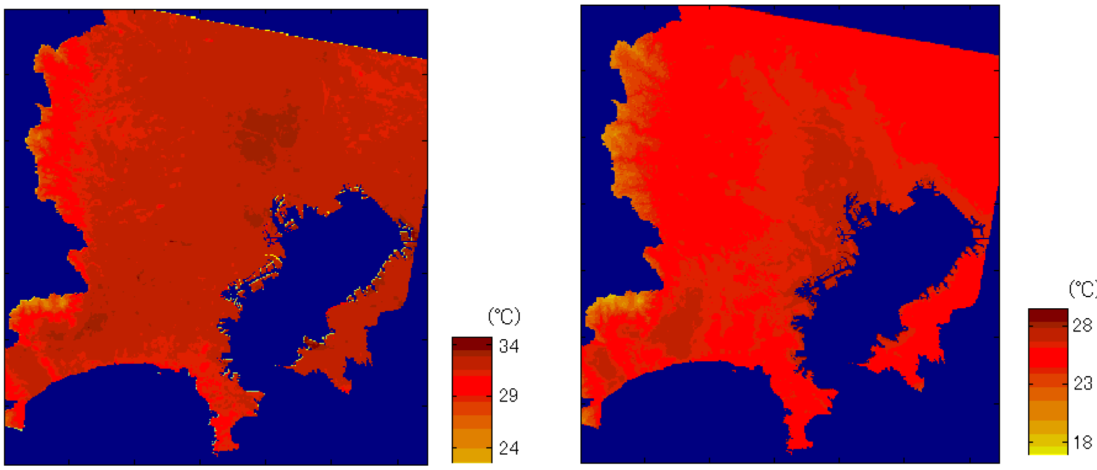


Fig 2 Surface temperature ((a) 2002/8/10 10: 43, JST (b) 2002/7/16 21: 40, JST)

3.2 Air temperature

Air temperature map must be made with hig h resolution in order to utilize the surface temperature map. Air Temperature is affected by many factors such as the ocean, land cover and topography. In order to estimate the contribution of the each factor statistically, multi-regression analysis is applied in Kanto area (Hirano and Kaya, 1998). In this method, geographical data such as land use, the distance from sea, and land features is applied as an explainable variable and the air temperature is applied as an explained variable (Table2). As the result, the monthly and hourly average temperature in Kanto area is calculated with 300m spatial resolutions. This data can be fundamental information of this area's temperature

In this study, the distribution of air temperature is calculated by interpolating the residual between the multi-regression data and actual measurement data to multi -regression data.



(a) (b)

Fig 3 The distribution of air temperature ((a) 2002/8/10 10: 43, JST (b) 2002/7/16 21: 40, JST)

Table 1 Used parameters

	Variable	
a	Latitude	
b	Longitude	
c	Slope	*
d	Geological Laplacian	*
e	Distance from coastline	*
f	Distance from Sagami Bay	*
g	Distance from Tokyo Bay(west)	*
h	Distance from Tokyo Bay(east)	*
I	NDVI	
j	Ratio of artificial coverage	*
k	Ratio of farmland coverage	*
l	Ratio of green coverage	*

*: Variables finally applied in this study

4.Conclusions and future works

It is confirmed that distribution maps of surface temperature and air temperature that have similar high resolution can be made by using medium-resolution ASTER data and ground truth data. After adjusting these two maps, the value of convective heat transfer rate must be multiplied. It is known that this value can be determined mainly from wind velocity and land covers, but it is very complicated to get the data. So, the method to determine this value with simple procedure but more considerable accuracy must be considered in future works.

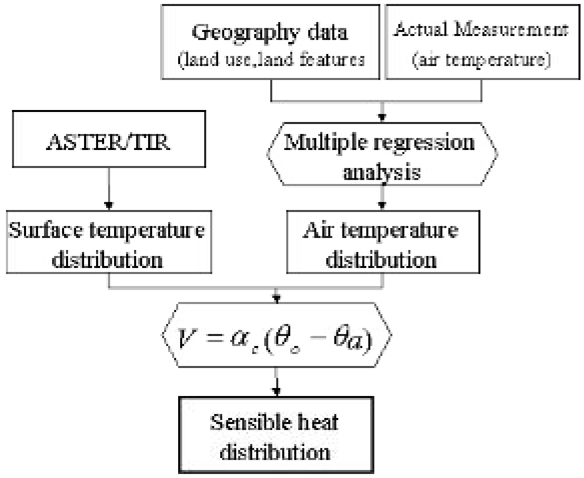


Fig 4 The flow to make a sensible heat distribution

5. Acknowledgement

We are grateful to ACT-JST "Research and Development for Applying Advanced Computational Science and Technology" of Japan Science and Technology Corporation for their support.

6. References

[1] Yujiro HIRANO, Toshiaki. I and Yoichi. K, “Estimation of Temperature Distribution and Its Application to Evaluate of Urban Thermal Environment in Tokyo”, Environmental Engineering Research, Vol.36, 1999

[2] Yujiro HIRANO and Yoichi KAYA, “An Analysis of the Spatio-Temporal Structure of Urban Air Temperature In the Southern Part of Kanto Plain”, Theory and Applications of GIS, 1998, Vol.6 No.2, pp.1-10