Estimating the Heat Island Development Using Landsat TM and AMeDAS Data

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Abstract: In the present investigation, an estimation of the growth of heat island development of Tokyo metropolis which accounts nearly 100 sq. km of areal spread has been carried out. Band 6 data of LANDSAT TM (Thematic Mapper) data acquired on August 1984 and 1994 have been used for estimating the expansion of the heat island development. Since the vegetation decrease is usually associated with the heat island development, a ratio of green covering has also been assessed using TM data. In order to establish the relationship with the air temperature, AMeDAS(Automated Meteorological Data Acquisition System) data have been correlated.
Keywords: Heat Island, Tokyo Metropolis, Landsat TM, AMeDAS

1. Introduction

The urbanization around the center of Tokyo progressed with the increase of population in the center of Tokyo. The housing development and city traffic developed the suburbs which were an agricultural area changed to urbanization for the use bubble term to which land and the stock soared around 1985. The range of the Tokyo metropolis already amounts to about 100 sq. km, and many cities exist also on the outskirts in the center of Tokyo. The effects of vegetation density on the surface temperatures in the urban and suburban areas of Tokyo Metropolis on clear winter days are examined[1]. Regarding the temperature of a city or its circumference area as spatial information, just the observation to which the city central part and the suburban part were restricted is inadequate. The remote sensing which has wide area nature, simultaneity, periodicity, and economical efficiency is the best tool to grasp the temperature information for such a wide area. Then, in order to investigate the actual condition, change of a spatial heat island has been estimated using Landsat TM heat infrared data of 2 stages of 1984 and 1994 which is compared with the bubble term, and this research considered the influence a city change has affected temperature from ratio of green covering and AMeDAS data.

2. Data

1) Satellite Data

Landsat TM data of the Kanto scene is shown in Table 1.

Table 1. Used Satellite Data

Landsat TM Data		
Date	JST	Scene
August 14,1984	21:00	Path :205/Row :209
August 10,1994	20:48	
July 31,1984	9:45	Path :107/Row :35
July 19,1997	9:46	
Novemver 04,1984	9:45	
Novemver 19,1995	9:15	
February 14,1987	9:36	
February 23,1996	9:21	

2) Study Area and AMeDAS Data

AMeDAS started operation from 1974 and there are about 1300 observation points (about 17km interval) which observe precipitation in all parts of Japan now. Among these, in addition to precipitation, in 850 places (about 20km interval), the temperature, wind direction, wind speed, and daylight hours are observed. This research made use of observational region of the AMeDAS observation point covering the area of TM thermal image(Table 1) of the study area for the nighttime, scenes of Tokyo, Saitama Prefecture, Chiba Prefecture, and Kanagawa Prefecture (Table 2), and used the AMeDAS temperature data for 11 years from 1984 to 1994.

Table 2. Observation Point of AMeDAS which Analyzed

observatory	latitude	longtitude	altitude[m]
Kumagaya	36 ° 068 ′	139 ° 23.0 ′	30
Kuki	36 ° 050 ′	139 ° 38.4 ′	12
Hatoyama	35 ° 582 ′	139 ° 15.4 ′	44
Urawa	35 ° 524 ′	139 ° 35.4 ′	8
Koshigaya	35 ° 534 ′	139 ° 47.6 ′	5
Tokorozawa	35 ° 462 ′	139 ° 25.0 ′	119
Ome	35 ° 472 ′	139 ° 19.0 ′	155
Nerima	35 ° 440 ′	139 ° 40.2 ′	38
Hachioji	35 ° 398 ′	139 ° 19.2 ′	123
Fuchu	35 ° 409 ′	139 ° 29.2 ′	58
Tokyo	35 ° 412 ′	139 ° 45.9 ′	7
Sinkiba	35 ° 380 ′	139 ° 50.5 ′	6
Abko	35 ° 525 ′	140 ° 02.0 ′	20
Funabashi	35 ° 437 ′	139 ° 59.8 ′	24
Chiba	35 ° 360 ′	140 ° 06.4 ′	4
Kisarazu	35 ° 225 ′	139 ° 55.3 ′	5
Ebina	35 ° 260 ′	139 ° 23.2 ′	18
Yokohama	35 ° 262 ′	139 ° 39.4 ′	39

3. Method

1) Change of a Brightness Temperature Distribution

Heat islands of the cities in the Kanto Plain are recognized in Landsat TM thermal band on 14 August 1984[2]. According to Landsat TM thermal band on 10 August 1994, it is found that each city region is expanded. However, DN value changes with the states of performance degradation of a sensor or the atmosphere, the earth surface of 2 stages that a heat island phenomenon cannot be compared in the absolute value of temperature. When change of a spatial heat island had been grasped and the difference of DN value of 2 stages was noticed the development of heat island of this region bears high significance.

2) Relationship between Ratio of Green Covering and Air Temperature

The NDVI is generated from TM data as in eq.(1)

$$NDVI = (\tilde{n}^{NIR} - \tilde{n}^{Red})/(\tilde{n}^{NIR} + \tilde{n}^{Red}) \quad (1)$$

Where $\tilde{n}^{NIR}$ and $\tilde{n}^{Red}$ are, respectively, the reflectances in the near-infrared band 4 and red band 3. In this research, the vegetation region was defined as in eq.(2), and the vegetation region was extracted from TM data (Table 1) of daytime.

$$0.1<NDVI<1 \quad (2)$$

There exists a negative correlation between the amount of vegetation, and the remotely sensed surface temperature, and showed that the remotely sensed surface temperature was large in the area where few amounts of vegetation are observed[2]. The correlation of the remotely observed brightness temperature and air temperature is found to be high[3]. It is thought that the amount of vegetation and air temperature also have a good correlation to each other.

Subsequently, the ratio of green covering was estimated for regions around AMeDAS observatories (table 2) for 4 sq. km using TM data of daytime. TM data of daytime and the AMeDAS data of the same year were used for the annual mean value of the daily maximum temperature, the daily minimum temperature, and at 9 p.m. temperature of a summer, autumn, and winter. The winter records are from December, the next year January, February and March, and that of summer in June, July, August and September, and of autumn in October and November. Next, the relations between ratio of green covering of TM data corresponding to the season and the annual mean value of the daily maximum temperature, the daily minimum temperature, and at 9 p.m. temperature of each season, were investigated(Fig. 2,3, and 4).

4. Results ＆ Discussions

1) Change of a Brightness Temperature Distribution

The difference in the brightness temperature obtained from TM/band6 of 14 August 1984 and 10 August 1994 night was shown in Fig. 1. The outskirts of Tokyo (Otemachi) which is the center of the central Tokyo, and the outskirts of Yokohama of the Kanagawa Prefecture eastern part have a small change of brightness temperature. However, it is clear that change of brightness temperature is large in the area around Hachioji and Fuchu in western Tokyo, in the area of circumference of Koshigaya, Urawa of Saitama Prefecture, and Funabashi of Chiba Prefecture. Urbanization has progressed from this in the suburbs and it has grasped spatially that the heat island is expanded in a suburb from center of Tokyo.

Fig.1 Distribution of Brightness Difference of Temperature at about 9 p.m. on 14 August 1984 and 10 August 1994

2) Relationship between Ratio of Green Covering

and Air Temperature

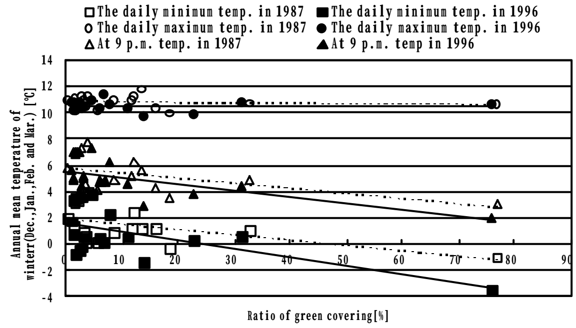

Fig.2 Relation between Ratio of Green Covering and Air Temperature of Winter

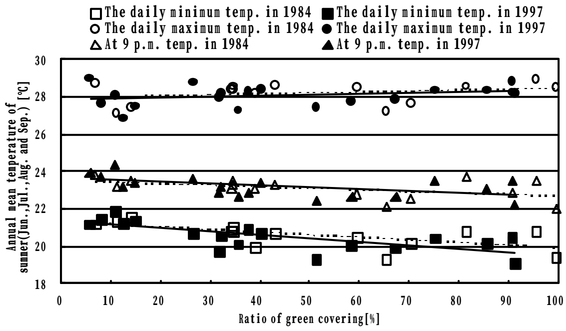

Fig.3 Relation between Ratio of Green Covering and Air Temperature of Summer

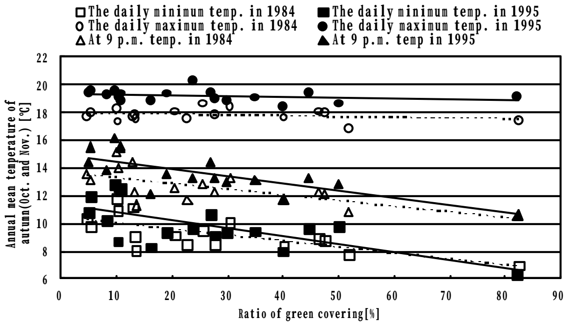

Fig.4 Relation between Ratio of Green Covering and Air Temperature of Autumn

As for the annual mean value of the 9 p.m. temperature and the daily minimum temperature, the tendency for small ratio of green covering to become high, so that for any season not having correlation with ratio of green covering as for the annual mean value of the daily maximum temperature. As a result, the correlation between air temperature and the amount of vegetation was obtained. Since, the area where the amount of vegetation decreased in autumn with many calm days especially, the average value of the daily minimum temperature was going up, it was shown clearly that the influence of the daily minimum temperature by urbanization is dependent on the amount of vegetation.

3) Influence of Urbanization on Air Temperature

By paying attention to the daily minimum temperature with large amount of vegetation and their correlation, it found that the area where change of brightness temperature is large depends on change of temperature using AMeDAS data (from 1984 to 1994). Change of brightness temperature is used for the annual mean difference of the daily minimum temperature of many cities of the study area in Tokyo on the basis of small Tokyo (Otemachi). For the secular rate of change from 1984 to 1994 as inclination of a regression, showed the brightness difference of temperature(Fig. 1). In the study area where a brightness difference of temperature is large, Nerima, Koshigaya, Tokorozawa, Kuki, and Funabash is larger than the annual mean increasing rate of the daily minimum temperature of Tokyo(Otemachi), and has caused change of a spatial heat island. It has checked that the heat island was expanded in the circumference of suburban not only from heat infrared data but the temperature of AMeDAS data.

Negative correlation is found the between ratio of green covering and the daily minimum temperature, and the influence of urbanization affects the daily minimum temperature became clear that it is dependent on the amount of vegetation. The city in which the heat island has been expanded spatially is analyzed by asking for secular change of the annual mean temperature difference of the daily minimum temperature with many cities on the basis of Tokyo with little change of the heat island about the brightness temperature in 1984 and 1994.

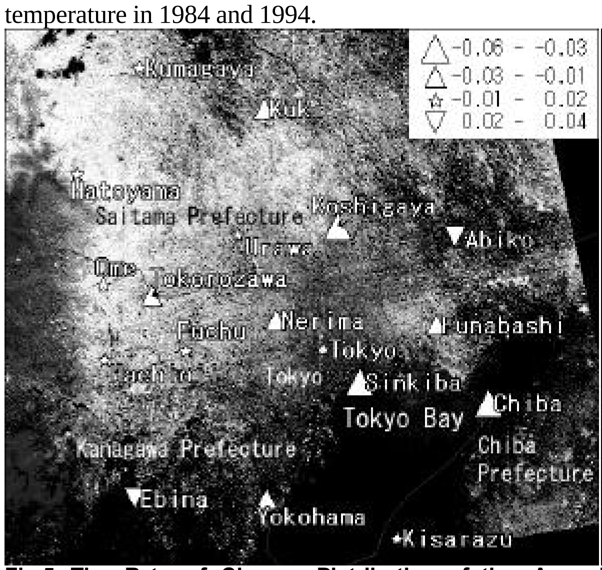

Fig.5 The Rate of Change Distribution of the Annual Average Temperature Difference of the Daily Minimum Temperature of Many Cities and Tokyo

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