# A Study on Surface Temperature Patterns in the Tokyo Metropolitan Area Using ASTER Data

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**Abstract:** This study reports the surface temperature pattern of the Tokyo Metropolitan area using the ASTER surface temperature product. The product is an image processed by applying temperature-emissivity separation to atmospheric corrected infrared thermal radiance of the land surface, then converted to surface temperature by using Planck's function. Daytime and nighttime observation in a cold season and a warm season were used in this study. As a result, 1) contrast between urban and suburban, 2) extraction of heating area in urban, 3) measurement of cooling effect of green space were achieved.
**Keyword:** ASTER, Surface Temperature, Urban Area.

## 1. Introduction

It is evident that temperature in an urban area is becoming hotter. Many studies have been conducted on this phenomenon. Measurements of urban heating have been done applying meteorological data of a high-density observation system or remote sensing data of airborne or satellite systems [1][2][3]. The latter method is superior in that the spatially distributed information can be obtained at a relatively low cost. However, surface temperature is not physically equal to air temperature, and it is difficult to accurately analyze the actual status of urban heating, which is identified as an atmospheric phenomenon. Moreover, complicated image processing technology such as radiometric correction, atmospheric correction and temperature-emissivity separation would be required to extract surface temperature based on remote sensing data.

If in case complicated image processing becomes unnecessary and possible to be applied to urban area worldwide at low cost, it would lead to progress urban climatological studies by applying surface temperature. For this purpose, this study reports the surface temperature pattern in urban area based on ASTER surface temperature product.

## 2. Study Area

This study was conducted in the Tokyo Metropolitan area located at 35.7N, 139.8E and covers 621 square kilometers. The area faces the Tokyo Bay to the east and rivers run across in both north and south sides of the area. The western part of the area is a hilly zone. Geographically, the area consists of a plateau from 20 to 30m high and the other lowlands. Most of the land is covered with artificial features except for urban parks such as Meijijingu, Yoyogi Park, Central Park and others, ranging more than 1 square kilometer.

Annual air temperature of the area averages at 15.9 deg. C., August is the highest and January is the lowest, with the largest difference of about 20 deg. C. throughout one year.

## 3. Methods

The ASTER sensor on NASA's Terra satellite has five channels to observe thermal images with 90m of spatial resolution. Surface temperature of ASTER standard product was applied in the study. ASTER surface temperature product is processed by applying temperature-emissivity separation to atmospheric corrected infrared thermal radiance of the land surface, then converted it to surface temperature using Planck's function [4]. Digital Number (DN) is a signed 16-bit format with ten-folded surface temperature (Kelvin unit) record.

The images used were observed in a cold season (8 December 2000, 22:00 JST and 26 December 2000, 10:46 JST) and a warm season (22 September 2001, 21:54 JST and 24 September 2001, 10:39 JST).

In order to contrast urban with suburban, worked out profiles of surface temperatures stretching from the urban center (Tokyo) all through to the suburban (Koshigaya: about 26km distance from Tokyo) (fig. 1) and statistics were calculated (table 1.). The means of 270 square meters (3 by 3 pixels) were used for the profile to avoid unique values. In order to extract heating areas, the urban area commonly covered in the images was extracted respectively to emphasize contrast one by one (fig. 2). To measure cooling effect of green spaces, surface temperature (180 square meters: 2 by 2 pixels) and NDVI (180 square meters: 12 by 12 pixels), were derived from ASTER visible to near infrared images with 15m of spatial resolution, over the area covered with grass and tree in Meijijingu, Yoyogi Park (table 2.).

## 4. Results and Discussion

### 1) Contrast Urban with Suburban

In the profiles, the largest surface temperature increase from suburban to urban was observed at cold season nighttime. The mean difference between urban

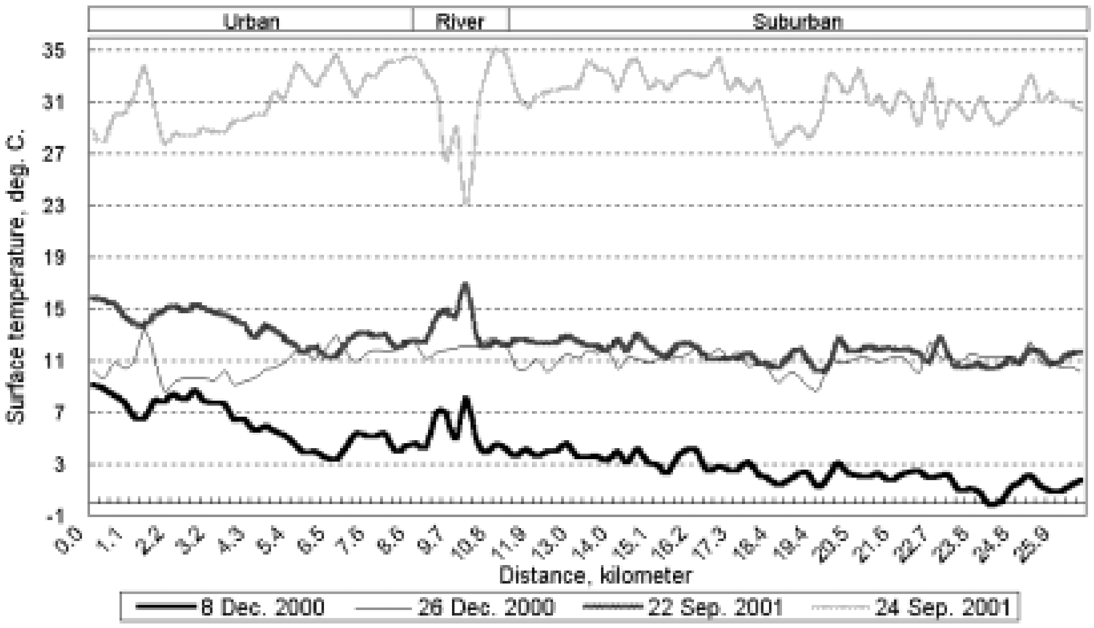


**Fig. 1. Profiles of surface temperature**

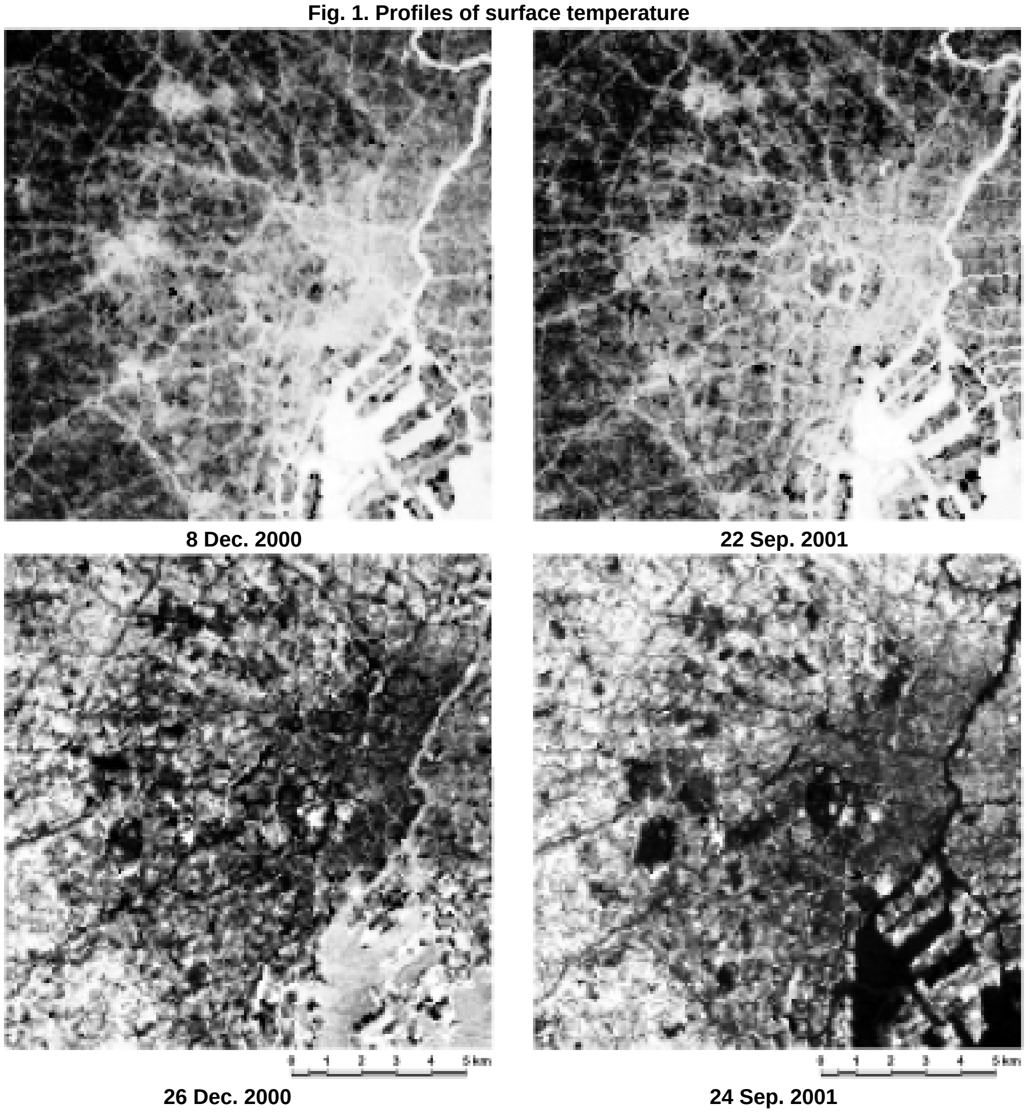


**Fig. 2. Surface temperature images derived from ASTER surface temperature product. Higher temperature area is closer to white and lower temperature area is closer to black. The images are processed enhancing contrast in respective image and the same color among the images does not represent the same temperature.**

**Table 1. Statistical table for profiles of surface temperature and meteorological data (Temperature unit: deg. C.) Tokyo belongs to urban and Koshigaya belongs to suburban.**

| Date | 8 Dec. 2000 | 26 Dec. 2000 | 22 Sep. 2001 | 24 Sep. 2001 |
|---|---|---|---|---|
| Surface temperature (mean of profile) | | | | |
| Time | 22:00 JST | 10:46 JST | 21:54 JST | 10:39 JST |
| Urban | 6.1 | 10.8 | 13.6 | 31.2 |
| Suburban | 2.5 | 11.1 | 11.6 | 31.6 |
| Urban – Suburban | 3.6 | -0.3 | 2.0 | -0.4 |
| Air temperature | | | | |
| Time | 22:00 JST | 11:00 JST | 22:00 JST | 11:00 JST |
| Tokyo<br>Koshigaya | 9.5<br>5.3 | 7.2<br>6.7 | 15.4<br>13.4 | 21.1<br>21.5 |

**Table 2. Surface temperature and NDVI in green space (Temperature unit: deg. C.)**

| Date | | 8 Dec. 2000 | 26 Dec. 2000 | 22 Sep. 2001 | 24 Sep. 2001 |
|---|---|---|---|---|---|
| Grass | Temp. | 3.4 | 11.3 | 13.0 | 25.4 |
| | NDVI | – | 0.09 | – | 0.41 |
| Tree | Temp. | 6.2 | 8.8 | 13.9 | 23.5 |
| | NDVI | – | 0.18 | – | 0.41 |

range (Tokyo to river) and suburban range (beyond river to Koshigaya) is 3.6 deg. C. This measurement result is consistent with that of air temperature that marked the largest difference between urban (Tokyo) and suburban (Koshigaya) at cold season nighttime.

In nighttime, the profiles showed higher temperature in urban range and in daytime it showed higher temperature in suburban range, regardless of seasons.

More specifically, fluctuations in the profile seem to have been affected by the types of features (water, green and artificial cover), and the existence of high-rise buildings and traffic infrastructures (stations and roads).

### 2) Heating Area in Urban

The mean surface temperatures in the respective four images are 6.0 deg. C. (8 Dec. 2000), 11.2 deg. C. (26 Dec. 2000), 13.9 deg. C. (22 Sep. 2001) and 31.0 deg. C. (24 Sep.2001).

By making comparison, the similarity between cold season and warm season was high in nighttime (correlation factor: 0.92). The tendency of surface temperature distribution was almost the same. The heating areas in nighttime are commercial, business centers and trunk roads.

Whereas the similarity in daytime was low (correlation factor: 0.36) and a marked difference was shown in water bodies with small annual temperature change. Other areas generally showed a close distribution in two seasons. The heating area in daytime is a residential district located in outer urban center.

### 3) Cooling Effect on Green Space

The cooling effect of green space was marked in warm season daytime.

As for comparison between grass and tree, grass showed lower surface temperature in nighttime and tree showed lower in daytime, regardless of seasons. Such transformation is consistent with controls of radiant cooling with higher sky view factor, and the existence of shade and transpiration [5].

The difference in surface temperature between grass and tree was larger in a cold season and the NDVI showed that grass was similar to bare land. In a warm season, although surface temperature of grass and tree was different, NDVI showed the same. The fact that the sample is limited, and that there is difference in spatial resolution, should be taken into consideration, but the data indicates that NDVI is not necessarily a reliable source to determine accurate surface temperature.

## 5. Conclusions

This study targeted the Tokyo Metropolitan area in an attempt to understand surface temperature pattern in an urban area based on ASTER products in daytime and nighttime of cold and warm seasons respectively. As a result of the study, 1) contrast urban with suburban, 2) extraction of heating area in urban, 3) measurement of cooling effect on green space were achieved. Also, ASTER surface temperature product was effective in simplifying the research methodology at a low cost.

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