# Monitoring Urban Heat Environment in East Asia

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The "Heat Island" is expanding for many big cities in the world, and the phenomenon is analyzed in terms of•@local/regional energy balance, economic activities, climatic aspect and so on. It is discussed as the site specific issue5), however it is occurring in many places on a global scale with different intensity. It seems to be important to analyze the heat island phenomenon among cities in different geographic locations to understand its mechanism and forecast its progress, because there exist different stages of the heat island and they are growing at different development stages.

The Institute of Industrial Science, University of Tokyo has been receiving NASA's satellite "TERRA/MODIS" data starting from May, 2001 in order to monitor the environment and disaster parameters around the East Asia6). A project was launched to analyze and assess the environment and disasters that occurred in the cities in Asia. In order to acquire TERRA data for expanded continental-scale i.e. into the Southeast Asian sub-region, the IIS has provided Asian Center for Research on Remote Sensing, AIT one identical MODIS receiving facility. That station is managed by the Joint Management Committee composing of ACRoRS (AIT), Geo-Informatics and Space Technology Development Agency (Thailand).

In this study, the comparison of the heat island intensity for cities in East Asia and different stages of economic development in different geographic locations is made.

## Data used

In this study, five cities are picked up for analyzing the heat environment or the so-called heat island. The cities are: Tokyo (Japan), Seoul (South Korea), Pyongyang (North Korea), Beijing and Shanghai (China), those are within the coverage of the ground station of University of Tokyo, Komaba, Tokyo. Table-1 shows the list of data used in this study. In order to obtain cloud free data, the date for summer data and winter data, and the time for day-time data and night-time data are not unified. For example, the date of summer-night data for Tokyo is 2nd of June, which is rather early comparing the date for summer-day data, which was observed on 24th of July. In this study, the differences are modified by normalized methodology.

## Methodology

Fig-1 shows the data prosessing flow in this study. The first step of the study is to make the land cover classification. TERRA / MODIS has 3 different modes of spatial resolution - 250m, 500m and 1000m - with 36 spectral bands in total. In the study, the land cover characterization is made using 250m resolution optical images with categories of built up, forest, grass, water body and bare soil. The classification result is used to provide the emissivities of the land cover categories7). Emissivity is

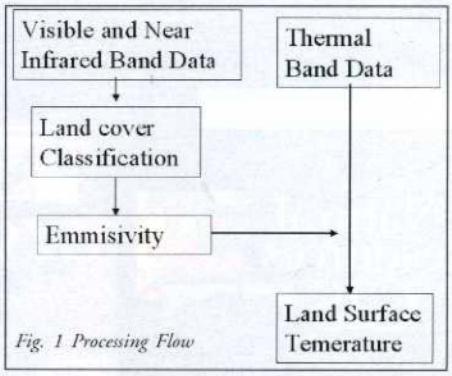


*Fig. 1 Processing Flow*

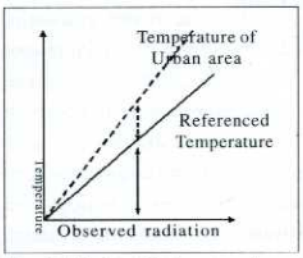
*Table-1 List of Data used*

| City | Summer/Winter | Day/Night | Date | Local Time | G M T |
|---|---|---|---|---|---|
| Tokyo | Summer | Day | 2001/07/24 | 10:36 | 01:36 |
| | | Night | 2001/06/02 | 22:04 | 13:04 |
| | Winter | Day | 2001/11/23 | 11:08 | 02:08 |
| | | Night | 2001/11/23 | 22:11 | 13:11 |
| Seoul | Summer | Day | 2001/08/27 | 11:59 | 02:59 |
| | | Night | 2001/08/27 | 23:03 | 14:03 |
| | Winter | Day | 2001/11/19 | 11:32 | 02:32 |
| | | Night | 2001/11/19 | 22:35 | 13:35 |
| Pyongyang | Summer | Day | 2001/08/27 | 11:59 | 02:59 |
| | | Night | 2001/08/22 | 22:45 | 13:45 |
| | Winter | Day | 2001/11/19 | 11:32 | 02:32 |
| | | Night | 2001/11/19 | 22:35 | 13:35 |
| Peking | Summer | Day | 2001/08/21 | 11:33 | 03:33 |
| | | Night | 2001/08/20 | 21:57 | 13:57 |
| | Winter | Day | 2001/11/20 | 11:13 | 03:13 |
| | | Night | 2001/11/20 | 22:17 | 14:17 |
| Shanghai | Summer | Day | 2001/07/21 | 10:42 | 02:42 |
| | | Night | 2001/0917 | 22:19 | 14:19 |
| | Winter | Day | 2001/10/30 | 10:56 | 02:56 |
| | | Night | 2001/10/30 | 22:00 | 14:00 |

then used to estimate the land surface temperature from the brightness temepature value in the thermal band image with 500m resolution data1,2,3,4). Finally the heat island impact was analyzed. However, the land surface temperature is influended by the geographic conditions such as the climate and weather at the time in the area, so that it is difficult to compare the temperature itself to indicate the heat island intensity. In order to compare the heat island impact among the cities, the normalized surface temperature images were prepared by equalizing the temperature values of forested region(Veg-2 in the classification category in this study) in suburbs where the heat island effect is supposed to be unrelated. Fig-2 shows the method of calculating the normalized land surface temperature. In this study the temperature at Vegetation-2 category in Seoul image was used as the parameter for normalizing the land surface temperature for other cities.

## Results

Fig-3 shows the results of the analysis. The left column of the figure shows the images of 250m resolution data composed with red-band/red-plain, infrared-band/green - plain, and infrared-band/blue-plain, for 5 cities. The right column shows the land




$$T_{mod} = \frac{T \times T_{Veg2(Seoul)}}{T_{Veg2}}$$

$T_{mod}$ : Modified Temperature
$T$ : Observed Rediation
$T_{veg2}$ : Te mperature at Veg2 region
$T_{veg2(Seoul)}$ : Temperature at Veg2 region in Seoul

*Fig. 2: Relationship between observed temperature and normalized temperature*

surface temperature images for the cities. After normalizing the surface temperature using the surface temperature on the vegetated region classified as "Vegetation-2" of the land cover classification, the heat flux intensity was calculated.

Table-2 shows the comparison of the accumulated heat flux intensity within the urban area delineated with the same area for the 5 cities. In this table, the heat flux intensity of Pyongyang is set as "1" for summer-day, summer-night, winter-day, winter-night, and the intensities for 4 other cities with 4 different season and time are calculated respectively.

| | Tokyo | Seoul | Pyongyang | Beijing | Shanghai |
|---|---|---|---|---|---|
| Summer/Day time | 107 | 43 | 1 | 52 | 18 |
| Summer/Night time | 70 | 21 | 1 | 10 | 5 |
| Winter/Day time | 59 | 22 | 1 | -1 | 12 |
| Winter/Night time | 1 | -4 | 1 | 35 | 1 |

*Table-2 Comparison of heat flux intensity among the 5 cities*

From this table, the heat flux intensity in Tokyo is most significant among the 5 cites, except the winter-night time. The second significant city is Seoul, however the heat flux intensity of Beijing is most significant in the winter-night time among the 5 cites, and second significant at the summer- day time.

The analysis was made using the single image for the 4 different season/time series(Summer, Winter, Day and Night), therefore, there might exist some reasons excluding the heat island impact, such as geographic, climatic and local characteristics influencing the local heat flux on the day observed by the satellite.

## Conclusion

In this study, the land surface temperature was calculated using thermal band with 500m resolution TERRA MODIS data in combination with the visible band data of 250m resolution for 5 major cities in East Asia. And a methodology to indicate the heat flux of urban area to estimate the heat island phenomenon from the satellite images under the different geographic, climatic conditions was used. The method enables the comparison of heat flux of the 5 cities using the MODIS data.

Continuous observation will be made for more quantitative analysis in terms of heat flux as well as the vegetation function to reduce the heat island phenomenon, using long term satellite information which avoids the temporal error such as local climatic condition including the weather of the observation day and time, and sensor anomalies. Furthermore, some more cities from South East Asia such as Bangkok, Hanoi, Hochimin city, Jakarta, Kuala Lumpur, Singapore, covered by Bangkok broadcasting station, will be added for the study.

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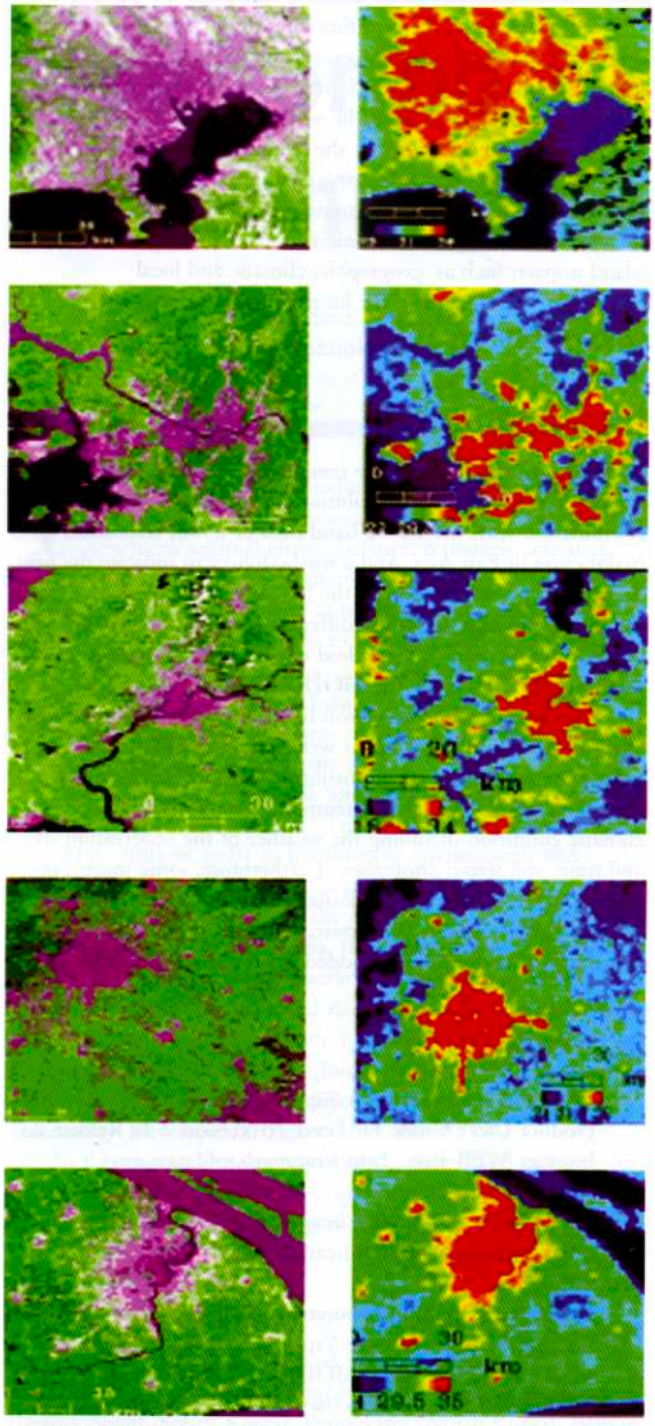

*Fig-3 Visible band and thermal band for the study sites (Tokyo, Seoul, Pyongyang, Beijing and Shanghai, from top)*


yasulab.iis.u-tokyo.ac.jp/%7Emodis/index.htm

- Japan Association of Remote Sensing, Remote Sensing Note, p14, 1996 ■