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 in the site specific issue, 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 mechanisms and forecast its progress, because these 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 Asia. A project was launched to analyze and assess the environment and disaster 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 IIJ has provided Asia Center for Research on Remote Sensing, AIT one identical MODIS receiving facility. That center is managed by the Joint Management Committee comprising of ACliRS (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 of the so-called heat island. The cities are: Tokyo (Japan), Seoul (South Korea), Pyongyang (North Korea), Beijing and Shanghai (China). These 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 clear data, the data for summer data and winter data, and the time for day-time data and night-time data are not unified. For example, the data of summer-night data for Tokyo is 2nd of June, which is rather early comparing the data for summer day data, which was observed on 26th of July. In this study, the differences are modified by normalized methodology.

Methodology

Fig. 1 shows the data processing 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 categories. Emissivity is the ratio of the net radiation that is absorbed in a surface to the net radiation that is absorbed in a blackbody at the same surface temperature. Emissivity is shown in the following table.

<table>
<thead>
<tr>
<th>City</th>
<th>Summer Day</th>
<th>Summer Night</th>
<th>Winter Day</th>
<th>Winter Night</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tokyo</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Seoul</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Pyongyang</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Beijing</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Shanghai</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
then used to estimate the land surface temperature from the brightness temperature value of the thermal band image with 50m resolution data (2, 3, 6). Finally, the heat island impact was analyzed. However, the land surface temperature is influenced 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 framed region (Veg-2 in the classification category in this study) in subarea where the heat island effect is supposed to be unobtrusive. Fig. 2 shows the method of calculating the normalized land surface temperatures. In this study, the temperature at Vegetation-2 category in the image was used as the parameter for normalizing the land surface temperature for other cities.

Results

Fig. 3 shows the result of the analysis. The left column of the figures shows the images of 250m resolution data compared with red-band/red-plain, infrared-band/green - plain, and infrared-band/blue-plain for 5 cities. The right column shows the land surface temperature images for the cities. After normalizing the surface temperature using the surface temperature of the 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 Poyanggong 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.

From this table, the heat flux intensity in Tokyo is most significant among the 5 cities, 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 cities, 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 satellites.

Conclusion

In this study, the land surface temperature was calculated using thermal band with 50m resolution TERRA MODIS data in combination with the visible band data of 250m resolution for 5 major cities in Southeast 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, utilizing long term satellite images 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, Hachiminy city, Jakarta, Kuala Lumpur, Singapore, covered by Bangkok broadcasting stations, will be added for the study.

References

- Institute of Industrial Science, University of Tokyo, MODIS DB Reception Facility at IIS, Internet WEB Page, http://
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