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# Study on Evaluation Method of City Heat Island Spatial Distribution

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**_Abstract_**

*Urban heat island effect is the regional ecological problems of fast city construction , because the city heat island spatial distribution changes with time.How to quantitatively express this change is one of the important work of the city heat island research. How to compare different images of the space difference of heat island distribution is one of the research content . In this study ,the thermal infrared image of HJ-1B satellite and temperature image inversed from the thermal infrared image were normalized.We put forward and adopts the gap dimension to evaluate spatial distribution of different images. The results show that the spatial distribution of heat island based on temperature image is more concentrated than that of the thermal infrared image, which provides a new evaluation method for the research of city heat island spatial distribution between different images.*

***Keywords***: *heat island ; thermal infrared image; UHI; Lacunarity dimension*

## 1.Introduction

With the development of of global urbanization, city heat island has become an increasingly prominent issue [1-4]. The traditional surface observation way is difficult to fully grasp the city space and ground heat island,to study the urban heat island effect using remote sensing image has become the mainstream way [2-6].

Among the remote sensing images used in the study of city heat island, NOAA/AVHRR datas provides the earliest images, but the spatial resolution of 1KM is not suitable for the thermal environment of the city scale analysis. ASTER datas with high resolution provide multiple thermal infrared channel, but collection archive is small and acquisition time is long. So ASTER datas are not suitable for study on the dynamic change of ground heat field. In contrast, Landsat TM/ETM remote sensing data with high spatial resolution and multi-band spectral information has been widely applied.In addition,the HJ satellite and high resolution earth observation satellite satellite lauched by China provide muilti-time and multi-spectral remote sensing information to study the urban heat island effect .

In order to research the development and change of the city heat island, remote sensing images of different periods need to be compared. The conventional approach is to obtain the research area of the thermal infrared image and surface emissivity to retrieve land surface temperature [7-9]. But due to the changes of surface emissivity changes with the seasons, how to reasonably determine the surface emissivity is key to retrieving land surface temperature [10-14]. At present most studies use the daytime summer images to study urban heat island effect, the remote sensing image for other period of urban heat

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island effect is little studied.

In order to quantitatively study the differences between the city heat island of different images, this study selected in Wuhan area as an example, because of the heat island effect is very remarkable, therefore, it is necessary to study the hot island spatial distribution of Wuhan City and hot island changes. This study selected HJ-1B satellite thermal infrared image and surface temperature image inversion by thermal infrared image, used the lacunarity dimension to describe heat island distribution characteristics of different images in the same season.

## 1. Different Images of Urban Heat Island Distribution Feature Recognition

### 1.1. The Heat Island Distribution Characteristics of The Thermal Infrared Image

This study selected HJ-1B satellite thermal infrared image in July 9, 2011, the IRS-4 band HJ-1B satellite accepts the thermal infrared radiation.Through thermal radiation value received by the IRS-4 band we can calculate the corresponding surface temperature. Because the city heat island is concerned about the temperature distribution of the relative strength of the city space, and the surface radiation temperature shows significant linear relationship with the low altitude temperature , therefore,we can use ground radiation temperature (temperature) to study the city heat island.

Because the city heat island focuses on the spatial distribution of temperature , and the seasons only change the brightness temperature strength, does not change the brightness temperature of the spatial distribution [15]. Therefore we normalize the brightness image and temperature image. The normalizationof the formula is as follows:

$$N_i = \frac{T_i - T_{\min}}{T_{\max} - T_{\min}} \tag{1}$$

$N_i$ is the thermal infrared image pixel value after normalization. $T_i$ is the thermal infrared image pixel value, $T_{\max}$ is the max t value in the thermal infrared image of the research region, $T_{\min}$ is the min value in the thermal infrared image of the research region.

Reference vegetation classification system, the normalization of the brightness temperature level is divided into (0~25%, 25%~50%, 50%~75%, 75%~100%) 4 grades. Four grages represent low temperature zone, medium temperature zone, high temperature zone , extra-high temperature zone. The extra-high temperature is defined as the Wuhan city heat island. The method of ENVI software is used to make the urban brightness temperature grade distribution figure, as shown in Figure 1.

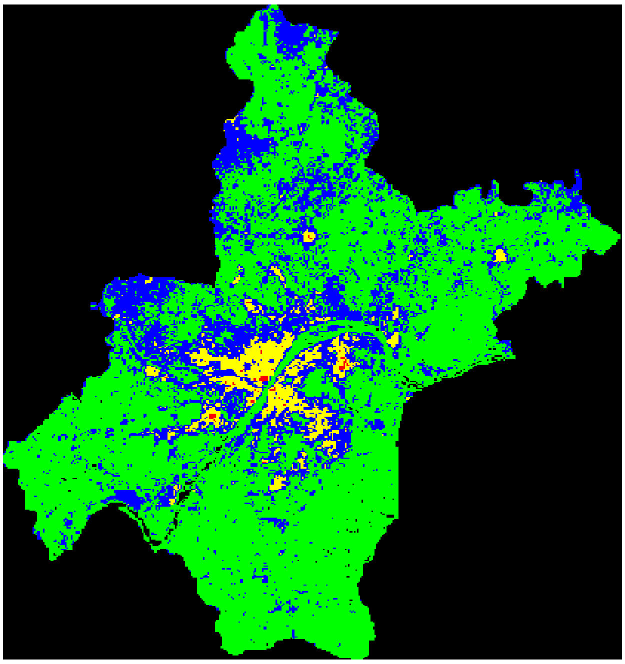


**Figure 1. City Thermal Infrared Image Grade Distribution**

### 1.2. The Heat Island Distribution Characteristics of The Surface Temperature Image

In this study we use the HJ-1B satellite thermal infrared image of July 9,2011 to inverse ground surface temperature by mono window algorithm.The water was removed,the emissivity of ground objects was defined by NDVI threshold method.The surface temperature image was processed by Formula (1) and the result was shown in Figure 2.

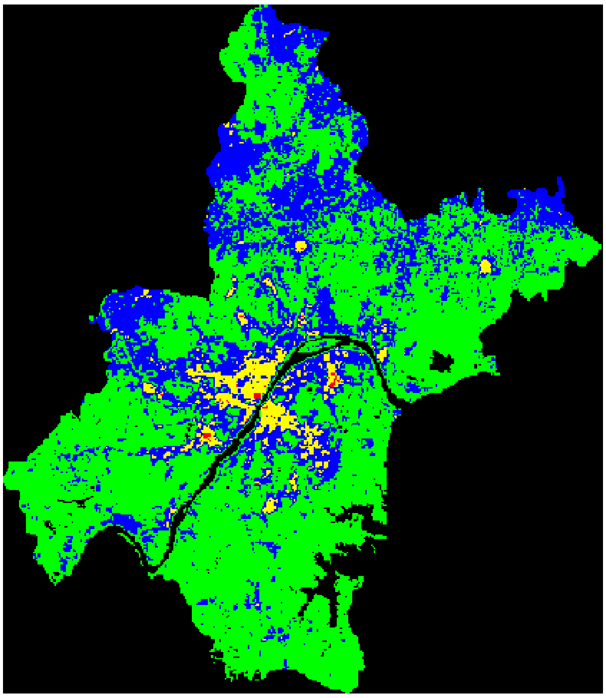


**Figure 2. City Temperature Image Grade Distribution**

## 2. Study on Spatial Distribution Characteristics of Wuhan City Heat Island

### 2.1. Lacunarity Index Concept

Because lacunarity index can measure the degree of aggregation of the landscape space, it is widely used in landscape fractal analysis and the landscape texture analysis.Mandelbrot proposed the concept of lacunarity index in 1983 [16-17]. Plotnick introduced it to the landscape ecology research in 1993. Based on grid map the method does not require stable system hypothesis and is not affected by the boundary . The calculation method is as follows: sample grid is defined as R; Move the sampling grid template, statistics the number of different high temperature zone ; Calculate S distribution in the entire study area, defined as Q (S, R);Calculate S first order origin moment of Z (1) and second order origin moment of Z (2) , formula is as follows:

$$Z(1) = \sum_{S=0}^{R^2} SQ(S,R) \tag{2}$$

$$Z(2) = \sum_{S=0}^{R^2} S^2 Q(S,R) \tag{3}$$

The lacunarity index is defined as:

$$\wedge(R) = \frac{Z(2)}{(Z(1))^2} \tag{4}$$

Formula (3) indicates that the lacunarity index is the absolute value, it is affected by the grid scale, the scale effect is produced. That is to say, for the same research object, we adopt different measure to calculate the sampling grid, we can get agroup lacunarity index changing with the grid scale. This kind of "modifiable area unit" for the explanation of the research object aggregation is bad [18-24].

### 2.2. Lacunarity Dimension

In order to correctly express the distribution characteristics of Wuhan city heat island effect, we must first solve the "modifiable area unit" problem caused by the scale effect . Reference the fractal theory,we proposed and established the mapping relation of natural logarithm based on sample grid size and lacunarity index, using regression model to calculate lacunarity dimension, the formula is shown below:

$$\ln \Lambda = \Lambda_0 - D \ln R \tag{5}$$

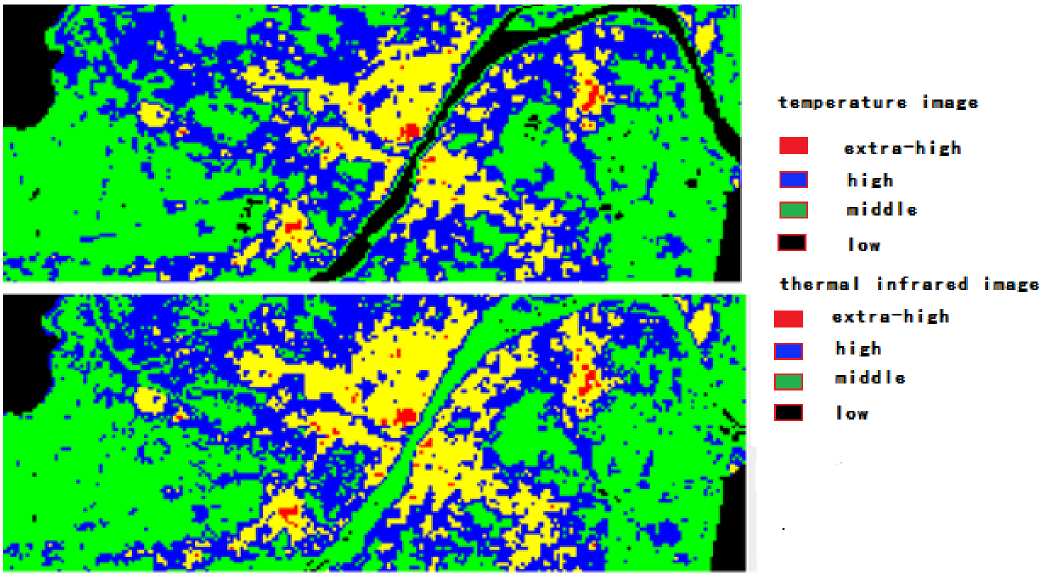
$\Lambda_0$ is the initial lacunarity index, $D$ is the lacunarity dimension.When D is larger, it shows the object is more scattered; when D is smaller, it shows the object is more aggregated in spatial distribution.

Lacunarity dimension does not change with the sampling grid scale change, so there is no lacunarity index "modifiable areal unit problem".It can well solve the spatial scale effects caused by clearance index. At the same time, because the lacunarity dimension is a relative value,it can quantitative compare different scale lacunarity index of the research object. It is more intuitive and accurate than conventional lacunarity index , which can effectively solve the aggregation of objects reflected in different scales.

## 3. Experiment Resluts

In the course of the experiment, in order to further compare the differences of heat island effect between thermal infrared image and temperature image .We defined the extra high temperature area as Wuhan City heat island and used the lacunarity index to evaluate the spatial distribution characteristics. Figure 3 shows the classification level map according to the brightness image and temperature image.




This research adopted the sliding window of 3 * 3 to calculate heat island distribution characteristics of different images , the result is as follows:

**Table 1. Calculation Results**

| | Temperature image | Thermal infrared image |
|---|---|---|
| lacunarity index | 306.5110 | 256.3629 |

The greater the gap index, aggregation degree of Wuhan city heat island is higher, otherwise, Wuhan City heat island aggregation degree is lower. That is to say, the city heat island based on thermal infrared image represents more decentralized. This is consistent with the results in Figure 3.

In order to solve the modifiable areal unit problem, according to the relationship between different sample scales and lacunarity index, the lacunarity dimension is calculated to quantitative evaluation of Wuhan City heat island aggregation degree in space.

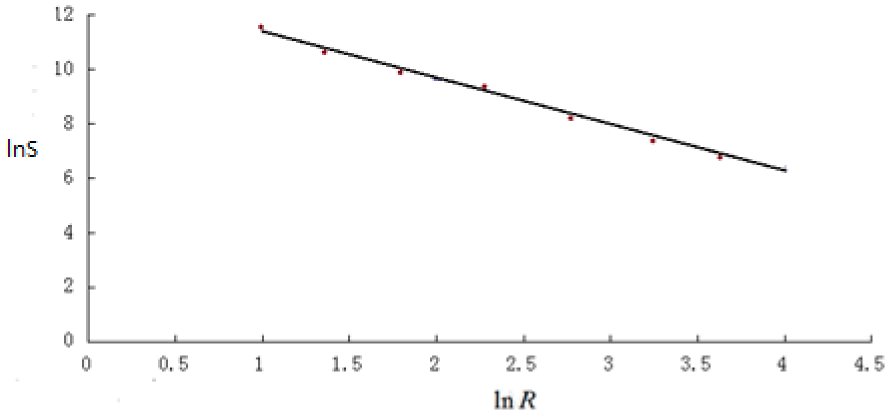



**Figure 4. Heat Island Lacunarity Index and Grid Scale Regression Analysis Based on Temperature Image in Wuhan City**

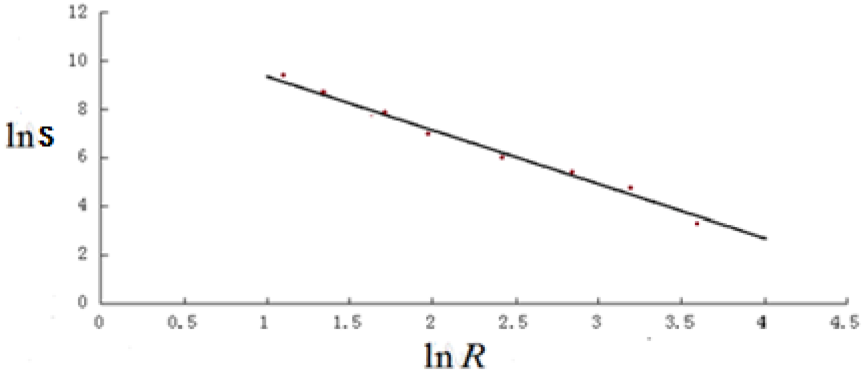



**Figure 5. Heat Island Lacunarity Index and Grid Scale Regression Analysis Based on Thermal Infrared Image in Wuhan City**

**Table 2. Regression Analysis of the Double-logarithmic Fitting Curve for Different Images**

| Name | The Fitted Equation | The Correlation Coefficient | Lacunarity Dimension |
|---|---|---|---|
| Temperature image | $\ln\Lambda = -1.6048\ln R + 12.781$ | 0.9415 | 1.6048 |
| Thermal infrared image | $\ln\Lambda = -1.2176\ln R + 10.59$ | 0.9587 | 1.2176 |

Figure 4 and Figure 5 show, Wuhan City Heat Island lacunarity dimension D=1.6048 based on thermal infrared image, Wuhan city heat island temperature lacunarity dimension D=1.2176 based on temperature image. In addition, Wuhan City heat island scale and degree of linear fitting lacunarity index were all above 0.94.This shows that the linear fitting is right, the significant level is high, the regression results are reliable.

According to the calculation results we find lacunarity dimension is different in the different images.The urban heat island distribution of thermal infrared image is more dispersed.This is consistent with the before calculated results by the 3*3 calculation window.

## 4. Discussion and Conclusion

In the absence of ground object accurate information, how to make use of thermal infrared images to study the urban heat island effect is a worthy problem [25-34].Because of the heat island effect is mostly concentrated in the summer,research the heat island effect for the rest of the season is relatively small，due to land surface temperature inversion and emissivity limit. This study quantitatively processes thermal infrared image and temperature image, makes quantitative analysis on spatial distribution of heat island in Wuhan.This research uses the fractal theory to improve the existing gap index,quantitatively evaluates the wuhan city heat island distribution in the thermal infrared image and temperature image. In addition, this study provides a new method for the evaluation of city heat island spatial distribution characteristics, can be applied to the evaluation of different images (such as MODIS, ASTER, a high score on the 1st, HJ satellite, landsatTM/ETM) and the differences between heat island spatial distribution characteristics, and provides a new idea for the research of the city heat island.

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