STUDY ON THE DISTRIBUTION CHANGES OF URBAN HEAT ISLAND BASED ON HEAT-GREENNESS FEATURE SPACE

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ABSTRACT:
Many scholars at home and abroad are extensive concerning about the forming mechanical of urban heat island phenomenon. According to correlation study, the surface temperature in the center of Beijing city and suburbs is separated by 6℃[1]. This paper is a case study on Beijing, successfully retrieve the radiance temperature and Normalized Difference Vegetation Index (NDVI) from the Landsat TM data, analyse the relation model of radiance temperature and NDVI. This paper use the TM date of 1992 and 2004 to construct correspondence relation model, and analyse the model changes. As a result, radiance temperature and NDVI have a strong negative correlation. Under a certain range, the radiance temperature is higher, the correlation between radiance temperature and NDVI is stronger, the slope's absolute value of linear regression model will be steeper. This paper do a dynamic study of correspondence relation model between radiance temperature and NDVI in Beijing, well reflect the relation changes between radiance temperature and NDVI, and provide some Scientific theoretical for urban planning and greenland planning in the future of Beijing.

1. INTRODUCTION

Urban heat island effect is the formation of the development of urbanization, Urban heat island effect make average temperature in urban is much higher than the suburbs. In the cities, factories, motor vehicles, air conditioners and household stoves and hotels, and other large energy consumption, release Waste heat into the atmosphere. Tall buildings obstruct air passage so that the city reduce wind speed, exacerbated the heat island effect. In recent years, due to the rapid development of urban construction, urban heat island effect become increasingly evident. The hot weather have a serious impact on people's lives and work, and damage to human health, even caused some people lost their life due to heat stroke[2]. At the same time, the heat island phenomenon was exacerbated by air pollution[3], the hot gas emited from ground form a warm air mass near the ground, blocked the circulation of dust, and formed the "Dust dome" is harmful to people[4]. However, a considerable amount of research shows that: green coverage and urban heat island is inversely proportional, green coverage rate higher, the lower the intensity of heat island, form the low-temperature region by green space in the cities, become the fine environment outdoor recreation activities in the cities.

As urban green space can effectively reduce the heat island phenomenon, so scholars from domestic and foreign are wide concern the relationship between the vegetation cover and the urban heat island. As the rapid development of remote sensing technology, that brought great convenience for large-scale, continuous study of heat island effect. Currently, the primary research means with remote sensing data is to analysis the relation of NDVI and the ground temperature or brightness temperature to study urban heat island effect. Ping Tian,et al[5]. use the TM images of Hangzhou to study the heat island effect, the results show that there was a clear correlation between the heat island effect and vegetation cover, the correspondence relation model: H=exp(-1.619490NDVI-0.871240), correlation coefficient is 0.88. Zhangyan Jiang,et al[6]. use the TM data of Beijing study the relationship between heat island effect and NDVI, the results show that there has a obvious negative correlation between the heat island effect and NDVI, Ts=37.26-12.66×NDVI，correlation coefficient is 0.82, residual standard deviation is 1.057 ℃.

Many research only study the relationship between NDVI and the temperature on a certain period, did not study the relationship changes at different times. With the impact of urbanization and global warming, whether the relationship between NDVI and temperature will be change? This paper using two remote sensing data analyse coefficient changes of the model between NDVI and radiance temperature, do a preliminary dynamic study for the relationship changes between vegetation cover and urban heat island phenomenon.

2. THE GENERALITY OF THE STUDY REGION AND DATA SOURCE

Beijing is in the north of North China Plain, adjacent to Tianjin in the east, the rest were nearby the province of Hebei, the city center located in 39°N, 116°E. Terrain is high in northwest, and low in southeast. There is mountain in West, north and northeast, in south-east is plain to the Bohai Sea. Just as shown in Figure 1. The whole area is 16,800 square kilometers, population is 1,700 million. Beijing is warm semi-humid of continental monsoon climate, summer is hot and rainy, cold and dry in winter, spring and fall is short, the average temperature is 10~12 ℃. When come to September, rainfall decreased significantly, the temperature began to decrease, and the temperature difference between day and night increased, as shown in Figure 2.

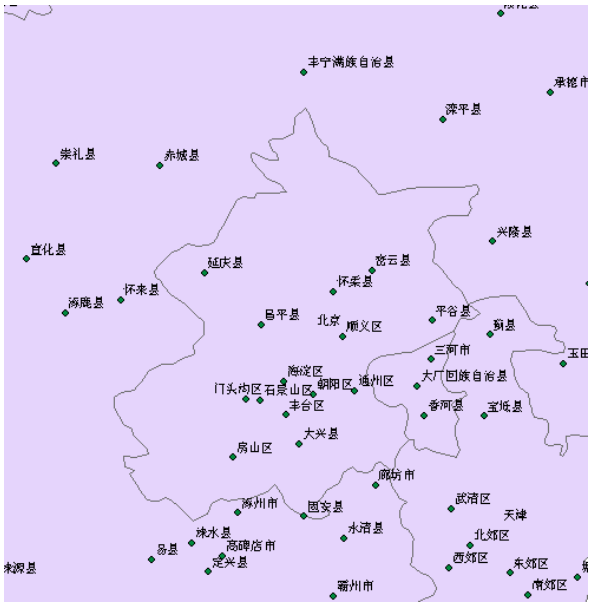

Fig1 Beijing's geographical location map

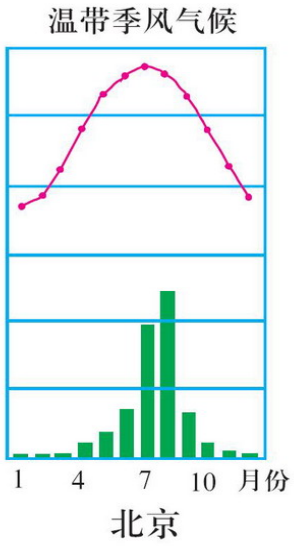

Fig2 Beijing's temperature and rainfall changes during a year

The rapid development of remote sensing technology make it convenient for large-scale study of urban heat island effect, some research extract NDVI and other vegetation index, and analysis the relationship between NDVI and radiance temperature or ground temperature to study the relationship between the urban heat island effect and vegetation[7] - [10]. Based on September 7, 1992 and September 8, 2004 in Beijing's LandSet5 TM images as the data source, the track of date is 123-32. TM images include seven bands, the resolution were 30 meters. The major application of image is extract NDVI with the third band and fourth band, while use the sixth-band of remote sensing data to extract radiance temperature.

3. RESEARCH METHOD AND DATA PROCESSING

3.1 Image preprocessing

LandSet5 data is the basis data of this paper, band combination should be process before data use, make the seven single band image to a multiband image, in order to extract NDVI of the study area.

It's necessary to do geometric correction after band combination, so that the object on the image can associated with its actual location, providing location information for analysis of the data. In the process of correction, the author use the vector data of Beijing Municipal water systems as reference, choose precise positioning as control point such as the crossing point of river, a total of about 20 control points, and its accuracy at 0.5 pixel, then use the method of neighbouring to do Geometric correction.

After the correction of the image data process border clipping with the vector data of Beijing border, only retain the scope of Beijing on the remote sensing images. This step is aimed at when select characteristic section ensure that choice is within the framework of Beijing.

3.2 NDVI extraction

NDVI: Normalized Difference Vegetation Index, like other vegetation index shows the rate of vegetation cover, it is the most extensive application amongst all vegetation index. NDVI can be used to detect the growth of vegetation, and vegetation coverage, and so on. The calculation formula of NDVI for TM data:

$$NDVI=(NIR-R)/(NIR+R)$$

In the formula: NIR is the gray value of near-infrared band, R is the Gray value of red-band.

NDVI is within the range [1, 1], and negative is for the cover of cloud, water, snow, high reflectivity of visible light; 0 is for rock or bare soil, and so on, NIR and R are approximate equivalent. Positive is that there are vegetation cover, and with the coverage increases, NDVI will increase too. It's generally believed that when the NDVI <0.1, vegetation is sparse. Figure 3 and 4 are the NDVI map of two years.

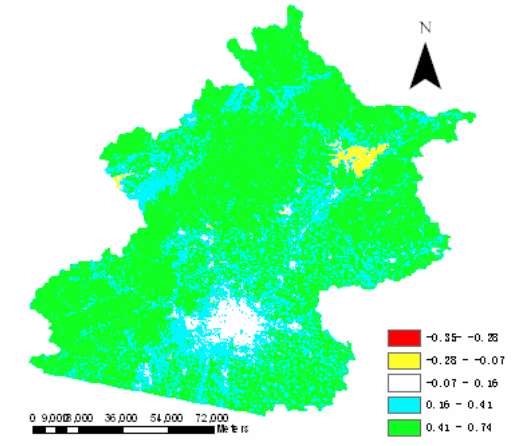

Fig3 NDVI map of 1992

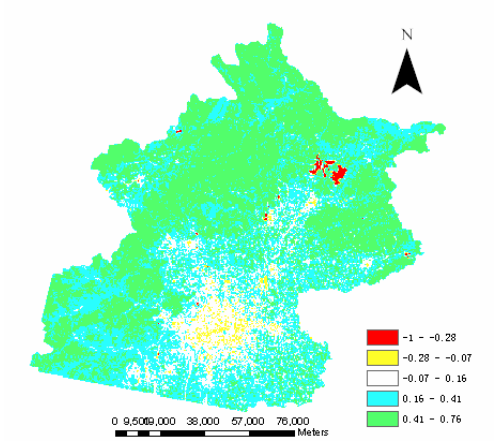

Fig4 NDVI map of 2004

NDVI in 1992 distribute from -0.355 to 0.735, and in 2004 distribute from -1 to 0.756. As can be seen from the map, with the exception of a few places such as Miyun Reservoir, there is no obvious changes in Beijing's western and northern suburbs, changes mainly occurred in urban areas. As the impact of, urban areas is small in 1992, NDVI is higher around urban area, a large number of green space is occupied because of urbanization in 2004, the NDVI in these areas dropped from 0.3 to about 0.

3.3 Extraction of radiance temperature

Many scholars use image data and meteorological data to inverse surface temperature, to study the relationship between urban heat island effect and NDVI. In this paper, due to the lack of accurate weather data, surface temperature inversion did not succeed, so the author choice radiance temperature in final. Although the radiance temperature is not the same value with ground temperature, but with a strong correlation exists, the spatial distribution of radiance temperature can be a good fit on the ground temperature distribution in the space[11]. Therefore, in this study radiance temperature can used instead of ground temperature. Radiance temperature is coming from the sixth band gray value of the TM data, radiance temperature is not equal to the actual temperature, it's slightly less than the actual temperature, but there is a certain correlation between them. Radiance temperature is that when the object's spectral radiance (λε) is equal to the spectral radiance of the blackbody that its temperature is Tb. The sixth band of TM recorded the DN value, can not be directly applied to analysis of heat island effect, DN values should be transform into radiance temperature for analysis. According to QIN Zhi-hao,et al[12], which study the extract radiance temperature, firstly, the DN value of sixth band should be converted to radiance Lb, the formula as following:

$$Lb = Lmin + (Lmax - Lmin)DN/255$$

In the formula, Lmax, Lmin respectively for the band detectors can detect the maximum and minimum value of radiation. Lmax, Lmin value is fixed, Lmax = 1.56mw • cm-2 • sr-1 • μ m-1, Lmin = 0.1238 mw • cm-2 • sr-1 • μ m-1, as to the LandSet5 satellite, the formula can be translated into:

$$Lb = 0.1238 + 0.005632156 * DN$$

Radiance Lb can be transformed into the radiance temperature according to the following formula :

$$Tb = K2/\ln(K1/Lb + 1)$$

Where, K1, K2 is a constant, K1 = 60.776 mw • cm-2 • sr-1 • μ m-1, K2 = 1260.56 mw • cm-2 • sr-1 • μ m-1, Lmax and Lmin is the same mean with the former formula. Figures 5 and 6 are the radiance temperature map of the two years.

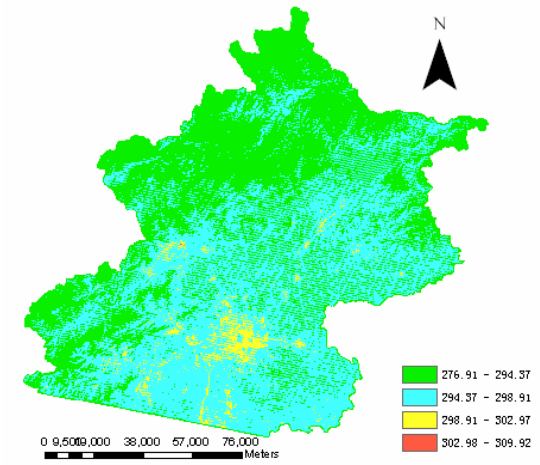

Fig5 The distribution of radiance temperature In 1992

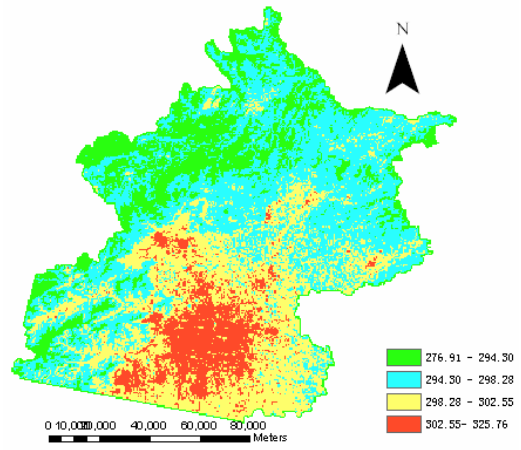

Fig6 The distribution of radiance temperature In 2004

Above are the radiance temperature map of the two years, in 1992 the maximum of radiance temperature is 308.316 K, in 2004 the maximum of radiance temperature is 320.294 K, increased by 12 ℃. From the map can be seen, the high temperature region in 04 expand a lot compared to 92.

3.4 Correspondence relation model of NDVI and radiance temperature

From the radiance temperature map and NDVI map, we can see that the lower radiance temperatures are mainly distributed in mountainous areas of city's west and north, there has well vegetation cover, and the less human interference, while the higher values NDVI also distribute in this region, which suggest that there exist some relationship between them.

In order to objectively study the correspondence model between NDVI and radiance temperature, the researchers initially use the vector date of land use in Beijing as reference, choose characteristic section in each category, NDVI and radiance temperature values are very similar in the same type of land use, there is round distribution in graphics, they are no relation, just as shown in Figure 7. Therefore, researchers select a large profile on the same location in the images of each year,

as shown in Figure 8. Include a variety of land use types. The profile is North-South direction, throughout Beijing, the section begin at the Huairou District from north, through Changping District, Xicheng District, Xuanwu District, end of Daxing District in the final. The profile include woodland, grassland, water, construction sites and other land-use types, with strong representation, NDVI and radiance temperature have a strong relation. So we can discuss the relationship between radiance temperature and NDVI under different types of land use. Figure 6 and 7 are distribution of corresponding relation between NDVI and radiance temperature in each year.

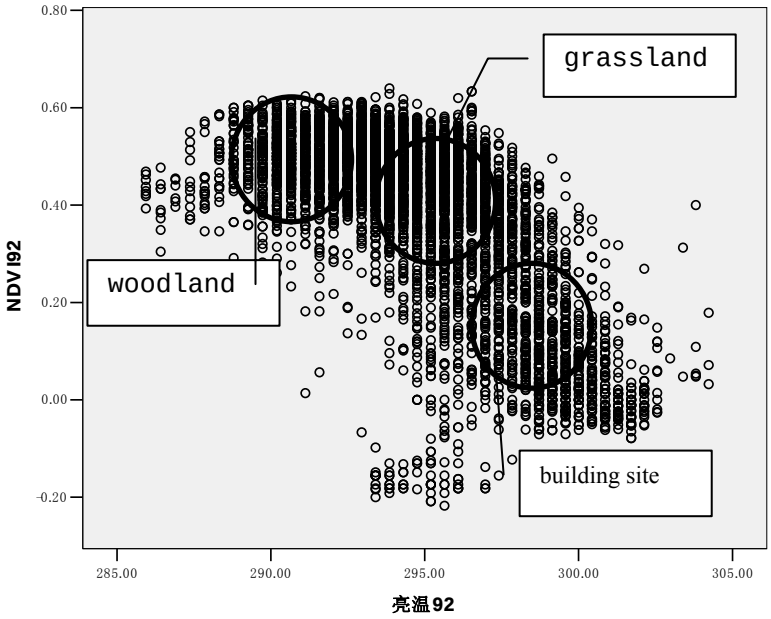

Fig7 The distribution of NDVI and radiance temperature in 1992

Fig8 The map of characteristic section

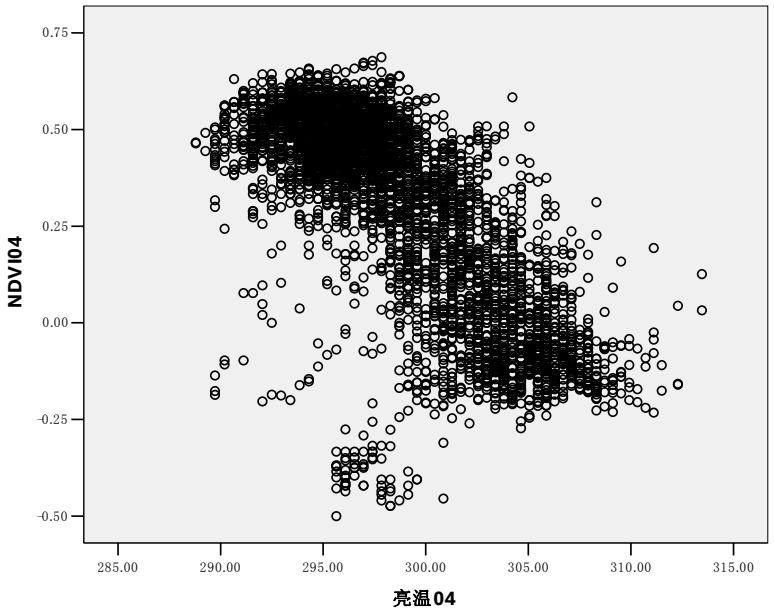

Fig9 The distribution of NDVI and radiance temperature in 2004

	regression model	regression equation	determination coefficient
1992	cube	$Tb=299.039+4.086NDVI^3-68.418NDVI^2+73.443NDVI$	0.480
	square	$Tb=298.633-4.723NDVI^2-11.916NDVI$	0.448
	linear	$Tb=299.027-11.295NDVI$	0.432
2004	cube	$Tb=303.906-9.650NDVI^3-40.643NDVI^2+53.357NDVI$	0.617
	square	$Tb=302.947-6.642NDVI^2-15.450NDVI$	0.567
	linear	$Tb=302.428-12.769NDVI$	0.526

Table1 The regression analysis of NDVI and radiance temperature

Researchers analyse the relationship between NDVI and radiance temperature with a variety of models, including the index, linear, polynomial. The results showed that polynomial model can well simulate the relationship between NDVI and radiance temperature in 1992 and 2004, well reflect the relation of radiance temperature and NDVI, just as shown in table 1.

4. CHANGES OF CORRESPONDENCE MODEL BETWEEN NDVI AND RADIANCE TEMPERATURE.

Although the regression model can not show the relationship between NDVI and the real surface temperature, it can reflect a relation, confirmed that vegetation cover can effectively reduce the urban heat island effect. From Table 1 can be seen that determination coefficient of all model in 2004 have greatly increased compared with 1992, which indicate that the relation between NDVI and radiance temperature become stronger, the changes between radiance temperature and NDVI is more regular. Determination coefficient of regression model reached about 0.5, which shows that NDVI has significant influence on the radiance temperature. From the value change, the impact of NDVI on radiance temperature become more obviously compared with 1992. The change of temperature is affected by many factors, the above-mentioned suggest that the significant of NDVI factors in temperature change become stronger.

Through the comparison of characteristics profile, the NDVI average on profile in 1992 is 0.37, the average temperature is 294.85 K; the NDVI average on profile in 2004 is 0.29, the average temperature is 298.62 K. The linear regression model show that, the absolute value of model slope increased 1.474 from 1992 to 2004. Research shows that the radiance temperature and NDVI have obvious negative correlation; with the change of time, the range radiance temperature and the average value increase, determination coefficient and the slope of the regression equation will increase, which suggest that with the Increase of NDVI, the rate of the decrease of radiance temperature increase too.

5. CONCLUSION AND DISCUSSION

⑴There are many factors impact urban heat island effect[13], the researchers only analyzed the relationship between vegetation cover and radiance temperature. The results showed that the vegetation cover and radiance temperature have significantly negative correlation, that is to say the higher the vegetation coverage, the lower the heat island effect, and vice versa.

⑵This study is designed to explore the model between of NDVI and temperature changes with time. Global warming, the heat island effect have a greater impact to people's production and daily life, with the increase of temperature, whether the role of vegetation cover in reducing urban heat island will change.

⑶Research shows that the negative correlation model between radiance temperature and NDVI is changing. With time change,

the range radiance temperature and the average value increase, determination coefficient and the slope of the regression equation will increase, that the NDVI change will cause greater changes to radiance temperature.

⑷The above analysis shows that vegetation cover in reducing the urban heat island effect has a more prominent role with high temperature. In other words, the same vegetation coverage can be more effective to reduce urban heat island effect in high temperature conditions.

⑸Radiance temperature and NDVI are affected by many reasons[14], weather, atmospheric conditions, such as the different of the date, might affect the accuracy of model, land use change between the two year also can affect the accuracy of the model. The author only selected one image in each year as representative data, so the difference in remote sensing image itself is likely to affect the accuracy of the model. At the same time, this paper use less data, the author hope that other scholars use more data to verify and edit the model that this paper study.

REFERENCES

[1]Xiaoming Hu,et al. Numerical Simulation of Features of Surface Boundary-Layer over Beijing Area. Acta Scicentiarum Naturalum Universitis Pekinesis. 2005,VOL41,NO.4,514-522.

[2]Dui Wu,Xuejiao Song. Environmental meteorology and special weather forecast[M]. Beijing: China meteorological press, 2001.12-19.

[3]Yiting Wang. Introduction to the environment [M]. Beijing: Tsinghua University Press, 1985.177-178.

[4]Wei Cao.The Influence of Heat Environment in Cities on the Eco-capacity. Planners. 2005,VOL21NO.10:15-17

[5]Ping Tian,et al. Urban Heat Island Effect and Vegetation Cover Index Relation Using Landsat TM Image. Bulletin of Science and Technology. 2006,9,VOL22NO.5,708-713

[6]Zhangyan Jiang,et al. Heat Island Effect of Beijng Based on Landsat TM Data. Geomatics and Information Science of Wuhan University. 2006,2,VOL31NO.2,121-123

[7] D. R. STREUTKER. A remote sensing study of the urban heat island of Houston, Texas.INT.J.REMOTE SENSING, 2002,VOL23, NO.13, 2595–2608

[8] Qihao Weng.Estimation of land surface temperature–vegetation abundance relationship for urban heat island studies. Remote Sensing of Environment 89 (2004) 467–483

[9]Yanxia Wang,et al. Relationship Between City Green Land and Urban Heat Island Effect. Subtropical Plant Science, 2005,34(4):55-59.

[10]Soushi Kato.Analysis of urban heat-island effect using ASTER and ETM+ Data: Separation of anthropogenic heat discharge and natural heat radiation from sensible heat flux, Remote Sensing of Environment 99 (2005) 44 – 54

[11]Sui Zhang,et al. INVESTIGATION ON HEAT-ISLAND EFFECTION IN WUHAN CITY ZONE BY REMOTE SENSING.Resources and Environment in the Yangtza Basin, 2003,12(5):445-449.

[12]Zhihao Qin,et al. Mono-window Algorithm for Retrieving Land Surface Temperature from Landsat TM6 data. Acta Geographica Sinica, 2001,56(4):456-466.

[13]Xuechun Lin ,Shuqiu Yu. Interdecadal changes of temperature in the Beijing region and its heat island effect. Chinese J . Geophys. (in Chinese) ,2005 , 48 (1) : 39～45.

[14]Xueqi Xia,et al. Analysis of Topographical Effect on Retrieval of LAI from Remotely Sensed Data. Remote Sensing Information, 2004(2):16-19.