RESEARCH ON SPATIAL-TEMPORAL CHANGE OF URBAN THERMAL ENVIRONMENT BASED ON REMOTE SENSING

Q. G. Zhou[a], Y. zhang[a] *

[a] Tourism School of Chongqing Technology and Business University, Chongqing 400067, P. R. China- (zqg1050, zy1050)@ctbu.edu.cn

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ABSTRACT:

Appling remote sensing technology to monitor urban thermal environment change, can reveal the spatail-temporal change process and discover the important regions of urban thermodynamic field distribution. In this paper, three periods LANDSAT remote sensing image were applied to analysis the changes of urban thermal environment in Chongqing China. The results indicated the processes and trends of urban thermal environment change in Chongqing urban. The spatial-temporal changes of Chongqing urban thermal environment were obvious from 1993a to 2004a. The area of higher surface temperature regions increased from 1993a to 2001a, and decreased from 2001a to 2004a. The spatial distribution of six temperature regions changed too. Where, highest temperature regions spatial distribution in 2004a was most dispersed, in which the area of highest temperature centres was the largest, but the area of single thermal centre was the smallest. And the total of high temperature centres in 1993a was the least, but the area of single high temperature centre was largest. The locations of highest temperature centre were moving mostly. The city of Chongqing was developed continuously and rapidly from 1993a to 2004a, and the area became larger. The land surface changed company with the urban expands. Reasonable land utilities can reduce the effects of urban thermal environment, which can be caused by urban expanding. This research provides references and basis for urban sustainable development and utilization.

1. INTRODUCTION

Urban thermal environment change is an important environment change reacted to the process of human activity concentration (Chelo et al. ,2006 and Jiang et al.,2007). This environment change has important impact on human production and living. No considering global climate change, the main factors that cause urban thermal environment change include three types (Lo et al., 1997). One is the change of urban land surface, such as urban expand, the change of greenbelt quantity. The other one is the change of urban geometry structure (Xiao et al., 1990). The last one is the change of the artificial energy dissipation activity. Those factors can lead to the ability change of land surface absorbing solar radiation and own emission, then cause the spatial-temporal pattern change of urban thermal distribution. Appling remote sensing technology to monitor urban thermal environment change, can reveal the spatail-temporal change process and discover the important regions of urban thermodynamic field distribution. It provides references and basis for urban sustainable development and utilization (Goward, 1981 and Xu et al., 2007).

In general, the main method of monitoring urban thermal environment is combining route and fixed point observation (Fo, 1995). This method cannot comprehensive reflect land surface radiation rapidly. The development of thermal infrared remote sensing can solve this problem better (Kealy et al, 1993 and Waton, 1992 and Jiang, 2007). It can detect temperature characters of urban land surface effectively, and reveal the change trend dynamically and periodically. Some satellites carry thermal infrared sensors, such as NOAA AVHRR, LANDSAT, CBERS, and so on. TM and ETM are the two main sensors on American LANDSAT satellite. They have higher resolution in space and spectrum. The spatial resolution of TM thermal infrared band is 120 meter, and ETM is 60 meter. Applying TM/ETM remote sensing image to monitor the change of urban thermal environment has good effect (Chen et al, 2006 and Becker, 1987).

In this paper, three periods LANDSAT remote sensing image were applied to analysis the changes of urban thermal environment in Chongqing China. After the processing of the infrared bands, the distribution maps of urban thermal environment in the three periods were obtained. Through the analysis of urban thermal environment distribution maps, the spatial distribution modes of thermal environment were revealed. After the distribution maps being overlaid by GIS technology, transfer matrixes of thermal environment between different periods were formed. The spatial-temporal change process of Chongqing urban thermal environment was found from transfer matrixes. This research can provide references and basis for urban sustainable development and utilization.

2. GENERAL CONDITIONS OF STUDIED AREA

Chongqing municipality is located at southwest of china, form 105°11′E to 110°11′E and from 28°10′N to 32°13′N. The landform of Chongqing is complex, which the area of mountain is 62466 km2, about 75.3% of total area, the area of hilly is 14954 km2, about 18.2% of total area, and flat land is only 4914 km2, about 6% of total area. The climate of Chongqing is humid monsoon climate. Because of the high temperature in summer, Chongqing is called the one of the three furnaces at

* Corresponding author: Ye Zhang; Email: zy1050@ctbu.edu.cn

Yangtze River coastal. Chongqing urban is typical mountainous city, which flat land is scarcity. And it is taken apart by Yangtze River and Jialing River. Because the fog weather is outstanding, the Chongqing urban is called fog urban.

3. DATA SOURCES AND PROCESSING

3.1 Data Sources

The remote sensing data included ETM images in 4 April 2004 and 22 MAY 2001, and TM image in 24 May 1993.

3.2 Infrared Remote Sense Images Processing

After those images been radiometric corrected and precise corrected of geometric distortion, land surface temperatures were calculated. There need three processes to calculate the land surface from TM/ETM images. Because of the differences of parameters, the calculate formals to TM and ETM are different. First, the gray value (DN) of thermal infrared image was converted into spectral radiation value (L_λ). It can be realized by formula 1 (to TM) and formula 2 (to ETM) (Bendor et al., 1997).

$$L_\lambda = 0.0056332 \times DN + 0.1238 \qquad (1)$$

$$L_\lambda = 0.0370588 \times DN + 3.2 \qquad (2)$$

Then, the spectral radiation value was converted into brightness temperature value (T_B) by formula 3. Brightness temperature is a relative temperature according to the thermal radiant intensity accepted by sensors on satellite orbit. Affected by atmosphere and land surface in the process of thermal radiating, this temperature isn't factual land surface temperature. But the land surface temperature is obtained from brightness temperature (Qin, 2001).

$$T_B = \frac{K_2}{\ln\left(\frac{K_1}{L_\lambda}+1\right)} \qquad (3)$$

Where K_1 = 60.776 $mWcm^{-2}sr^{-1}\mu m^{-1}$ to TM and 666.09 $mWcm^{-2}sr^{-1}\mu m^{-1}$ to ETM

K_2 = 1260.56 K to TM and 1282.71 K to ETM.

Because the researched area locates in a small scope with cloudless condition in the days, in which applied remote sensing image received by TM or ETM sensor, different areas have been considered as having same effect by atmosphere. And the atmosphere emission abilities of different land surface are same too. So, the value of brightness temperature can be converted into land surface temperature (St) from formula 4 (Chen et al., 2002).

$$S_t = \frac{T_B}{1+(\lambda \times T_B/\rho)\ln\varepsilon} \qquad (4)$$

Where λ =11.5 μ m

ρ =1.438×10-2MK

ε = 0.95.

According to calculation results, land surface temperature in research area was divided into high temperature region, sub-high temperature region, medium temperature region, sub-medium temperature region, sub-low temperature region and low temperature region (figure 1, 2, 3).

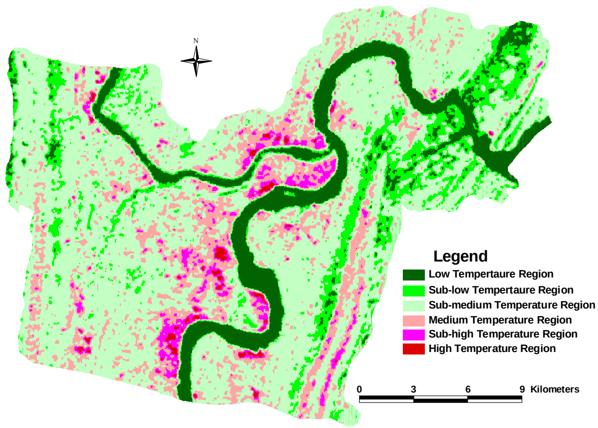

Figure 1. Land surface temperature distribution in 1993

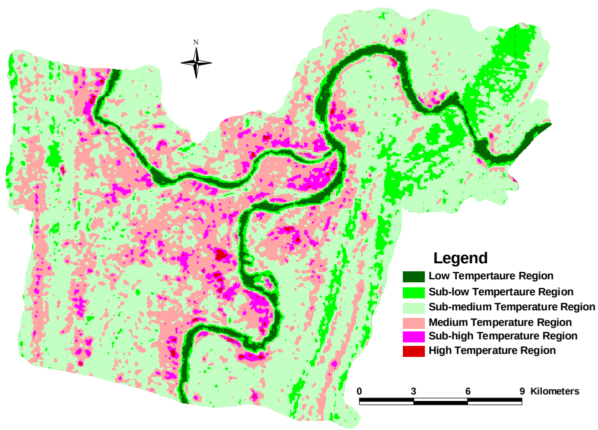

Figure 2. Land surface temperature distribution in 2001

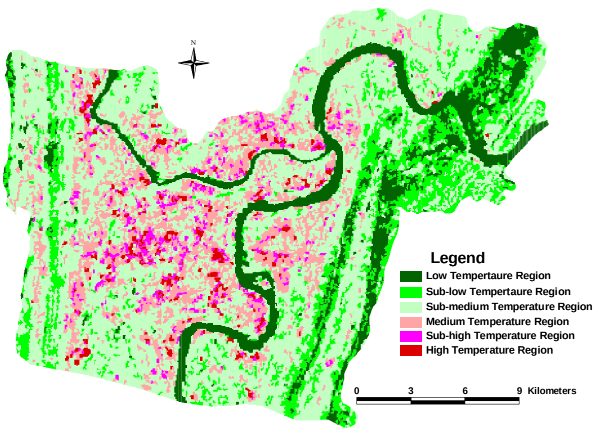

Figure 3. Land surface temperature distribution in 2004

4. ANALYSIS OF SPATIAL-TEMPORAL CHANGE OF CHONGQING URBAN THERMAL ENVIRONMENT

4.1.1 Spatial distribution of Chongqing Urban Thermal Environment

Then the spatial distributions of the six temperature region were analyzed from figure 1 to figure 3 and table 1. High and sub-high temperature regions concentrated distributed around few high temperature centres in 1993, which only occupied 3.02% of the total area. The high temperature centres main close to river. In 2001, the area of High and sub-high temperature regions was 2674 hectare, which occupied 3.78% of the total area. The high temperature centres become more, some close to river, and some in other area. In 2004, the area of high and sub-high temperature regions was 3310 hectare, which occupied 4.68% of the total area. High temperature centres main located in the area which far from river.

Year		Low Temperature Region	Sub-low Temperature Region	Sub-Medium Temperature Region	Medium Temperature Region	Sub-high Temperature Region	High Temperature Region
1993	Area(Hectare)	28132	4200	24694	11552	1986	150
	Percentage of total area (%)	39. 78	5. 94	34. 92	16. 34	2. 81	0. 21
2001	Area(Hectare)	26374	7253	28798	5615	2385	289
	Percentage of total area (%)	37. 3	10. 26	40. 72	7. 94	3. 37	0. 41
2004	Area(Hectare)	31909	7180	20620	7695	2250	1060
	Percentage of total area (%)	45. 12	10. 15	29. 16	10. 88	3. 18	1. 5

Table1. The Distribution of Six Temperature Region in Three Periods

	Low Temperatur e Region	Sub-low Temperatur e Region	Sub-Medium Temperatur e Region	Medium Temperatur e Region	Sub-high Temperatur e Region	High Temperatur e Region	Total Amount of Convertin g in	Percen t (%)
Low Temperatur e Region		12	1	0	0	0	13	0. 1
Sub-low Temperatur e Region	1909		441	1	0	0	442	3. 34
Sub-Medium Temperatur e Region	893	2996		1467	15	0	4478	33. 83
Medium Temperatur e Region	343	167	6100		629	47	6943	52. 45
Sub-high Temperatur e Region	73	4	175	866		154	1199	9. 06
Temperatur e Region	8	1	5	9	38		53	0. 4
Total Amount of Converting out	3226	3180	6722	2343	682	201		
Percent (%)	19.74	19.46	41.13	14.33	4.17	1.23		

Table2. Temperature Regions Transfer from 1993 to 2001 Unit: Hectare

	Low Temperature Region	Sub-low Temperature Region	Sub-Medium Temperature Region	Medium Temperature Region	Sub-high Temperature Region	High Temperature Region	Total Amount of Converting in	Percent (%)
Low Temperature Region		2802	1193	54	4	0	4053	19.70
Sub-low Temperature Region	9		5269	96	3	0	5377	26.14
Sub-Medium Temperature Region	25	398		5664	331	8	6426	31.24
Medium Temperature Region	2	28	1993		819	18	2860	13.90
Sub-high Temperature Region	0	8	271	720		10	1009	4.90
Temperature Region	0	3	150	289	404		846	4.11
Total Amount of Converting out	36	3239	8876	6823	1561	36		
Percent (%)	0.18	15.75	43.15	33.17	7.59	0.18		

Table3. Temperature Regions Transfer from 2001 to 2004 Unit: Hectare

4.2 Spatial-Temporal Change of Chongqing Urban Thermal Environment

The processes and trends of urban thermal environment change in Chongqing urban can be found from table2 and table 3. The spatial-temporal changes of Chongqing urban environment were obvious from 1993 to 2004.

The areas of all the six temperature regions changed. Among them, the area of higher surface temperature regions increased from 1993 to 2001, and was decreased from 2001 to 2004. The spatial distribution of the six temperature regions changed too. Where, highest temperature regions spatial distribution in 2004 was most dispersed, in which the total of highest temperature centre was the most, but the area of single thermal centre was the smallest. And the total thermal centre in 1993 was the least, but the area of single thermal centre was the largest. The locations of highest temperature centre were moving mostly. From 1993 to 2001, 201hm2 of other temperature regions converted into high temperature region, and then only 531hm2 of high temperature region converted to other temperature regions converted. However, the total area of high temperature region decreased about 710 hm2 from 2001 to 2004. The city of Chongqing was developed continuously and rapidly from 1993 to 2004, and the area became larger. The land surface changed company with the city expands. Reasonable land utilities can reduce the effects of urban thermal environment, which can be caused by urban expanding. Comparing to 1993, the direction of land surface become hotter in northwest and east mainly.

5. CONCLUSIONS

Appling RS technology, it is possible to analysis the distribution of thermal environment according to the practical needs of a specific region. And the high spatial and temporal resolution of remote sense images can make the research of urban thermal environment change more effective.

In Chongqing urban, the temperature regions changed from 1993 to 2004. The distributions of highest temperature regions were experienced a process from concentration to dispersion. In total, the urban thermal environment becomes hotter from 1993 to 2004. The change process of highest temperature centres from 1993 to 2004 indicates that urban expand is not always cause land surface hotter. Unreasonable land use is the main cause to make urban hotter. Reasonable land utilities can reduce the effects of urban thermal environment. According the distraction and the change of urban thermal environment, the government of Chongqing urban should take measures to prevent and control urban thermal pollution.

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