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Inversion and Variation Analysis of Urban Surface Temperature based on Landsat 8 Data

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Abstract. In order to study the change of urban surface temperature, the urban heat island effect was studied. Taking Changqing District of Jinan City as the research object, Landsat 8 images from 2013 and 2019 in the research area were used, and remote sensing technology was combined with the spectral characteristics of remote sensing images to retrieve the surface temperature in Changqing District and analyse its surface temperature change. The research results show that the temperature in the urban area is relatively high, and the surface temperature in Changqing District in 2019 showed a significant upward trend compared to 2013. Further analysis indicates that there is a heat island effect in Changqing District, and relative departments can adopt measures such as increasing urban green area and water volume to alleviate the urban heat island effect and thermal environmental problems.

Keywords: Landsat8, Inversion of surface temperature, Thermal infrared remote sensing, Urban heat island effect

1. Introduction

With the urban heat island effect and global climate change, urban related surface temperature changes have attracted more and more attention from domestic and foreign scholars. Surface temperature plays a crucial role in the exchange of energy between the Earth's surface and the atmosphere, and has an important impact on climate, environmental change, and human production and life. Land surface temperature change is one of the important indicators for monitoring earth resources and studying surface ecological environmental systems, and is of great significance for hydrological, ecological, environmental, and biogeochemical studies. Since the launch of TIROS-II in the 1960s, people have begun to measure sea surface temperature using satellite thermal infrared bands. With the continuous development of remote sensing technology and the continuous improvement of satellite data quality, the technology of using meteorological satellite data (such as NOAA-AVHRR) to obtain sea surface temperature is gradually becoming mature [1]. The success of sea surface temperature remote sensing inversion technology has made land surface temperature remote sensing inversion become another research hotspot in the field of remote sensing. Many researchers have conducted surface temperature inversion based on different thermal infrared data [2-5]. Research results show that surface temperature inversion plays an important role in urban heat island effect analysis, geothermal resource exploration, and so on. [6-7]. At the same time, surface temperature is an indispensable and important impact factor in many aspects such as studying global climate change, ecological assessment, disaster monitoring, and urban thermal environment conditions. Based on the remote sensing data, it can provide rich quantitative and qualitative analysis data for real-time monitoring of regional changes.

Based on this, using remote sensing technology to retrieve surface temperature from images of the study area provides a reliable basis for urban temperature change analysis. This article uses remote sensing images from Landsat 8 sensors and their thermal infrared spectral characteristics to calculate and divide the surface temperature in Changqing District, Jinan City, to obtain two urban surface temperature distribution maps. It compares and analyses the surface temperature distribution in Changqing District in 2013 and 2019, and analyses the heat island effect in Changqing District from the changes in temperature distribution locations

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and temperature trends, and then study the relationship between surface temperature changes and urban development planning.

2. Materials and Methods

2.1. Area analysis

Changqing District is located in the southwest of Jinan City with a long history and culture, a beautiful ecological environment, and prominent geographical advantages. The sloping terrain is high in the southeast and low in the northwest. From southeast to northwest, it is followed by mountains, hills, piedmont plains, and the Yellow River depression. The length from north to south is 50.3 kilometres, and the width from east to west is 50.8 kilometres. The total area is 1178.08 square kilometres.

2.2. Data introduction

The image data in this article is the Landsat 8 sensor data [8] are downloaded from the geospatial data cloud platform (the image data of Changqing District, Jinan City in September 2013 and September 2019). The data processing mainly uses remote sensing software ENVI5.3 and ArcMap10.7 to achieve the cutting of vector data in the research area.

2.3. Method

In this paper, the Atmospheric correction method [9-10] is used for retrieving surface temperature. Its basic principle is to estimate the impact of the atmosphere on surface thermal radiation firstly, and then subtract this part of the atmospheric impact from the total amount of thermal radiation observed by satellite sensors to obtain the intensity of surface thermal radiation, which is then converted into the corresponding surface temperature.

3. Analysis of Surface Temperature Changes

3.1. Calculation of surface specific emissivity

In this paper, the NDVI threshold method proposed by Sobrino is used to calculate the surface specific emissivity,

$$\varepsilon = 0.004Pv + 0.986 \tag{1}$$

Where, *Pv* is the vegetation coverage, calculated using the following formula:

$$Pv = [(NDVI - NDVI_{soil})]/[(NDVI_{Veg} - NDVI_{soil})] \tag{2}$$

In the formula, NDVI is the normalized vegetation index, $NDVI_{Soil}$ is the NDVI value for areas completely covered by bare soil or vegetation, and $NDVI_{Veg}$ represents the NDVI value of pixels completely covered by vegetation, that is, the NDVI value of pure vegetation pixels. Take the empirical values $NDVI_{Veg}$=0.70 and $NDVI_{Soil}$=0.05, that is, when the NDVI of a certain pixel is greater than 0.70, the value of Pv is 1; When NDVI is less than 0.05, Pv takes a value of 0.

Using ENVI software to calculate and obtain vegetation coverage images based on (b1 gt 0.7) * 1+(b1 lt 0.05) * 0+(b1 ge 0.05 and b1 le 0.7) * (b1-05) / (0.7-0.05).

We calculate the surface specific emissivity image based on (0.004 * b1+0.986).

3.2. Blackbody radiation brightness and surface temperature calculation

Inputing parameters such as imaging time and center longitude and latitude to obtain atmospheric profile information of Changqing image. After obtaining the Band10 radiation brightness images of the two images using the original image, the formula for calculating the blackbody radiation brightness is derived from the above:

$$(b2 - 0.65 - 0.92 \times (1 - b1) \times 1.12)/(0.92 \times b1) \tag{3}$$

$$(b2 - 1.59 - 0.8 \times (1 - b1) \times 2.65)/(0.8 \times b1) \tag{4}$$

Where, *b1* is the surface specific emissivity image; *b2* is the Band10 radiation brightness image. The blackbody radiation brightness image at the same temperature can be calculated.

Using (1321.0789)/log (774.8853/b1+1) - 273; (1321.0789)/log (774.8853/b1+1) - 273, where *b1* is a blackbody radiance image at the same temperature, and two periods of surface temperature images in degrees Celsius can be calculated separately (Fig. 1).

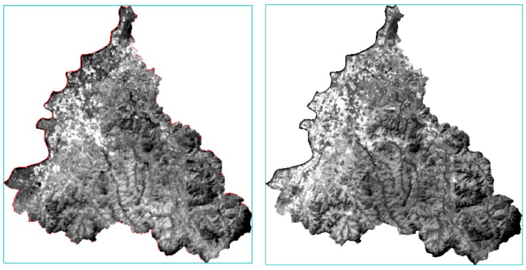

Fig.1: Surface temperature images in 2013 (left) and 2019 (right)

3.3. Division of surface temperature

The surface temperature image layer in the layer manager divides the temperature into 16 temperature regions. Browsing the spatial distribution range of several temperature ranges (see Fig. 2).

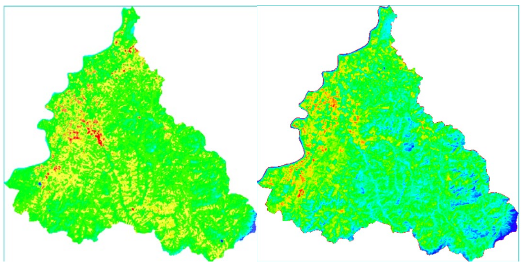

Fig.2: Temperature interval distribution in Changqing District in 2013 (left) and 2019 (right)

3.4. Comparative analysis of surface temperature distribution

After completing the surface temperature calculation, the statistical inversion results show that 81% of the temperature in Changqing District in September 2013 was concentrated in the range of 22 ℃ to 26 ℃, while the temperature in Changqing District in September 2019 was mainly concentrated in the range of 25 ℃ to 31 ℃ (Fig.3). According to the query, the temperature range in Changqing District of Jinan City in September 2013 was mainly between 22 ℃ and 26 ℃; The surface temperature in September 2019 was mainly between 25 ℃ and 31 ℃, so most of the inversion results in this study are within this range, and the inversion results have certain reference value.

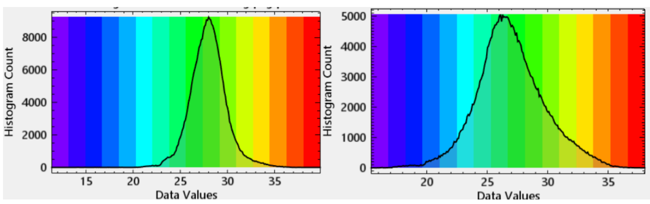

Fig.3: Surface temperature interval in Changqing Region in 2013 and 2019

The temperature in the same month from 2013 to 2019 showed an overall upward trend based on the two images, and the higher temperature range was mainly distributed in urban land. From this study, we can obtain the inversion results of surface temperature in Changqing District and the changes in its temperature distribution range. Based on this, it can be found that the study area is mainly composed of sub low temperature areas and mid temperature areas, with a significant increase in the range of mid temperature areas from 2013 to 2019. The distribution map shows that the average surface temperature of urban construction land is the highest, while the average surface temperature of mountains, water bodies, and other non-urban features is relatively low, reflecting the urban heat island effect to some extent. Further analysis shows that the temperature rise in Changqing District is closely related to global warming, urban development, and human activities.

4. Conclusion

In this paper, we used Landsat8 data to obtain the surface temperature of Changqing district from 2013 to 2019, combined with the remote sensing technology the spectral characteristics of remote sensing images. The main conclusions are as bellows,

(1) After completing the surface temperature calculation, the statistical inversion results show that 81% of the temperature in Changqing District in September 2013 was concentrated in the range of 22 ℃ to 26 ℃, while the temperature in Changqing District in September 2019 was mainly concentrated in the range of 25 ℃ to 31 ℃.

(2)The temperature in the same month from 2013 to 2019 showed an overall upward trend, and the higher temperature range was mainly distributed in urban land, which may be paid attention for the government.

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6. References

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