A Study of Land Surface Temperature Retrieval and Thermal Environment Distribution Based on Landsat-8 in Jinan City

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Abstract. Based on the medium resolution Landsat 8 OLI/TIRS, the temperature distribution in four seasons of urban area in Jinan City was obtained by using atmospheric correction method for the retrieval of land surface temperature. Quantitative analysis of the spatio-temporal distribution characteristics, development trend of urban thermal environment, the seasonal variation and the relationship between surface temperature and normalized difference vegetation index (NDVI) was studied. The results show that the distribution of high temperature areas is concentrated in Jinan, and there is a tendency to expand from east to west, revealing a negative correlation between land surface temperature distribution and NDVI. So as to provide theoretical references and scientific basis of improving the ecological environment of Jinan City, strengthening scientific planning and making overall plan addressing climate change.

1. Introduction
With rapid economic development and rapid population growth, the expansion of urban scale results in urban heat island in China, which seriously affected the urban local climate, air waste, residents’ physical health, economic growth and so on.

RS and GIS tools were used to monitor urban thermal environment [1, 2]. By using thermal infrared remote sensing images, American scholar Gallo [3] studied the relationship between the ground temperature and normalized vegetation index NDVI in a region of Seattle, and obtained a conclusion that the two mention above have an inverse relationship. Rao [4] used remote sensing images of thermal infrared channels to invert the surface temperature of different parts of the city for the first time. Based on the remote sensing images of Landsat TM thermal infrared channels, scholars Larson and Camahan [5] studied the surface temperature distribution of the study area to conclude that the surface temperature in urban area is higher than that in rural areas.

The Range of latitude and longitude in Jinan City is 36° 1’N-37° 4’ and 116° 12’-117° 44’. In Jinan, the south is high in terrain, while the north is low. Jinan city is responsible for important economic, social and political functions.

As the capital city of Shandong Province, the impact of heat island effect is more obvious in Jinan City, especially in summer and autumn. So the study of urban thermal environment is only a research focus but also of highly important practical significance.
2. Data Sources & Technical Process of the Study

The satellite images used in this study are Landsat 8 OLI / TIRS data from Jinan City, which are downloaded from the geospatial data cloud. And four clear images took are selected. And the DEM data is the global 900 m spatial resolution elevation data used to calculate the average elevation of the study area. Atmospheric profiles can be obtained by entering the shadow and centre latitude and longitude from the website provided by NASA.

Technical process of the study is shown in Figure 1.

![Diagram](Fig 1. Technical Process.

3. Results & Analysis

3.1. Seasonal Distribution Characteristics of Thermal Environment

Comparing the surface temperature intensity grade map of the four seasons of Jinan City, a result shows that the urban heat island in summer and autumn is more obvious, followed by spring, and in winter the city has the weakest heat island effect. The temperature distribution curves are in accordance with the normal distribution. The specific temperature classification and the statistics of surface temperature in four seasons is shown in Table 1 to Table 4, and results of density slice are shown in Figure 2 to Figure 5.
### Table 1. Classification of Spring Surface Temperature in Jinan Urban Area

| Level | Low temperature zone | Sub moderate temperature zone | Moderate temperature zone | Sub high temperature zone | High temperature zone |
|-------|-----------------------|-------------------------------|---------------------------|---------------------------|-----------------------|
| Multiple of variance Surface temperature (°C) | >1                      | 0.5                          | 0.25                      | 0.25                     | 1                     |
|       | 0-13.62               | 13.62-18.60                  | 18.60-21.09               | 21.09-23.58               | 23.58-33.83           |
| Percentage (%) | 1.6369               | 18.4827                      | 35.7514                   | 32.6438                   | 11.4868               |

### Table 2. Classification of Summer Surface Temperature in Jinan Urban Area

| Level | Low temperature zone | Sub moderate temperature zone | Moderate temperature zone | Sub high temperature zone | High temperature zone |
|-------|-----------------------|-------------------------------|---------------------------|---------------------------|-----------------------|
| Multiple of variance Surface temperature (°C) | <2.5                  | 0.5                          | 0.25                      | 0.25                     | 0.5                   |
|       | 0-31.43               | 31.43-35.64                  | 35.64-37.75               | 37.75-39.86               | 39.86-49.00           |
| Percentage (%) | 0.0195        | 8.0424                       | 43.5008                   | 29.0801                   | 15.1954               |

### Table 3. Classification of Autumn Surface Temperature in Jinan Urban Area

| Level | Low temperature zone | Sub moderate temperature zone | Moderate temperature zone | Sub high temperature zone | High temperature zone |
|-------|-----------------------|-------------------------------|---------------------------|---------------------------|-----------------------|
| Multiple of variance Surface temperature (°C) | >1                      | 0.5                          | 0.25                      | 0.25                     | 1                     |
|       | 0-19.77               | 19.77-26.95                  | 26.95-30.54               | 30.54-34.13               | 34.13-47.00           |
| Percentage (%) | 0.6810        | 12.1859                      | 51.5447                   | 24.7418                   | 10.8450               |

### Table 4. Classification of Winter Surface Temperature in Jinan Urban Area

| Level | Low temperature zone | Sub moderate temperature zone | Moderate temperature zone | Sub high temperature zone | High temperature zone |
|-------|-----------------------|-------------------------------|---------------------------|---------------------------|-----------------------|
| Multiple of variance Surface temperature (°C) | >1                      | 0.5                          | 0.75                      | 1                         | 2                     |
|       | -18-1.27              | 1.27-2.09                    | 2.09-3.32                 | 3.32-4.96                 | 4.96-13               |
| Percentage (%) | 27.5746        | 18.0826                      | 37.7643                   | 15.0338                   | 1.5448                |
3.1.1. Analysis in summer. In summer, the temperature of land surface in summer is mainly distributed around 36 °C. The high temperature area in summer accounts for 15.1954% in the study area, which is the highest among the four seasons. The variance in summer is relatively large, which explains the surface temperature is relatively dispersed.

There are four high-temperature areas in summer, which are the northern part of the northwest corner of the Yellow River, the built-up area center, the high-tech zone and the soil area in southern mountainous areas. The built area center and high-tech zones of the two high-temperature area link up into a single stretch, being in accordance with the direction of urban expansion.

The temperature of the waters is relatively low, such as Yellow River, Queshan Reservoir, Wohushan Reservoir, also a few sporadic low-temperature areas in the southern mountains.

3.1.2. Analysis in autumn. In autumn, the temperature is mainly distributed around 28 °C. The high temperature area is concentrated mainly on the area beside the Daming Lake, extending from east to west, among which the high temperature area located in the east of the high-tech zone is scattered.
Moreover, due to higher soil moisture content under vegetation and absorbed heat flying to the atmosphere that can be converted into latent heat, the surface temperature of the southern mountainous areas is relatively low.

3.1.3. Analysis in Spring & Winter. In spring, the temperature is mainly about 16 °C. Although the high temperature areas in spring accounts for 11.4868%, urban heat island is not serious as shown in Figure 2. And its high temperature areas are mostly distributed in the southern mountainous area, which is mainly because of low vegetation coverage.

In addition, when it is the satellite shooting time (GMT 02:48 or so), bare soil that have a smaller heat capacity warms up fast, which resulted in a large high temperature area. Benefiting from the sufficient spring water and the adjustment of Daming Lake and Magpie Hill reservoir, the temperature in the center areas beside Daming Lake is not too high.

In winter, the temperature is mainly about 3 °C, and its high temperature zone takes up only 1.5448% of the study area, which is the smallest in four seasons. The high temperature area is mainly distributed in waters such as Wohushan Reservoir, Daming Lake, Eastern High-tech Zone Jinan Iron and steel plant.

When it is the time of taking images (GMT10:48 or so), the height of the sun in the winter is relatively low, resulting in rise of the temperature above the ground is not fast. From Table 1, the maximum surface temperature is 13.690857°C, while the average value is 1.270211 °C. At night the temperature is higher than that on land because the water has a high heat capacity, causing the surface temperature still lower than the surface of the water. As for the high-temperature area of Jinan Iron and Steel Plant, the surrounding heat was caused by that of being emitted from the steel plant.

3.2. Spatial Distribution Characteristics of Thermal Environment
The maps of heat island trend ellipse and heat island center of four seasons in Jinan city are shown in Figure 6-9.

It can be seen from Figure 8 that the direction of the expansion of urban heat island is southwest-northeast, and the long axis of the trend ellipse is mainly within the range between Jinan International Convention and Exhibition Center and Wohushan Reservoir.

In summer, the heat island of Jinan (Figure 6) mainly expands from Daming Lake to Jinan Iron and Steel Plant. The direction is still southwest-northeast, and the heat island focus is near the Quanfu Intersection; In autumn, heat island expands from University of Jinan to Olympic Sports Center. The focus is probably in the intersection of Jingshi Road and Shanda Road; in winter, the heat island area is small, mainly expanding from Wohushan reservoir to Jinan Iron and Steel Plant, and the heat island center is located in Shandong Provincial Museum.

In general, the direction of the development of urban heat island is closely related to the development of Jinan City. The direction of the island was southwest-northeast, in accordance with the direction of urban development in Jinan, especially when the southwest area and high-tech zone is growing more and more rapidly. At these places, the underlying surface is mainly impermeable to concrete, bringing the city heat island effect more obvious.
3.3. Correlation Analysis of Surface Temperature and NDVI

In order to study the relationship between spatio-temporal distribution of thermal environment and vegetation, the study uses the NDVI distribution map to analyze in the same period. The data that was selected in 536 points (NDVI>0) were imported into regression analysis to evaluate the correlation between NDVI and surface true temperature.

The relationship between surface temperature and NDVI in summer and autumn is studied because the effect of vegetation cover on surface temperature is negligible. The results are as follows.

It can be seen from Figure 10 and Figure 11 that the correlation between the true temperature and NDVI is negative. In summer, NDVI values in the southern mountainous areas increased, and the inhibition of temperature was significant; In autumn, the NDVI increases more obviously, and the NDVI value of the region is basically the same as the distribution of high temperature area.

From Figure 12 to Figure 13, it is clear that the NDVI values in the southern mountainous areas are generally small, while the vegetation cover is low and the temperature increases rapidly after the surface absorbing the surrounding heat. But waters are rather special with low NDVI values. This is because specific heat capacity of water is relatively large and the surface temperature rises slowly.
In places like the railway station, main road, business district, long-distance passenger station and other places with a large flow of people, artificial surface is relatively dense and the NDVI value is small, resulting in relatively high surface temperature.

Fig 10. Summer Surface Temperature and NDVI Correlation Analysis.

Fig 11. Autumn Surface Temperature and NDVI Correlation Analysis.

Fig 12. NDVI of Summer.

Fig 13. NDVI of Autumn.

4. Conclusion
The results of this paper show the distribution of the surface temperature of spring, summer, autumn and winter in Jinan. Then the temperature stratification, statistical analysis, thermal environment time, spatial distribution characteristic and the correlation analysis between surface temperature and NDVI were carried out based on the surface temperature distribution. The results are as follows:

1. Combined with density slice analysis of four seasons of, the heat island effect in spring and summer is more obvious;
2. The results show that the temperatures in spring, summer, autumn and winter are mainly distributed at 15-25 °C, 30-40 °C, 26-36 °C and -2-5 °C respectively. Variance of winter is relatively small, with a more concentrated pixel distribution;
3. The results show that the temperature distribution curves in Jinan are in accordance with the normal distribution;
4. The development direction of Jinan city hot island is southwest-northeast, in accordance with the direction of urban development in Jinan;
5. The results show that the real temperature and NDVI have a negative correlation, with the correlation coefficients 0.68 and 0.66 respectively.
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