Wetland Monitoring and Land Surface Temperature Response in Panjin City Based on Tiangong-2 Data

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Abstract. In the research area Panjin city, visible and near-infrared remote sensing images by Tiangong-2 wide-band imaging spectrometer was used to extract wetland. According to the established remote sensing interpretation signs, the wetland types of Panjin city in 2018 are extracted by using the method of partition classification. The thermal infrared imaging spectrometer of Tiangong-2 was used to invert the land surface temperature based on the split-window algorithm. This paper comprehensively analyzed the distribution of wetland cover types of Panjin city in 2018 and their impact on land surface temperature. The results show that in 2018, Panjin wetland covers an area of 3,184.89 km\textsuperscript{2} and the major type of wetland is artificial wetland. The area is reduced successively according to paddy field, reed swamp, mudflat wetland, suaeda salsa swamp, aquaculture farm, reservoir/pond and river wetland. The overall accuracy of partition classification method is 89.97\%, kappa coefficient is 0.8761. The applicability of Tiangong-2 wide-band imaging spectrometer in wetland monitoring is verified. The split-window algorithm can be used to effectively invert the land surface temperature of Tiangong-2 data, and the land surface temperature results obtained by inversion are in good consistency with those obtained by MODIS inversion, the correlation coefficient reached 0.79. Through counting, the land surface temperature of different wetland types is different, among which the land surface temperature of mudflat wetland is the highest and that of reservoir is the lowest.

1. Introduction
Wetlands have a wide range of distribution, contain stable environment, protect biodiversity function, and play an extremely important role in the global and regional ecological process. Wetlands, together with oceans and forests, are known as the three major ecological systems of the earth [1]. Panjin wetland is located in the core of Liaohe Delta, and is the largest warm temperate coastal wetland in China and even in Asia [2]. The wetland area of Panjin city plays a decisive role in climate regulation and air purification of northeast China and even the whole country and surrounding countries. In recent years, due to the interference of natural and human factors, wetlands are suffering from the impact of climate change, overexploitation or other factors, which leads to wetland areas, ecological function and health status of the ecosystem declined sharply [3]. In order to protect the ecological environment of Panjin wetland, carry out wetland restoration project, rationally develop wetland resources, and realize
sustainable utilization, it is necessary to master the surface cover status of Panjin wetland, so as to systematically and deeply study the structure, function, value and function of wetland.

Land surface temperature (LST) reflects the energy change and exchange process of the earth surface material, which is an important index of earth science research. The regional distribution of LST has important application value in the fields of climate change, vegetation ecology, environmental monitoring and urban heat island [4]. Scholars at home and abroad have proposed a variety of LST inversion methods for different sensors. These algorithms can be roughly divided into five categories: single-channel algorithm, multi-channel algorithm, multi-angle algorithm, multi-temporal algorithm and hyperspectral inversion algorithm [5]. In the multi-channel algorithm, the split-window algorithm for two thermal infrared channel data is simple and mature, and it is one of the most widely used temperature inversion algorithms at present. The split-window algorithm was originally proposed by McMillin et al [6], which is based on two thermal infrared bands of AVHRR data to retrieve sea surface temperature, and then it has been extended to land surface temperature inversion. In recent years, scholars at home and abroad have carried out a series of research and application of split-window algorithm based on ASTER [7], MODIS [8], Landsat-TIRS [9], Himawari 8 AHI [10] and other data.

The Tiangong-2 is the second Space Laboratory independently developed by China. It combining image and spectrum is a new generation optical sensing instrument. It is the first time for a single instrument at home and abroad to realize the integration function of visible light, hyperspectral, short-wave infrared and thermal infrared multi-spectral wide-field of view full push-sweep imaging [11]. According to the current researches on wetlands, Landsat, MODIS and high-resolution remote sensing images are the main remote sensing data sources, and the researches on Tiangong-2 data are relatively limited. Moreover, there are few recent studies on Panjin wetland, especially on the combination of wetland type and wetland LST response.

In conclusion, this article is based on Tiangong-2 data, using RS and GIS technology, set up suitable for Panjin wetland classification system, at the same time select suitable for Panjin wetland classification algorithm in many algorithms. Based on the results of wetland extraction, the spatial distribution of Panjin wetland was discussed, and the rationalization of remote sensing monitoring process for China's wetlands was proposed, and the corresponding relationship between LST inversion and various types of wetlands was explored.

2. Study Area and Data

2.1. Study Area

Panjin city is a well-known wetland capital and ecological homeland. Shuangtai Estuary wetland in Panjin city has been included in the list of wetlands of Ramsar Convention. Panjin wetland is located in the south of Songliao plain which is in the core area of Liaohe Delta, at the mouth of Daliaohe river, Shuangtaizi river and Daling river. The geographical position is between 40°39′ N~41°27′ N, 121°25′E~122°31′E. Panjin wetland covers an area of 315,000 hectares, accounting for about 80% of the whole area, and plays an important role in climate regulation and air purification of Liaoning province and surrounding areas. The area is low-lying and flat, with an altitude of 1.3~4.0 m, belonging to the warm temperate continental sub-humid monsoon climate zone. The climate features four distinct seasons, the same season of rain and heat, the same season of dry and cold, appropriate temperature and abundant sunlight, with obvious monsoon climate characteristics. The average annual temperature is 9.2℃, and the average annual precipitation is 651 mm. Wetland vegetation mainly consists of reed swamp and paddy field. Panjin wetland is the largest coastal reed swamp in the world, and its reed output ranks second in the world (figure 1).
2.2. Data
The Tiangong-2 Space Laboratory was launched on September 15, 2016, and enter the orbit on September 23, 2016. The platform provided data services after June 2017. Until July 19, 2019, it was off track. Tiangong-2 space experiments involving multiple fields, among them, earth observation and space earth science include a wide-band imaging spectrometer, three-dimensional imaging microwave altimeters and ultraviolet edge imaging spectrometers. The wide-band imaging spectrometer is the first in the world to be packaged as a single instrument [12]. Wetland extraction should be carried out with images with abundant rainfall and high leaf green content, and the cloud amount should be less than 10% to ensure the quality of remote sensing images. Therefore, the data of Tiangong-2 wide-band L2 grade after system radiation and geometric correction on June 1, 2018 was selected, which was derived from the official manned space applications data promotion platform (http://www.msadc.cn/), the spatial resolution is 100m. The accuracy of the data extracted from the Tiangong-2 wetland was evaluated by the Landsat 8 operational land imager (http://glovis.usgs.gov/) remote sensing image of the region on May 5, 2018. Due to the poor quality of thermal infrared image data on June 1, 2018, the L2 product obtained at 10:00 on August 10, 2018, which is similar to its date, was selected with a spatial resolution of 400m. And this data a scene image can cover Panjin city scope, the image quality is good, the cloud amount is small. LST inversion results verify that with the help of MODIS LST data product MOD11A (https://modis.gsfc.nasa.gov/).

3. Methodology
3.1. Technical route
The selected remote sensing images are firstly preprocessed, including radiation calibration, atmospheric correction, geometric precision correction and image clipping according to the study area. The main methods of remote sensing interpretation of wetland include index threshold method [13], the support vector machine (SVM) classification method [14], decision tree classification [15], object-oriented classification method [16], multiband multi-platform composite remote sensing classification [17], etc. Based on the characteristics of multiple spectral channels of Tiangong-2 wide-band imager, adopt the method of partition classification for target object extract. According to the spectral curve of surface features and Normalized Difference Vegetation Index (NDVI), the wetland was roughly classified, and then further distinguished by shape index combine with spectral curve.

In this paper, on the basis of the traditional split-window algorithm, the LST of Panjin city is inversed by adjusting the parameters of the algorithm according to the characteristics of Tiangong-2 with two adjacent thermal infrared bands (T1: 8.125 ~ 8.825 μm, T2: 8.925 ~ 9.275 μm). The LST can be obtained by combining the radiation transmission equations of two thermal infrared bands. The type of wetland and the land LST of the extracted Panjin city are evaluated. And then the LST of different wetland types is compared and analyzed. The specific flow chart is shown in the figure 2.
3.2. Wetland information interpretation

According to the requirements of the relevant technical regulations of wetland monitoring, such as the standards of wetland classification in the national technical regulations on wetland resources investigation, combining the actual situation of Panjin wetland and the interpretation mark of Tiangong-2 images. Finally, a secondary classification system of wetland suitable for the study area was established. The first category is divided into natural wetland and artificial wetland. The second level is divided according to the hydrological status and landscape type of the wetland. The natural wetland is divided into mudflat wetland, Suaeda salsa swamp, reed swamp and river wetland, while the artificial wetland is divided into paddy field, reservoir/pond and aquaculture farm.

Based on the established wetland classification system of Panjin city, combined with the characteristics of the study area, the spectral characteristics of the ground objects show that the spectral differences of water bodies, vegetation and mudflat are obvious, and the method of partition classification [18] is more suitable. According to the difference of the spectral curve, the study area is roughly classified into the mudflat wetland, the water body and the vegetation, and then the three zones are classified separately.

3.2.1 Extraction of vegetation information. For the secondary classification of vegetation areas, the spectral curve characteristics of typical vegetation can be used. The vegetation area mainly includes the vegetation reeds and Suáeda salsa in the coastal wetland, and the spectral characteristics of suáeda salsa swamp and reed swamp under the Tiangong-2 wide-band imager. It can be seen that the peak value of reed swamp in the green band (band10) and the valley value of suáeda salsa swamp in this band can be used to identify two types of ground features as opposed to their peak and valley value in the red band (band8). Because of the water body information, the paddy field can have the vegetation index NDVI=(NIR-R)/(NIR+R), in which the near-infrared band and the red band are brought into band4 and band8 respectively, and the reflectivity of the band6 band is low are combined for extraction. For green land mixed with coastal vegetation and paddy fields, the normalized difference vegetation index can be used to eliminate them.

3.2.2 Extraction of water body information. Secondary classifications of water bodies are river, aquaculture and reservoir/pond. Because the spectral curves of different types of water bodies have little difference, but their shape characteristics are obviously different, so shape index [19] is selected as for...
further classification. Shape index is a measure of spatial structure that represents the geometric shape of plaque. It reflects the regular degree of plaque. The more irregular the shape of plaque, the smaller the shape index. That is to say, the shape index of water patch can effectively identify water body types, for example, the river is curved and the reservoir is flat. In addition, aquaculture farms have a similar shape index to reservoirs, but aquaculture farms have regular distribution rules, so they can be extracted according to regular texture. In addition, if the river in the water body is extracted and discontinuous, the shape index cannot be identified. Therefore, the result of classification should be led out into the GIS software to identify this part of the river through visual interpretation, edit the classification category, and improve the classification accuracy.

3.3. Land surface temperature inversion
The thermal radiation transfer equation is the basis of thermal infrared remote sensing and LST inversion. Because the wide band data of Tiangong-2 have two adjacent thermal infrared bands, the radiation transmission equation of the two bands is combined, and the LST is obtained by the split-window algorithm.

3.3.1. Linear simplification of the Planck function. The Planck function is used to calculate the relationship between the radiance of the two thermal infrared bands of Tiangong-2 wide band data in the temperature range of 273 ~ 322K. The relationship between the radiance and the temperature is approximately linear. The equation (1) is obtained by linear regression.

\[ B_i(T) = 0.175T^4 - 42.881, \quad R^2 = 0.994 \]
\[ B_i(T) = 0.170T^4 - 40.861, \quad R^2 = 0.995 \]

(1)

3.3.2. Temperature is solved by using the Planck function [20], and the calculation formula is as shown in the formula (2):

\[ T_i = \frac{K_{1,2}}{\ln(1 + \frac{K_{1,2}}{T_i})} \]

In the formula, \( I_i \) is the radiance, \( K_{1,1} = 2hc^2/\lambda_i^4 \), \( K_{1,2} = hc/(k\lambda_i) \), \( h \) is the Planck constant, \( c \) is the speed of light, \( k \) is Boltzmann constant, \( \lambda_i \) is the center wavelength in the i-th channel.

The central wavelength of Tiangong-2 wide band data is \( \lambda_1 = 8.475 \mu m \) in thermal infrared data \( T_1 \) band and \( \lambda_2 = 9.1 \mu m \) in thermal infrared data \( T_2 \) band. According to Planck formula, the \( K_{1,1} \) and \( K_{1,2} \) of Tiangong-2 wide band data are obtained. \( K_{1,1} = 2724.1W \cdot m^{-2} \cdot sr^{-1} \cdot \mu m^{-1} \), \( K_{1,2} = 1697.3K \), \( K_{2,1} = 1908.6W \cdot m^{-2} \cdot sr^{-1} \cdot \mu m^{-1} \), \( K_{2,2} = 1580.7K \).

3.3.3. Estimation of Atmospheric Water Vapor content and Atmospheric transmittance. The atmospheric moisture content and the atmospheric transmittance are the key parameters in the process of LST inversion. Because the wavelength ranges of the fourth band (0.845~0.885 \( \mu m \)) and the second band (0.930~0.950 \( \mu m \)) of the wide band data of Tiangong-2 are similar to those of the second band and the 19th band of the MODIS data [21], the formula for the inversion of atmospheric water vapor content from the wide band data of Tiangong-2 is shown in formula (3).

\[ \omega = \left( \frac{\alpha - \ln(\rho_1/\rho_2)}{\beta} \right)^2 \]

(3)

In the formula, \( \omega \) is the atmospheric water vapor content \((g \cdot cm^{-2})\), \( \alpha \) and \( \beta \) are constants, \( \alpha = 0.02, \beta = 0.6321 \), \( \rho_1 \) and \( \rho_2 \) are the land surface reflectance of the second and fourth wave bands of the Tiangong-2 data.
The relationship between the atmospheric transmittance and the moisture content of the two thermal infrared bands in the range of 8 to 9.3 μm in the wavelength range of 8 to 9.3 μm by Zhang Xiao et al [22] is used to calculate the atmospheric transmittance.

3.3.4. Estimation of Surface specific emissivity. In this paper, the mixed image element method proposed by Qin Zhihao et al [23] is used to estimate the specific emissivity of the surface. In the mixed image element method, the remote sensing image is divided into a water, a natural surface and a town surface. The specific emissivity of natural surface and urban surface in the range of thermal infrared band of Tiangong-2 is estimated by formula (4).

\[
T_1: \epsilon_{\text{surface}} = -0.0437 P_w^2 + 0.0793 P_w + 0.9346, \quad \epsilon_{\text{building}} = -0.0634 P_b^2 + 0.1083 P_b + 0.9271
\]

\[
T_2: \epsilon_{\text{surface}} = -0.0436 P_w^2 + 0.0777 P_w + 0.934, \quad \epsilon_{\text{building}} = -0.064 P_b^2 + 0.1019 P_b + 0.93
\]

(4)

4. Results and Discussion

4.1. Wetland classification results and accuracy evaluation

Combined with the wetland distribution map of Panjin in 2017 (figure 3), it can be seen that Panjin has a wide range of wetlands, and the regional resources are mainly developed in paddy fields, reed swamp and aquaculture farms. Paddy field is most widely distributed, mainly in the east of the study area. Panjin is a national high-quality rice production base. As can be seen from the figure, paddy fields have been dominant, occupying more than half of the wetland space. Marsh wetland is the main type of wetland in the north shore of Liaoqiong Bay. Marsh wetland mainly includes reed wetland, the development of reed field in this area conforms to the ecological law and has economic value. Panjin city in the national nature reserve, Shuangtaizi Estuary reserve is mainly reed marsh. Mudflat wetland is mainly distributed near the mouth of Liaohe river and is a place where a lot of materials are exchanged. In 2018, the wetland area is 3,184.89 km², of which 1,290 km² are natural wetlands and 1,893.91 km² are constructed wetlands. The results are shown in Table 1, paddy fields accounted for the largest proportion of wetland area in 2018, reaching 55.29 %. Reed swamp, mudflat wetland, suida salsa swamp, aquaculture farm, reservoir/pond and river wetland areas declined in turn.

![Figure 3. Distribution of wetland types in Panjin city in 2018](image)

Table 1. Area and proportion of various types of wetlands in Panjin city in 2018.

| Type           | Area(km²) | Proportion (%) | Subtotal(km²) | Proportion (%) |
|----------------|-----------|----------------|---------------|---------------|
| Natural wetland|           |                |               |               |
| River wetland  | 51.94     | 1.63           | 1290.98       | 40.53         |
| Mudflat wetland| 147.1     | 4.62           |               |               |
| Reed swamp     | 971.08    | 30.49          |               |               |
| Suaeda salsa swamp | 120.86 | 3.79           |               |               |
| Aquaculture farm| 80.72     | 40.53          |               |               |
| Artifical wetland|         |                |               |               |
| Paddy field    | 1760.86   | 55.29          | 3184.89       | 59.47         |
| Reservoir / pond| 52.33     | 1.64           |               |               |
Due to the extensive application of Landsat data in surface monitoring, wetland data taken by Landsat 8 satellite on May 5, 2018 were used to evaluate the accuracy of wetland extraction from Tiangong-2 data by confusion matrix method [24]. The accuracy evaluation results show the accuracy evaluation results of most wetland types are over 90% and the interpretation of effect is good.

4.2. Verification and Analysis of inversion results of Land surface temperature

Using the above-mentioned split-window algorithm, the inversion results of the LST of the Tiangong-2 are obtained (figure 4), and the MODIS LST products of the same time phase (figure 5) are selected for consistency analysis with it. It can be seen that the lowest temperature of the LST of the Panjin city, which is obtained by the data inversion of the wide band data of the Tiangong-2, is 300.0 K, and the low-temperature part mainly occurs in the water part, the maximum temperature is 321.2 K, and the high-temperature area is in a frequent area of human activity in the central urban area. The lowest temperature of the MODIS temperature product is 302.1 K, the maximum temperature is 316.7 K, and the high temperature area and the low temperature area are consistent with the results of the data inversion of the wide band data of the Tiangong-2. From the space, the LST results from the inversion of the wide band data of the Tiangong-2 are basically consistent with the spatial distribution of the MODIS LST products. The LST of the town is higher than that of the natural surface. The temperature of the water is the lowest, as can be seen from figure 4.

The LST in the northwest to the southeast direction of the LST fluctuation of the study area is selected to be a section line analysis on the LST of the Tiangong-2 and the MODIS inversion. The position of the section line is shown in figure 4, figure 5, and the analysis results are shown in figure 6. On the profile, the LST inverted by Tiangong-2 data is basically consistent with the fluctuation of MODIS LST product profile. Because of the high resolution of Tiangong data, the fluctuation of LST profile is relatively high. The high temperature center appears in urban areas and town, and the LST decreases gradually from urban areas to suburbs. The temperature of human activity is higher, the temperature of natural surface is lower, and the temperature of water is the lowest.

From the random selection of 300 sampling points in the study area, the LST results of Tiangong-2 wide band data are compared with those of MODIS LST products (figure 7). The average error is 0.26K and the standard deviation is 1.75K. The linear regression analysis shows that there is a high correlation between the two, the correlation coefficient is 0.79K, and the root mean square error is 1.66K. Due to the differences in transit time and spatial resolution between Tiangong-2 data and MODIS data, there are differences in LST inversion between the two data, and the specific reasons need to be studied in the future.

Figure 4. LST based on Tiangong-2 data
Figure 5. LST based on MODIS data
4.3. The type of different wetland and the response of land surface temperature

Combined with the wetland distribution map of Panjin city (figure 3), the mean, median, maximum, minimum and standard deviation of LST of each land use type were counted, as shown in Table 2. The LST of different wetland types is different. Compared with the average LST of each wetland type, the lowest LST of the reservoir is 304.0K, and the outline of the reservoir can be clearly seen in the LST map, while the LST of Mudflat wetland and aquaculture farm is relatively high 309.4 K and 307.9 K. Reed swamp and paddy field are widely distributed in the study area, and the temperature difference is small. The average LST of each wetland from high to low is as follows, mudflat wetland > aquaculture farm > suaeda salsa swamp > river wetland > paddy field > reed swamp > reservoir / pond.

The box line map is drawn by using the LST corresponding to different wetland types, as shown in figure 8. The distribution range of LST data of reservoir / pond is lower than that of other wetland types. The box body of Mudflat wetland, aquaculture farm and reservoir /pond type is longer, which says that the LST data is more scattered and unstable. While the box body of river wetland, Reed swamps and paddy field is shorter, which indicates that the LST is more concentrated and stable.

Table 2. Statistics on different types of wetlands LST (Unit: K)

| Wetland type               | Mean  | Median | Maximum | Std.  |
|----------------------------|-------|--------|---------|-------|
| River wetland              | 306.1 | 305.5  | 314.4   | 2.20  |
| Mudflat wetland            | 309.4 | 308.7  | 318.0   | 3.49  |
| Reed swamp                 | 305.6 | 305.2  | 316.3   | 1.42  |
| Suaeda salsa swamp         | 306.4 | 305.5  | 318.7   | 2.18  |
| Aquaculture farm           | 307.9 | 307.8  | 316.5   | 2.37  |
| Paddy field                | 305.8 | 305.1  | 316.8   | 2.00  |
| Reservoir / pond           | 304.0 | 302.9  | 313.6   | 2.76  |

5. Concluding

In this paper, taking the wide band remote sensing image data of Tiangong-2 as the main data source, supplemented by Landsat TM data and MODIS data, the wetland type information of Panjin wetland is extracted, and the LST is inversed by split-window algorithm, and the response of different wetland types to LST is analyzed, and the following conclusions are obtained.

1) The results show that the wetlands in Panjin city in 2018 are widely distributed, the eastern part of the study area is dominated by paddy fields, and the western part of the study area is distributed with
a large area of Reed swamps. The overall accuracy of wetland classification using Tiangong-2 data is 89.97%, and the kappa coefficient is 0.8761. The remote sensing extraction of wetland information in Panjin city is realized with high precision, and the applicability of Tiangong-2 wide band imaging spectrometer in wetland monitoring is verified.

2) Through the derivation of the split-window algorithm and the calculation of the required parameters, the results show that the results based on the inversion of Tiangong-2 data are in good agreement with the MODIS data, which can be extended to the sensor with thermal infrared band in the wavelength of 8–10 μm. It is verified that the split-window algorithm can be effectively applied to the wide band data of Tiangong-2, and Tiangong-2 provides new data for LST inversion.

3) Different wetland types have different LST responses. The average LST of each wetland from high to low is as follows: mudflat wetland > aquaculture farm > suaeda salsa swamp > river wetland > paddy field > reed swamp > reservoir / pond.

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