Recent Shoreline Variations Analysis Using Landsat 8 OLI Imagery in East Dongting Lake, China

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Abstract. Dongting Lake, located in the northeast of Hunan Province, is the second largest fresh water lake in China. Based on Landsat 8 OLI imagery in 2013 and 2016, the shoreline of East Dongting Lake in different periods was explained through processing of radiation correction, geometric correction and band combination, etc., and the temporal sequence variation characteristics of the lake shoreline were explored. The results show that there is no obvious variation in the shoreline around the lake, and the area of East Dongting Lake is stable of 1300km². Typical shoreline monitoring in the lake area shows that recently there is a new enclosed area in the middle of the Luhu Reed Field. The enclosed area covers an area of 1.98km², about 3,000 mu, and the top elevation of the enclosed area is between 30 and 32m. Moreover, East Dongting Lake is an internationally important wetland reserve and a significant regulating lake of the Yangtze River. The shoreline of East Dongting Lake is stable latterly, but the development of low enclosure and net enclosure in the lake area has not been prohibited for a long time. As far as the lake area management is concerned, we should pay more attention to supervision of illegal activities such as enclosing land in the lake area.

Keywords: Landsat 8 OLI imagery; shoreline variations; East Dongting Lake.

1. Introduction
East Dongting Lake is an internationally important wetland reserve and a significant regulating lake of the Yangtze River, which plays a vital role in the protection of flood control safety of the Yangtze River and the biodiversity of wetland biological resources [1]. Driven by political, economic and other factors, the area of East Dongting Lake has been shrinking in the past century [2-3]. In December 2016, General Office of the CPC Central Committee and General Office of the State Council issued opinions on Full Implementing the River Chief System, in which strengthening the management of river and lake shoreline is one of the six tasks of the River Chief System [4].

Due to the dynamic characteristics of the lake, the routine field survey has the characteristics of heavy workload, high cost and long period. However, remote sensing technology has the advantages of wide observation range, fast information acquisition, large amount of information, short update period and strong comparability. It has significant superiorities in coastline change, wetland evolution and reclamation dynamic monitoring. The Landsat series satellites of the United States have been in operation since 1972 and now have more than 40 years of image data. The spatial resolution of OLI of 15m can effectively detect the spatial characteristics of lakes. In this paper, Landsat 8 OLI Imagery was used as the data source to quantitatively analyze the recent variations of East Dongting Lake shoreline.
2. Materials and Methods

2.1. Study Area
East Dongting Lake, located in Yueyang City of Hunan Province (figure 1), is situated in the south of Jingjiang Section in the middle reaches of the Yangtze River [3]. The East Dongting Lake region receives the four rivers of Xiangjiang, Yuanjiang, Zishui, and Lishui, connecting the Yangtze River. It plays a key role in water security in the Yangtze River basin, and especially for the area around lake. The lake area starts from Leishi Mountain, where Dongting Lake meets Xiangjiang River in the south, and reaches Chenglingji in the north to join the Yangtze River. It is about 70 km from north to south and 30 km wide in the east and west. The west side of the lake is bounded by flood banks, and the east side is mainly the low hills.

![Figure 1](image1.png)

Figure 1. Location of the study area. (a) Sketch map of Dongting Lake. HD – Hudu; SZ – Songzi; OUC – Ouchi; ZS – Zishui; LS – Lishui; XJ – Xiangjiang; YJ – Yuanjiang [3]; (b) morphology of East Dongting Lake.

2.2. Remote Sensing Data
In this paper, Landsat 8 OLI remote sensing images from the United States Geological Survey (USGS) were selected as the data source for analysis, mainly including 1 scene of East Dongting Lake imagery in 2013 and 2016, respectively (table 1). Landsat 8 is the recently launched (on February 11, 2013) satellite and carries the Operational Land Imager (OLI) instrument. Landsat 8 OLI imagery has a spatial resolution of 15m, a revisiting period of 16 days, and 9 bands. One scene can completely cover the East Dongting Lake area. All Landsat imagery data has been obtained from USGS website. In this analysis, images with good data quality, cloudless or few clouds were selected.

| No. | Satellite | Instrument | Imaging date | Imaging time | Water level (m) |
|-----|-----------|------------|--------------|--------------|----------------|
| 1   | LANDSAT-8 | OLI        | 2013/06/13   | 10:58:41     | 30             |
| 2   | LANDSAT-8 | OLI        | 2016/06/05   | 10:56:22     | 32             |

2.3. Image Preprocessing
Image preprocessing is a necessary procedure for shoreline spatial interpretation, which mainly includes radiometric correction, geometric correction and band combination. The images of different
time phases are diverse because of the different light and atmospheric conditions, which require necessary radiometric correction. In this paper, Illumination Correction Model (ICM) is adopted to perform radiation correction for images, and its calculation formula is as follows [5]

\[ L_\lambda = Gain \cdot DN + Bias \]  

\[ \rho_\lambda = \frac{\pi \cdot L_\lambda \cdot d^2}{ESUN \cdot \cos(\theta)} \]

where \( L_\lambda \) is radiant luminance, \( DN \) is the pixel gray value, \( \lambda \) is the band value, \( Gain \) is the gain value, \( Bias \) is the bias value, \( \rho_\lambda \) is the reflectivity, \( d \) is the distance between the sun and the earth, \( ESUN \) is the radiant value of the solar spectrum, \( \theta \) is the zenith angle of the sun. These parameters can be obtained in the header file.

Due to factors such as sensor scans will cause the geometric distortion of image, using the ENVI software platform to carry out the image geometric correction. Image registration was adopted 1:50 000 topographic map, and select uniform distribution of ground control points, by using the quadratic polynomial model and the adjacent interpolation, to 15 m resolution image re-sampling, with correction of root mean square error (RMSE) control within 0.5 pixels. The purpose of the band combination is to maximize the prominence of the target information. To extract artificial shorelines, wavebands with prominent reflection on water, beach and land should be selected. Through the comparison test of various bands and their combinations in the study area, the synthesis of bands 3, 4 and 5 has higher spectral reflectance. In this paper, the convolution kernel of 3x3 pixels is used to enhance the boundary of the original image, and the enhanced image can more clearly show the linear texture features of the image. The data characteristics of Landsat 8 OLI band are shown in table 2, and the results of OLI combination of 3, 4 and 5 bands are shown in figure 2.

### Table 2. Data characteristics of Landsat 8 OLI band.

| No. | Spectral Band     | Wavelength (μm) | Solar Irradiance (W/(m²μm)) |
|-----|-------------------|-----------------|-----------------------------|
| 3   | Green             | 0.525–0.600     | 1826                        |
| 4   | Red               | 0.630–0.680     | 1574                        |
| 5   | Near Infrared     | 0.845–0.885     | 955                         |

Figure 2. Band composite images. (a) On June 13, 2013; (b) On June 5, 2016.
2.4. Shoreline Extraction

East Dongting Lake is a watershed restricted by dikes and natural shorelines of Dongting Basin. It is staggered by water surface and beach, and to a large extent, it is marked with the obvious mark of human influence. For this reason, this paper mainly monitors the impact of human activities on the lake area and extracts information mainly from artificial encircling shorelines. Most of the methods of extracting shoreline information from remote sensing images are based on spectral analysis of a single pixel, or manual interpretation is carried out by means of image texture, shape, regional features and other symbols. The method of neighborhood processing in spatial domain is adopted, and the gray value of pixels and surrounding pixels is used to calculate the boundary enhancement of the original image, so that the linear texture features of the image can be more clearly displayed. On this basis, the man-machine interactive interpretation is adopted to extract the shoreline information.

3. Results and Discussion

3.1. Recent Shoreline Variations of East Dongting Lake

With the advantage of large-scale macro observation by remote sensing, the comparison map of remote sensing shorelines extracted in 2013 and 2016 can be seen (figure 3a). In recent years, there has been no obvious change in shoreline around the lake. In 2016, the shorelines completely overlapped with those in 2013, and the area of the lake area was stable of 1300 km². Since the founding of the People's Republic of China, troops sent to the south to cultivate and surround the lake to build farmland, which opened the prelude of encircling the three sides of the East Dongting Lake. In the 1970s, the reclamation of Dongting Lake with the aim of preventing and controlling schistosomiasis entered a new climax. The data show that the area of East Dongting Lake decreased by 681 km² from 1954 to 1978. After the reform and opening up in 1978, the agricultural structure was adjusted and the fishponds were built in some areas, which made the area of East Dongting Lake decrease slightly. After the Yangtze River flood in 1998, the State Council made clear the countermeasures of "returning farmland to lakes", which made the area of East Dongting Lake stable. After the operation of the Three Gorges Reservoir in June 2003, the inflow of water and sediment decreased significantly. However, the flood control levee in East Dongting Lake is mainly confined by man-made embankments, and the change of inflow and sediment cannot change the position of flood levee. Therefore, the operation of the Three Gorges Project has not affected the shape of East Dongting Lake.

3.2. Variations of Lakes inside the Polder Land

In recent years, the shoreline of East Dongting Lake is stable. However, for a long period of time, the phenomenon of low enclosure and net enclosure in the lake area has not been prohibited for a long time. As far as the lake area management is concerned, more attention should be paid to and supervision of illegal behaviors such as lake enclosure, and relevant work needs to be further carried out. The Luhu Reed Field in the south of East Dongting Lake, known as "the first reeds field in south China", is the key and complicated area in the management of East Dongting Lake.

According to the remote sensing images of 2013 and 2016, it can be seen that there is a typical fenced area in Luhu Reed Field. Figure 3c shows the geometric shapes of the new fenced area. The figures show that the fenced area is located in the southwest of the lake, and the central point with east longitude 112°48' and north latitude 29°55'. The length of the east, west, south and north dike are 1.54km, 1.40km, 1.57km and 1.40km, respectively. The area of the fenced region is 1.98km², about 3,000 mu. It can be seen that the fenced region is completely submerged with the flood level of Chenglingji in June 2016 of 32 m, while the fenced region as a whole is exposed with the flood level of Chenglingji in 2013 of 29.9 m. According to the preliminary estimation, the ceiling elevation of buildings in the fenced area is between 30 and 32m. Of course, for the illegal levee discovered by remote sensing, in the stage of supervision and law enforcement, the field measurement should be further combined to verify the relevant change data.
Figure 3. Remote sensing results. (a) Shoreline variations; (b) low enclosure area on June 13, 2013; (c) low enclosure area on June 5, 2016. The red rectangle is the previous area, and the blue rectangle is the later added area.

4. Conclusions
Based on Landsat 8 OLI imagery of East Dongting Lake in two years, this paper explores the temporal variation characteristics of shoreline in recent years. The results show there has been no obvious variations in the shoreline around the lake, and the area of east Dongting Lake is stable of 1300km$^2$. Dongting Lake has experienced several stages, including large-scale reclamation from 1950s to 1970s, limited expansion in 1980s, and returning farmland to lake after the catastrophic flood in 1998.

East Dongting Lake is an important international wetland reserve and an important regulating lake of the Yangtze River. In recent years, the shoreline around East Dongting Lake has been stable, but for a long time, the phenomenon of low enclosure and net enclosure in the lake area has not stopped. As far as the lake area management is concerned, we should pay more attention to supervision of illegal activities such as enclosing land in the lake area.

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