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Application of Remote Sensing Axis Line Method in Xiaomiaohong Creek

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Abstract

The traditional researches on evolution of tidal creek have been limited for the reason that precise measured data be required. On the other hand, the Remote Sensing Axis Line method (RSAL) can monitor the evolution of the tidal creek accuratly and promptly. This paper extracted the Axis lines of Xiaomiaohong creek based on one MSS image and six TM images in the period of 1979, 1987, 1989, 1993, 1995, 2003 and 2009 with RSAL and took a further analysis. The results showed that: On the basis of overlaying generated axis line and DEM (digital elevation model) data both acquired in 2003, axis line can be the substitution of the thalweg line because of similar trend and minor deviation of above two kinds of lines, which is revealed that RSAL was serviceable and effective to understand dynamic evolution of tidal creeks quickly and accurately. The upper section of Xiaomiaohong creek was depositing and growing all the time and subordinate braches were gradually disappeared, the south side of middle section possessed relatively stronger hydrodynamic force and much more subordinate branches were developing.

***Keywords**: remote sensing axis line method, tidal creek, Xiaomiaohong creek, Lvsi port*

1. Introduction

The radial sand ridges of South Yellow Sea lies in the middle coastal of Jiangsu, between Xinyanggang and Yaowanggang, which is between abolished Yellow River underwater delta and Yangtze River underwater delta. The radial sand ridges stretch from south to north, 200km long from south to north, 90km wide from east to west, with Jianggang as its start point. The whole sea area is about 2×104km^2. About 70 sand ridges consist of the whole sand ridges group, 10 of which are above the ocean surface in low tide, expanding clockwise from north to south like a sector [1, 2].

It is a prerequisite to realize the importance of change of submarine relief, which can help to exploit the resources along the coastline and mud flat, protect the ecosystem and environment in tidal flat and wet land, as well as scientific-effectively manage the ocean. The desire of Jiangsu Province Government is urgent to build the ports and industry parks and exploit the resources of the mud flat. The radial sand ridges in South Yellow Sea are the key zone in both research and development. There is a necessity to understand the features and variation law of the radial sand ridges' terrain and landscape scientifically by using corresponding techniques, in order to provide the support in basic material and technique for a good plan in reasonable development.

Lvsi port is one of the radial sand ridge ports, has great potention in development. There is a necessity to understand the features and variation law of the terrain and landscape around the Lvsi port scientifically by using corresponding techniques, in order to provide the support in basic material and technique for a good plan in reasonable development. As the main channel affecting Lvsi port, Xiaomiaohong channel has relatively independent water-sand system. The revolution of Xiaomiaohong channel will impact on the construction of the Lvsi port directly.

The traditional researches on evlution of tidal creek have been limited for the reason that precise measured data be required. On the other hand, the Remote Sensing Axis Line method (RSAL) can monitor the evolution of the tidal creek accuratly and promptly [3]. This

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paper took a further analysis of RSAL and applied to Xiaomiaohong channel.

2. Study Area and Data Acquisition

2.1. Study Area

Xiaomiaohong channel as a representative tidal creek of radiate sand ridges area usually goes through submergence, and that parallels with coastline and orientates in a NWW-SEE direction. The length of this channel is about 38km and width of its entrance and mid-segment is approximate 15km and 4.5km respectively, its tail disappears in Rudong shoal. Several submarine shoals are developed in this area [4].

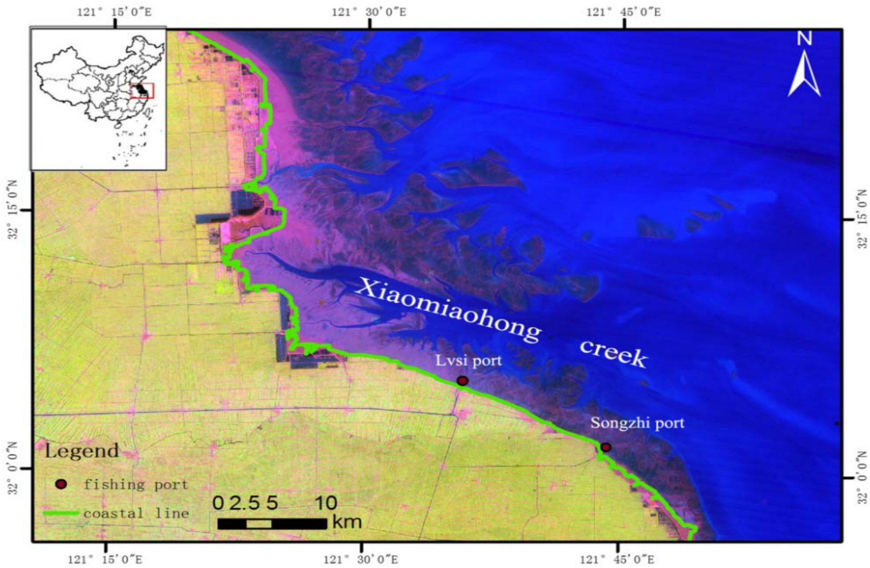

Figure 1. Research Area of Xiaomiaohong Creek

2.2. Data Acquisition and Preprocessing

In order to understand the migration and change of Xiaomiaohong creek in history period, 1 scene of MSS (Multi Spectral Scanner) imagery captured in 1979 and 6 scenes of TM (Thematic Mapper) imageries captured between 1987 and 2009 were collected, above imageries are all over a relatively low tidal conditions with cloud free. Image specific parameters see Table 1.

Remotely sensed imageries were geometrically projected to Gauss Kruger projection (GK-21 zone) and georectified to WGS-84 coordinates system based on 23 ground control points (GCPs), which are easily recognized and stable ground features and measured via RTK GPS in study area. A quadratic polynomial function and nearest neighbor resampling method were employed to rectify RS images and guarantee the root-mean-square (RMS) less than 0.5 pixel. In this process, the same batch of GPCs were utilized in each RS image, which means if rectified error occurred and led to the misregistration, the same error would be produced to every imagery, to some extent this way can avoid the variant error probably caused by using different batch of GCPs, while carrying out the history trend analysis of tidal creeks.

Table 1. Selected Images of Xiaomiaohong Creek

Images	Spatial resolution	Capture time
MSS	57m	1979.8.4
Landsat TM	30m	1987.5.18
Landsat TM	30m	1989.8.11
Landsat TM	30m	1993.3.31
Landsat TM	30m	1995.4.6
Landsat TM	30m	2003.3.31
Landsat TM	30m	2009.4.28

3. The Concept of Axile-line Method

Because of the bathymetry is difficult to measure, so the migration of tidal creeks is hardly determined as well. Here, axile line concept was introduced in our research and the characteristic of this method is to discuss the change of ground features in two dimensional spaces, because axile-line as a typical feature can represent the shape of tidal creek. If we can extract many axile-lines of our target tidal creek in historic period, the migration and change of this creek should be easily monitored [5,6].

3.1. Extraction of Axile-line

In hydraulic science, the thalweg of river is always conducted to analyze the evolution of river channel and predict its potential moving trend in future. Thalweg is defined as the connecting line of those points, which locate in the cross sections of river and with deepest water depth. From the definition of thalweg we can see, acquisition of thalweg severely depends upon water depth data, as well known to all water depth is hardly extracted from RS image, which means it is impossible to acquire thalweg of tidal creek only relying on RS image. However, it does not mean we have no chance to monitor the change of tidal creeks by RS image, because the basic idea of thalweg gives us an inspiration, so a similar substitute was come out and introduced for understanding the evolution of tidal creeks, which is axile line what we have proposed before and it will be used in tidal creek evolution research.

Recently, two kinds of way are widely used for extracting axile-line of polygon [7, 8], meanwhile, lots of software, such as R2V and ArcGIS have been developed and are able to generate axile-line rapidly and accurately [9]. An extension module Arcscan in ArcGIS package was an alternative way to extract axile-line of Xiaomiaohong tidal creek in terms of its compatibility with remote sensing data.

3.2. The Process of Extracting Axile-lines

(1) Water body separation

Tidal creek should be separated from raw image before extracting axile-line of out targets. Recently, many research proposed a lot of effective methods for separating water body, among them threshold is a mostly employed one. The water body separation progress are as follows: taking a TM image captured in 1995 as an example, several arbitrary profiles were extracted over TM5, a waveband centered at 1650 nm. We found that the value of DN (Digital Number) had an obvious variation nearby the water line, especially from one side cross another side, and finally a threshold value 25 was determined to build mask file for the purpose of separating water body.

(2) Axile-line extraction

Firstly, mask file should be prepared already for water body separation (Figure 2), which is binary image only containing black and white color and corresponding value is set to 0 and 1. Secondly, input the resampled binary image into ArcGIS and load Arcscan module, meanwhile create and load a new file which are shape format, keep edit condition and active Arcscan module. Select vectorization module and set conditions before running it. And then two parameters should be set, which are “maximum line width” and “former background color”. After finishing those setting, axile-line can be extracted automatically.Because of an automatic extraction method we utilized, so lots of redundant details are also generated concurrently, such as tiny axile-lines in subordinate branches of tidal creeks, so it is necessary to delete those lines for subsequent analysis.

a) b) c)

Figure 2. Extraction Process of Axis Line in Xiaomiaohong Creek (1995) a) DN histogram, b) the binary image, c) the axis line

3.3. Analysis of Axile-line

In order to analyze the migration and change of tidal creek of Xiaomiaohong, the representativeness of axile-lines should be evaluated firstly. The criterion of the judgment is whether axile-line can match thalweg very well. The way what we have used is to overlap the generated axile-line derived from TM image (2003) over topographic map measured in 2003, so it is rational to compare the difference between each other in the same year. The results (Figure 3) showed that the similar trend could be found between extracted axile-line and measured thalweg. In order to analyze the relationship between axile-line and thalweg clearly, three representative profiles were determined. Figure 3(a) showed that profile one crossed axile-lines and the intersections of profile 1 and generated axile-line were named to A and B from north to south. Profile 2 and 3 crossed axile-line as well and interactions of them are C and D respectively.

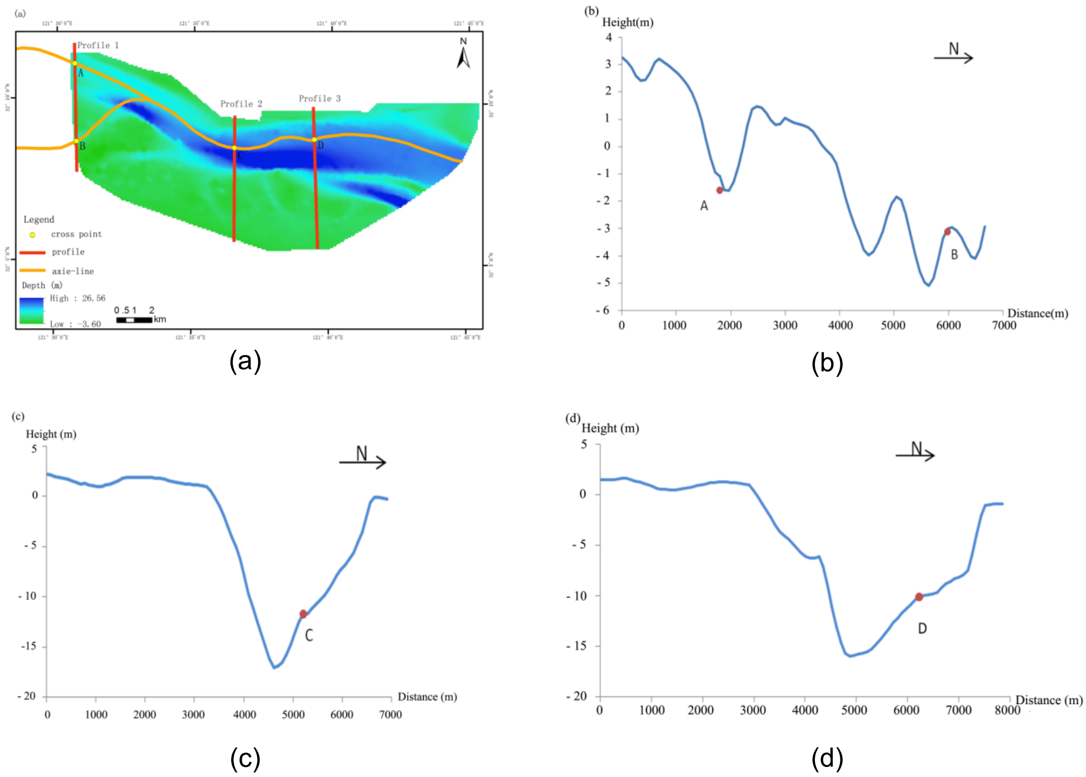

Figure 3. analysis of axis lines (a) sections' location (b) section 1 (c) section 2 (d) section 3

From Figure 3(b) we can see that blue curve is the elevation of profile 1 from south to north direction, two red points are interactions between thalweg and axile-line labeled with A and B, ideally point A and B should be located at the bottom of U-bend and its elevation should be relatively lower than those points located at two sides, at this condition the axile-line can be treated as thalweg and be able to represent the shape of tidal creeks. In reality the axile-line almost cannot match thalweg accurately as the result of the intersecting surface of creek is not symmetric, in another words it does not like 'U', so the bias is inevitable. Figure 3(b) showed that the location of point A matched the bottom very well but B was obviously shifted to north side. Figure 3(c) and 3(d) showed that both point C and D were located nearby the bottom of the curve, but their locations were shifted to north side as well.

This phenomenon reveals that if the slope of both sides is symmetric, the points in axile-line will matched with deepest bottom nicely such as point A, or else it is impossible to match with each other precisely and the shifted direction will be forward to that side with lower gradient, such as point C and D.

Although the bias between axile-line and thalweg is inevitable, it still has the potential to figure out the change and evolution of tidal creeks because of the primary trend can be expressed clearly by axile-line method.

4. Results and Discussion

4.1. The Historic Evolution of Xiaomiaohong Creek

The axile-lines were generated automatically one by one based on the progress what we have mentioned before. The general trend of Xiaomiaohong creek is NWW-SEE direction, and much more subordinate branches developed at upper section, seems claw-shaped.

In order to make the evolution of Xiaomiaohong clearly, this creek was segmented into 3 parts, which are upper, middle and down sections. Three vertical lines (L1,L2) was delineated as boundaries of those three parts, whose longitude are 121°25′36″E and 121°34 ′10″E respectively (Figure 4).

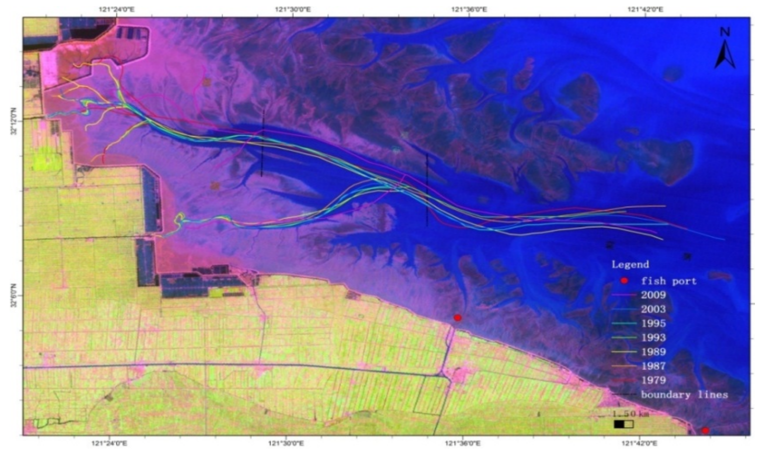

Figure 4. Changes of Axis Lines in Xiaomiaohong from 1979 to 2009

Upper section is thought of as the header of Xiaomiaohong creek and tiny braches developed very well in this part. It will be helpful to analyze the change of water catchment from outside of sluice gate. Similarly, in middle section flow input from an adjacent river will be also easily discussed.

4.1.1. The Axile-line Change of Upper Section

As determined above, the upper section is located at west of vertical line L1 and its evolving characteristic from 1979 to 2003 is as follows:

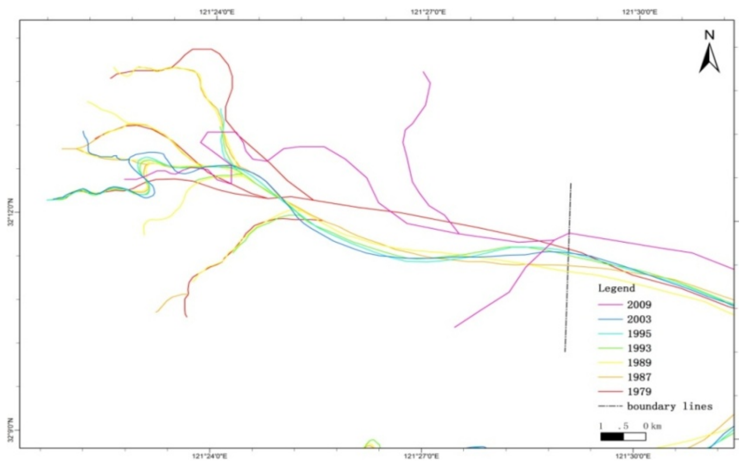

Figure 5. The Axile-line Change of Upper Section

(1) The length change of upper section

The variation of length is inclined to be elongate from 1979 to 2003 except a backward shortening in 1989.The total increased length is 2899m from 6202m of 1979 to 9101m of 2003, the increased length occupied 47% percentage to the length of 1979. In terms of the change of the channel of upper section is severe, the original point is very stable and almost has no change, that means the distance between original point to its horizontal point located in L1 has no change as well, meanwhile, the length of axile-line became longer, so it was indicated that the curvature of this section has been increased.

(2) The swing characteristic of upper section.

According to the morphology of axile-line in the upper section, a vertical line (Lu) whose longitude is 121°24′57″E was defined as the boundary to interpret the swing of upper section. We found that the axile-line at the west of Lu was inclined to north side and the maximum distance moved was approximate 724m, a backward phenomenon occurred at east side of Lu ,the general moving direction of axile-line is forward to south side and maximum distance swung was about 860m. The main characteristic of axile-line of each period is accorded with above trend except in 1979.

(3) The change of subordinate branches of upper section

Subordinate branches were mainly developed at the north side of axile-line in the upper section of Xiaomiaohong creek, its amount obtained a rapid development from 2 branches in 1979 to 4 branches in 1987, and continuing increased to 5 branches in 1989. After this period, the subordinate branches started to decrease, typically only 1 branch left in 1995. The length of axile-line of subordinate braches was also varied significantly, the average length of axile-line of branches was 3000m in 1989, which is the peak period, and an obvious decrease occurred later, for example only 1000m long of that in 1993.

4.1.2. The Axile-line Change of Middle Section

As determined above, the middle section is located between vertical line L1 and L2, its evolving characteristic from 1979 to 2003 is as follows:

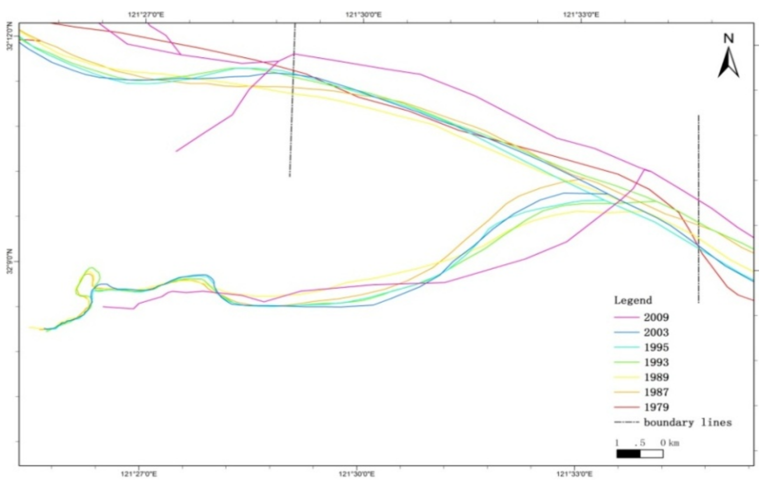

Figure 6. The Axile-line Change of Middle Section

(1) The length change of middle section

In the middle section, the length changed seldom and floated 14200m up and down, which means the curvature of this section almost had no change.

(2) The swing of axile-line of middle section

According to the morphology of axile-line in the middle section, a vertical line (Lm) whose longitude is 121°27′26″E was defined as the boundary to interpret the swing of middle section. We found that the axile-line at the west of Lm was inclined to south side and the maximum distance was approximate 1150m, the most active period occurred between 1979 and 1987. A backward phenomenon occurred at east side of Lm, the general moving direction of axile-line is forward to north side and maximum distance swung was about 500m. The main characteristic of axile-line of each period is accorded with above trend except in 1979.

(3) The change of subordinate branches of upper section

Subordinate branches started to develop at the south side of axile-line in the middle section of Xiaomiaohong creek. The average length of axile-line of branches was in a growing period between 1987 and 1993, reached its peak value in 1993 and became shrinking later. The general moving direction was forward to southeast and its maximum amplitude reached 600m approximately.

4.1.3. The Axile-line Change of Down Section

As determined above, the middle section is located at east side of vertical line L2, its evolving characteristic from 1979 to 2003 is as follows:

(1) The length change of down section

In the down section, the evolving characteristic of length of axile-line was provided with a shrinking in former period and increased later, the minimum and maximum was in 1993 and 2003 respectively.

(2) The swing of axile-line of down section

The axile-line of down section shifted from north to south and back north, back south again many times in history period. Its swing scope is between two horizontal lines whose latitude is 32°9′15″N, 32°8′16″N respectively.

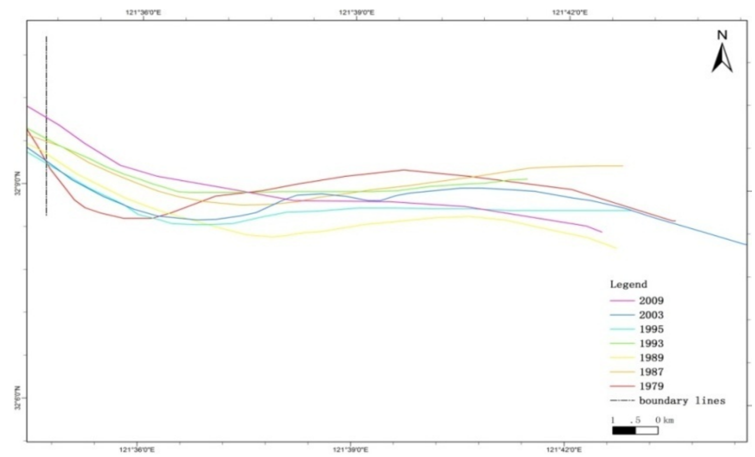

Figure 7. The Axile-line Change of Down Section

From what we have analyzed above, we can see that the upper section of Xiaomiaohong creek was depositing and growing at the former period, and subordinate branches were gradually disappeared. At the same time at the south of middle section new subordinate branches were developed, which revealed much stronger hydrodynamic force in this area.

5. Conclusion

In order to detect the change and evolution of tidal creek of radiate sand ridges in historic period, based on RS images this paper put forward to a method to extract axile-lines of creeks, which can represent its basic morphology. The main results were as follows:

(1) Based on generated axile-lines and measured bathymetry of Xiaomiaohong sea area, we found that the general trend of axile-line was not matched with thalweg accurately and had bias between them, in terms of the slope of both side was not symmetric. The much larger difference of gradient of both sides was, the much shift was. Although the bias was inevitable, after taking consideration of the offset distance, we considered that axile-line was still an excellent substitute to thalweg and be able to help us carry out the evolving analysis.

(2) Based on axile-line method and 6 scenes of RS images, the axile-lines of Xiaomiaohong creek were extracted. In order to discuss the change of this typical creek, it was segmented to three parts (upper, middle and down sections) according to its morphological characteristic. The results showed that the upper section was depositing and growing all the time and subordinate braches were gradually disappeared, the south side of middle section possessed relatively stronger hydrodynamic force and much more subordinate branches were developing. Based on the analysis we think this creek was stable and had limited impact on the facility of Lvsi port.

(3) More trials should be continuing for revising the shift between axile-line and thalweg of creek, probably paying more attention to the relation between slope and shift distance would benefit the adjustment of extract axile-line, so that a more representative feature line could be generated to guarantee more accurate monitoring results.

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