

# Building digital topography model of the intertidal zone between Caofeidian Nanpu town and Tanggu district using multi-period remote sensing data

Zhang Z G<sup>1</sup>, Wu F<sup>1</sup>, Li T Q<sup>1</sup>, Li Q<sup>1</sup>, Gao Z H<sup>1</sup> and Jin D J<sup>1</sup>

<sup>1</sup>China Aero Geophysical Survey & Remote Sensing Center for Land and Resources, 31 Xueyuan Road, Hiadian District, 100083 Beijing, P.R.C

E-mail:zhang\_zonggui@qq.com

**Abstract.** The intertidal zone, a change zone of land and sea interaction, has abundant land reserves, tourism and other resources, which has a location advantage of great engineering construction in China's coastal areas and thus is very important to investigate and monitor the topography of the tidal zone and also keep track of its topographic changes. In this study, the new section of the Bohai sea coastal zone from Nanpu to Tianjin Bohai sea area has been chosen as an example. Based on the terrain feature of the information expressed by the multi-period remote sensing image information and the tidal water level information as well as the tidal data acquisition time in the remote sensing image data, we have been calculated the water line (or edge point) digital elevation topography inversion analysis, and also constructed the digital terrain elevation model, and most importantly have provided a kind of quantitative method to get tidal zone (tide beach) terrain information.

## 1. Introduction

China's 18,000 kilometers of coastal zone is rich in nature resources, and the location advantage of coastal cities are obvious, such as tidal flat land resources, port resources, salt resources, fishery resources, oil resources, natural gas resources, tourism resources and placer resources, etc. [1]. Whereas there also exists fragile ecological environment and frequent disasters problems, including the population growth and urbanization, sea level rise and coastal erosion, shortage of fresh water resources and deterioration of water environment and degradation of fishery resources, and so on [2].

The intertidal zone of Bohai Sea mainly contains clay, sandy, rocky, artificial and plant, and among them the clay intertidal zone or tidal flat is the main intertidal zone of the Bohai Sea coast, and is also a typical silty tidal flat in China. Its stratum is basically covered by quaternary strata, and it is mainly composed of clay powder, sandy silt, sandy clay, silty clay, and other fine particles. Affected by the tidal water, the intertidal zone of Bohai Sea combines with the two sides of a certain range of land and shallow sea transition strip have rich land resources, tourism resources, etc., having the location advantages of great engineering construction in China's coastal areas. Thus, it is very important to investigate and monitor the topography of the tidal zone of Bohai Sea and also keep track of its topographic changes.

The traditional topographic measurement is limited by manpower, material resources and financial resources, and cannot conduct large-scale dynamic monitoring and is difficult to meet the monitoring requirements. Affected by the tide and silt, the people do not go, and the ship does not come, so the



Muddy intertidal zone in the terrain mapping is in the blank. With the development of remote sensing technology, remote sensing monitoring method has the characteristics of rapid large-area monitoring. Remote sensing technology can quickly obtain images that reflect the instantaneous state of the ground.

By this method, for tidal flats, it is possible to obtain the instantaneous water boundary information acted by tides and so on, furthermore, to calculate the elevation of the water line (or edge point) according to the tide data at the time of remote sensing image data acquisition. The tide terrain inversion based on remote sensing water line is becoming more and more realistic.

In this study, the new section of the Bohai sea coastal zone from Nanpu to Tianjin Bohai sea area has been chosen as an example. Based on the terrain feature of the information expressed by the multi period remote sensing image information, combined with the addition of the tidal water level information, we have made the digital elevation topography inversion analysis, and also constructed the digital terrain elevation model, and importantly have provided a kind of quantitative method to get tidal zone (tide beach) terrain information.

## 2. Survey of intertidal zone

According to the aerial geophysical remote sensing survey and application project area of Bohai coastal zone in 2016, combining with the situation of Bohai intertidal zone and the field reconnaissance, the tidal flat inversion test area chosen in this work is located in Bohai bay, which is between Tangshan South Town and Tianjin Binhai New Area Tanggu tide station, as shown in Figure 1. The tidal flat consists of silt and sandy, and the sandy tidal flat is full of various shapes of gravel and shells, covered with wormwood on its shore. Beach width (to the highest water level) is about 13m, 0-5m slope of about  $10^\circ$ , 5-13m slope of about  $15^\circ$ . The length, width and slope of the selected tidal flat are more suitable as a topographic inversion test area for tidal flats.



**Figure 1.** Sketch map(orange box) of topographic inversion test area of tidal flat.

## 3. Tidal flat topography construction method

### 3.1. Technique flow

The OLI (Operational Land Imager) Remote sensing image data was obtained by collecting multiple temporal phases LandSat8 and treated by the procedure of band extraction, atmospheric correction, image cutting, etc. The instantaneous water margin lines at different periods were then extracted by human-computer interaction to get the serialized water line data set. Combined with high tide level grid data generated by tide level data, the elevation of water level point was calculated. Followed by space interpolation, a highly reliable digital tidal flat elevation model DTFEM (Digital Tidal Flat

Elevation Model) was built. And finally use the aerial photography or unmanned aerial vehicle remote sensing data to verify.

### 3.2. Remote sensing water line extraction

The method of remote sensing water line extraction was to select the water line of image similar to the tide (high tide). The water line extracted from satellite images reflected the state of a tide moment, assuming that the water line was a contour line, and then the elevation of water level line can be calculated on the basis of the tide level data of nearby tide station. And then to inversion the tide level of tide gauges (tidal high base). A series of contour lines can be formed by obtaining a series of contour lines under different tide conditions. The digital elevation model DEM was established by digital elevation model construction technique to obtain the approximate terrain of tidal flat.

Using TM images, Kevin et al. [3] extracted the water margin of the Nile delta coast and monitored the changes in its coastline, whereas Ryu et al. [4] extracted the water channel line from the Gomso bay and discussed the relationship between the accuracy of the data in different bands and the fluctuation. Zheng Z S et al. [5] and [6] extracted the water line, using TM/ETM images for many years combined with different tidal ground spectral characteristics and the decision tree method as well as the regional growth algorithm, and simulated the satellite transit time water level by hydrodynamic model, in order to solve the problem of tide gauge shortage in the method of tide zoning correct. Hu W et al. [7] used MODIS /TM images to carry out the Multi time scale tidal flat elevation inversion of Dongsha shoal on the central coast of Jiangsu province, and they obtained the tidal terrain model with good precision through the fusion of MODIS images and TM images.

### 3.3. Remote sensing data selection

Considering the feasibility and cost and the incomplete high score data, LandSat8 and OLI images are collected in this study as the main remote sensing data source for analysis. The basis for selection is based on the appropriate the spatial resolution, the temporal resolution and spectral resolution.

In 2015, LandSat8 acquired a total of 23 scenes of remote sensing images covering the research area, excluding cloud and fog-stained images. And 11 scenes of OLI images were selected in this study, the transit time and of the corresponding tide height of each scene and are shown in table 1.

**Table 1.** General survey of remote sensing data.

Scenes number	Date	Sensor type	Transit time	Tide value (cm)
2015019	2015/1/19	OLI	10:48	141.77
2015035	2015/2/4	OLI	10:48	116.75
2015083	2015/3/24	OLI	10:47	151.84
2015115	2015/4/25	OLI	10:47	189.03
2015163	2015/6/12	OLI	10:47	201.91
2015195	2015/7/14	OLI	10:47	126.93
2015227	2015/8/15	OLI	10:47	67.62
2015259	2015/9/16	OLI	10:48	97.69
2015275	2015/10/2	OLI	10:48	118.05
2015307	2015/11/3	OLI	10:48	149.99
2015339	2015/12/5	OLI	10:48	113.09

### 3.4. Water level extraction and elevation of waterside line

In this study, the water body index method (NDWI, MNDWI) [8] is used to extract the water line, and then the remote sensing water line is further constructed according to the characteristics such as colour, texture and direction of the remote sensing image. The polynomial is used to fit the instantaneous tide position of the imaging time, and then this instantaneous tidal value is assigned to the corresponding water line, and the approximate elevation line of the tidal flat is obtained.

**3.4.1. Water line extraction.** The water line extraction technology flow is based on remote sensing image data. The water index NDWI and MNDWI [8] and [9] can be calculated by using formula (1) and (2), and then to get the imaging binary map by selecting the water index with the chosen threshold, finally, to extract the water line in the binary map.]

Because the water has the strong absorption characteristics of near-infrared and middle-wave infrared, combined with the experimental data, this study selects the two commonly used water bodies to extract the water line, that is, the normalized water index NDWI and the improved normalized water index (MNDWI):

$$NDWI = (Green - NIR) / (Green + NIR) \quad (1)$$

$$MNDWI = (Green - MIR) / (Green + MIR) \quad (2)$$

Here, Green is the Green band, NIR is the Near InfraRed band, MIR is the Middle InfraRed band.

The first step is to calculate the water index of the 11 scenes of OLI images using the above formula to obtain the NDWI and MNDWI data. The second step is to use the real colour image of each stage to visually select the water and land boundary points in the image to determine the threshold of the water body index. The third step is to compare the position of the water and land boundary points of the different periods under different thresholds, and select the applicable water index for each period as shown in Table 2.

**Table 2.** Water index and threshold.

Scenes number	Water index	Threshold	Scenes number	Water index	Threshold	Scenes number	Water index	Threshold
2015019	MNDWI	0.2	2015083	NDWI	0.1	2015227	NDWI	0.3
2015035	MNDWI	0.2	2015115	NDWI	0.1	2015259	NDWI	0.1
2015339	MNDWI	0.3	2015163	NDWI	0.1	2015275	NDWI	0.1
			2015195	NDWI	0.1	2015307	NDWI	0.2

**3.4.2. Water line screening and painting.** Because of the existence of long trenches on the tidal flat, there are cross or overlapping phenomena in the multi-temporal water lines extracted from the images, which make it difficult for the mathematical simulation to make the terrain singular. In order to eliminate the abnormalities of mathematical simulation, appropriate artificial editing can reduce the impact of the tide. In addition, it should screen the water line, and remove the impact of the high sediment concentration of seawater of the low tide, and also extract the obvious anomalies of the water line, as well as sea ice affect the water line, and the results are displayed in Figures 2, 3.



**Figure 2.** Extracts access to all water margin lines.



**Figure 3.** Painted and screened water line.

**3.4.3. Waterside line high tide acquisition.** In this study, we select the measured data of Nanpu tide station to calculate the corresponding tide value of each water line (Figure 1). The tidal high data of the Nanpu tide station records the tidal level of 3 to 4 moments in each day, that is, the maximum or minimum tide value of the period. According to the dynamic characteristics of the tide of the sea, the polynomial function is chosen to fit the change of daily tide level, and the tide level of the water line during the satellite transit is calculated, which is used as the water line tide value in Table 1.

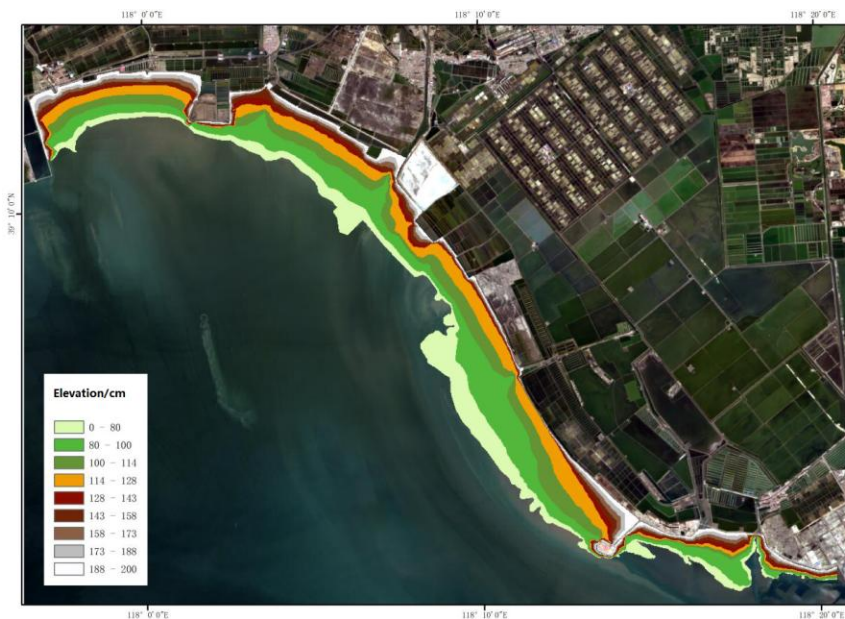
## 4. Results and analysis of DEM construction in tidal flat

### 4.1. Tidal flat DEM

The modified water lines are given the corresponding instantaneous tide height values (the high tide datum level), and the tidal flat contour data in the research experimental zone is generated. The tidal beach DEM is constructed by ArcGIS. As the interpolation method of ArcGIS is mainly based on the point vector interpolation, it needs re-sample the high line data of the tide level and select the appropriate interpolation method. In the interpolation, the distribution of the sampling points has a direct influence on the interpolation results, and the sampling point overdrive will reduce the interpolation precision and lose the detailed information, while the distribution is easy to show the terrain singularity.

In this study, we study the resampling of line vector to point vector by using five kind of accuracy of 30m, 60m, 90m, 120m and 150m, respectively. Based on the above five kinds of resampling precision point vector data, the interpolation methods such as Kriging, IDWI and Irregular Triangulation Network are compared with different parameters. The results show that the irregular triangles are connected to the tidal level contour vector data. And it is not sensitive to the change of the resampling precision. Therefore, it is necessary to preserve the details of the tide contour data as much as possible. Finally, the tide contour data is finally resampled by 30m and generated the tidal flat digital elevation model by using the Irregular Triangulation Network is shown in Figure 4.





**Figure 4.** Approximate topography build of tidal flat using tide level contour and TIN in test area.

#### 4.2. Construction result analysis

The DEM data of the experimental area measured by aerial photogram in 2016 were used as the validation data for the DEM retrieval. In order to facilitate the error statistics, the aerial photogrammetric DEM data is resampled to the same 30m×30m resolution grid size as the DEM retrieval. Then, to select randomly several topographic data of two DEM overlapped regions, the retrieved DEM is subtracted from the error of the DEM obtained by aerial photogrammetry. From the range of values of the difference, the maximum and minimum values of DEM elevation are retrieved locally, and its error is between -5m~2m, whereas the individual differences are -8.81m and 5.71m, according to the statistics data. It should be noted that this model is only approximate terrain inversion, and the aerial photogrammetric obtain of DEM is not low tide level acquisition, and thus DEM inversion results are only relative assessment, do not strictly assess the accuracy.

### 5. Conclusion

In this study, the extraction of water line has been developed by using the remote sensing data. Although the inversion of tidal flat topography is only a kind of approximate topography, it is still an effective way to keep track of the terrain data in the absence of measured terrain data.

Moreover, the remote sensing image data of the test area in this study is only 30 meters, but the intertidal zone terrain can meet the precision requirement of 1: 10000 ~ 1: 50000 scale remote sensing mapping & engineering drawing. Based on such technology, topographic mapping of muddy tidal flats that is difficult to reach (no man can go, and no ship can come) in traditional surveying and mapping can be carried out quickly and effectively with the use of multi-temporal satellite remote sensing data. The technical method is not only the energy saving cost, but also can fill the intertidal zone with long and wide muddy beach mapping blank.

If the domestic high resolution satellite remote sensing image data is complete, the accuracy can be improved to meet the accuracy requirements of 1:5000~1:25000 scale mapping, by using the high resolution GF-1/GF-2 optical remote sensing image data. With the use of high resolution domestic satellite remote sensing data, the precision of the built intertidal terrain model is improved. A high precision digital elevation terrain model (DEM) built by inversion in intertidal zone will be effectively applied to the coastal zone storm surge dam project construction, tidal flat reserve land resources survey and survey, muddy tide to bring the country to carry out major construction projects (nuclear power plant construction, cross-sea channel project, large-scale petrochemical refining construction,

coastal cities Group construction, etc.) site selection, coastal comprehensive geological survey, coastal zone resource development and land and sea co-ordination of sea and land terrain seamless stitching.

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