DISPERAL OF SUSPENDED SEDIMENT IN THE SOUTHWEST INSHORE OFF THE MODERN HUANGHE (YELLOW) RIVER ESTUARY

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ABSTRACT

In this paper, the surface suspended sediment concentration (SSC) in Yellow River estuary and the adjacent regions was quantitatively estimated by analyzing in situ SSC and spectral feature of these waters. A long time series synoptic maps of SSC have been retrieved at different time and multiple conditions, and the diffusion character of suspended sediment systematically was analyzed in offshore area of southwestern part of Yellow River estuary. The results showed that a littoral barrier drift southward commonly existed in western near-shore area, the diffusing direction of suspended sediment gradually turned to SSE direction when it was transported along the coast, and an approximately 20 degree-angle has formed between the coastline and a long-shore drift. Several years repetitive monitoring of coastal profiles and sediment data from field observation in study area all adequately illuminated the reliability of these conclusions.

\textbf{Index Terms}—Sediment load of Yellow River, Remote sensing reflectivity, SSC, coastal profile, Bottom sediment

1. INTRODUCTION

Rapid sediment accumulation has happened in Laizhou Bay for the southward dispersal and deposition of sediments off the mouth of Huanghe (Yellow) River since its mainstream was artificially diverted to Qingshuigou distributary in May 1976. Especially in the southwest nearshore area of Laizhou Bay, the seabed becomes shallow and the tidal flats become extensive, accompanying with drastic changes of seabed scour and silting. In consideration of the significant impacts of Yellow River delta evolution to the local area's agriculture and industry, studies on suspended sediment and its accumulation in the coastal sea of Laizhou Bay, especially in the southwest near-shore area, are very important.

2. IN SITU MEASUREMENTS

Spectral radiance and reflectance (350~1050nm) above the sea surface were measured with a spectroradiometer of FieldSpec Dual made by ASD company in USA, which was equipped with standard white plate, of which the diffuse reflectance is 25\%~30\% from 19th to 27th June 2004 in north near-shore area off Yellow River mouth (Fig.1)[1].

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Fig. 1. Location of observation stations and coastal profiles in Huanghe River Estuary and the adjacent coastal waters

During the field spectrometry, near-surface water samples were also collected from those stations. For SSC measurements, about 30~2000ml of the water sample was filtered at low vacuum pressure onto pre-weighed 0.45μm polycarbonate filters. The filter was rinsed with distilled water to remove salt crystals three times, then dried at 40°C in an oven and weighed using a microbalance to get SSC. Grain size of the suspended matter was determined using a laser particle size analyzer of Cilas 940L type. On the other hand, In-situ water samples and sea bottom sediments were obtained from north of Zimaigou River to south of Xiaoqinghe River from 20th to 30th January 2007 (Fig. 1). SSC, grain size and bottom sediment types were analyzed respectively to understand the characteristics of sediment diffusion and deposition.

3. DATA AND METHOD

Based upon in situ above-water radiance measurement and water sampling, responses of spectral signature to SSC of turbid waters in the Huanghe estuary have been discussed for SSC ranging from 5.4 to 1713.1mg/l. An empirical relationship between reflectance of turbid waters in Landsat TM/ETM band and SSC has been established through the simulation of Landsat spectral bands (visible to near infrared). General form of this model is: \( R = 0.0082 \ln(S) + 0.0002 \), where \( R \) is spectral reflectance in % extracted from band 3, and \( S \) is SSC in mg/l, while correlation coefficients is 0.93 [2].

Table 1 Summary information on the speed and direction of wind, and the tide condition for all Landsat data during the image acquired

<table>
<thead>
<tr>
<th>NO</th>
<th>Satellite image</th>
<th>Tide</th>
<th>Wind speed (m/s)</th>
<th>Wind direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1986-08-08 TM</td>
<td>Ebb</td>
<td>5</td>
<td>SSE</td>
</tr>
<tr>
<td>2</td>
<td>1989-11-20 TM</td>
<td>Ebb</td>
<td>4</td>
<td>SSE</td>
</tr>
<tr>
<td>3</td>
<td>1990-11-23 TM</td>
<td>Ebb</td>
<td>3.7</td>
<td>WNW</td>
</tr>
<tr>
<td>4</td>
<td>1992-08-24 TM</td>
<td>Ebb</td>
<td>4.3</td>
<td>SSE</td>
</tr>
<tr>
<td>5</td>
<td>1994-02-19 TM</td>
<td>Ebb</td>
<td>4.2</td>
<td>SSE</td>
</tr>
<tr>
<td>6</td>
<td>1994-09-15 TM</td>
<td>Ebb</td>
<td>4.8</td>
<td>NNE</td>
</tr>
<tr>
<td>7</td>
<td>1997-02-11 TM</td>
<td>Ebb</td>
<td>9.1</td>
<td>NW</td>
</tr>
<tr>
<td>8</td>
<td>1999-08-28 TM</td>
<td>Flood</td>
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<td>SSE</td>
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<td>Flood</td>
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<td>2003-05-27 ETM</td>
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<td>7</td>
<td>SE</td>
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<td>11</td>
<td>2004-09-10 TM</td>
<td>Ebb</td>
<td>3.2</td>
<td>NE</td>
</tr>
</tbody>
</table>

*July to October is high river discharge period, and November to June next year is low river discharge period.

11 Landsat images of different acquisition dates were used to detect the range of suspended sediment dispersing and depositing influenced by many factors in different periods at southwest nearshore area of Yellow River estuary (Tab.1). The Landsat Level 1 products were collected, Path radiance was corrected by Dark Object Subtraction (DOS) technique [3]. Under solar zenith angle between 30° and 45°, DOS2 was used for atmosphere correction, while the others adopted DOS1. For temporal and spatial comparative analysis between different data, histogram normalized was applied for all images. Land area was masked by using a threshold image generated from TM/ETM+ band-5 image corresponding to the respective band-3 image.

4. RESULTS

From the retrieval figures it is inferred that near-surface suspended sediment (SSC>50mg/l) was transported mainly near shore to both sides of the Yellow River mouth during high river discharge period, and also diffused to NW-SE direction off the river estuary during low river discharge period.

Fig. 2 Diffusing range of suspended sediment (SSC>3000mg/l) retrieved from Landsat images in southwest near-shore area of Yellow River mouth

According to statistic data, the sharp falling zone of highly turbid water that is more than 1000mg/l of SSC is located about a 10~20km distance from Tianshuigou River mouth southward in flood season, and a 20~35km distance in low flow (Tab.2). Comparison of the variation of
submarine topography from 1992 to 2000, a 15km range region of strip in shape southward from the Tianshuigou River mouth appeared to be eroded, revealing that intense local sediment resuspension has happened, and southward from there suspended sediment settled gradually. Sedimentation took place mainly from about 25km southward from the Tianshuigou River mouth to near the Zimaigou River mouth, showing the region where suspended sediment began to fall sharply. Furthermore, the diffusing direction of suspended sediment (SSC>3000mg/l) gradually turned to SSE direction when it was transported along the coast, and an approximately 20 degree-angle has been formed between the coastline and longshore drift (Fig.2). In the corresponding period, long-term detection of coastal profiles change showed that since 1976 the profiles from cs28 to cs32 had been eroded slightly landward side in distance less than 10km, and sedimentation that had been observed from cs32 southward indicated that suspended sediment (SSC>3000mg/l) gradually deposited around cs32 and cs33 at a distance 23km and 27km off the Tianshuigou River respectively (Fig.3).

Table 2 Distribution of suspended sediment (SSC >1000mg/l) retrieved from Landsat images and water-sediment load of Yellow River

<table>
<thead>
<tr>
<th>NO.</th>
<th>Satellite image</th>
<th>Sediment load (t/m³)</th>
<th>River Discharge (×10⁸ m³)</th>
<th>Orientation of deposit (°)</th>
<th>Distance (km)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>1986-08-08</td>
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<td>2</td>
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<td>4.48</td>
<td>838</td>
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<td>3</td>
<td>1990-11-23</td>
<td>16.78</td>
<td>894</td>
<td>SW</td>
<td>23.5</td>
</tr>
<tr>
<td>4</td>
<td>1992-08-24</td>
<td>88.61</td>
<td>2020</td>
<td>SW</td>
<td>17.3</td>
</tr>
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<td>5</td>
<td>1994-02-19</td>
<td>5.2</td>
<td>454</td>
<td>SSE</td>
<td>32.6</td>
</tr>
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<td>6</td>
<td>1994-09-15</td>
<td>32.46</td>
<td>1140</td>
<td>SSE</td>
<td>18.4</td>
</tr>
<tr>
<td>7</td>
<td>1997-02-11</td>
<td>0</td>
<td>0</td>
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<td>8.2</td>
</tr>
<tr>
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<td>1999-08-28</td>
<td>5.67</td>
<td>156</td>
<td>SSW</td>
<td>13.6</td>
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<tr>
<td>9</td>
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<td>63.6</td>
<td>SSE</td>
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<tr>
<td>10</td>
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<td>44.3</td>
<td>SW</td>
<td>15.9</td>
</tr>
<tr>
<td>11</td>
<td>2004-09-10</td>
<td>5.85</td>
<td>680</td>
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<td>20.1</td>
</tr>
</tbody>
</table>

*starting point is Zimaigou River mouth, direction along coastline

According to analysis of in situ observation from cs32 southward, the SSC increased gradually seaward, and the north was higher than the south in surveying area. The particle of bottom sediment became coarse from north of Zimaigou River to near the Xiaoqing River (Fig.4). The traverse distribution characteristics of bottom sediment types were that grain size became coarse seaward in the south of Zimaigou River, and in the north horizontal zoning paralleled to the coastal line had been formed. The sediment of zonary area that corresponded approximately to the bottom scour area was coarser than the bilateral. It is the sharply falling zone of long-shore transport of sediment load of Yellow River that these features were displayed. On the other hand, from Tianshuigou River to Xiaoqing River, changing trend of the heavy mineral that stable mineral increased gradually with the increase distance in the Yellow River estuary indicated that the sediment of long-shore transport mainly originated from Yellow River [4].
littoral barrier drift southward commonly exists in western near-shore area. The meta-analysis results of sediment characteristics and water depth change in offshore area of western part of Laizhou Bay demonstrated that there was a relatively complicated relationship between diffusing region of suspended sediment load of Yellow River and sea bottom scour/fill area. Since 1976, a 15km range region of strip shape southward from the Tianshuigou River mouth appeared to be eroded, further southward converting to siltation area.

6. ACKNOWLEDGEMENT

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7. REFERENCES


