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FIELD MEASUREMENTS OF SURFACE SUSPENDED SEDIMENT CONCENTRATION IN THE YANGTZE ESTUARY, CHINA

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Abstract: The Yangtze estuary, from Xuliujing to the mouth, is 145 km in length and the width extends from 5 km at Xuliujing to 90 km at the mouth. There are lots of influence factors on the motions of flow and sediment, including the tide, wave, bed form and the flow and sediment of upstream. Understanding on the motions of flow and sediment with the long term in-situ investigation is crucial to the management of multiple economic and societal issues ranging from commercial fisheries to contaminant transport and harbor maintenance in the estuary. This paper concluded some new results on the space-time distribution of the surface suspended sediment concentration in the Yangtze Estuary, China. Field data are obtained at the upper reach (Xuliujing station), middle reach (Hengsha station) and down reach (Sheshan station) of the estuary between Aug. 1998 and Jan. 1999. Wind wave conditions and its influence on sediment re-suspension and transportation also discussed in this paper.

Key words: Yangtze (Changjiang) Estuary, Suspended Sediment Concentration, Re-suspension, wind, Wave

1. INTRODUCTION

The Yangtze Estuary is famous for its large runoff and high suspended sediment concentration. The distribution of suspended sediment concentration is complicated. Systematic and long time-series field measurement are very few due to its spacious water area and the special delta characteristic of three-order bifurcation and four-mouths run out. Though there exist many research results on sediment transport (Shen, 1983; Shi, 1985; John, 1985; Gao, 1999; He, 1993; Pan, 1996). It is hard to see such kind of data on the surface suspended sediment concentration which measured everyday at Xuliujing, Hengsha and Sheshan gauging stations, between Aug. 1998 and Jan. 1999. This paper discussed the effects of runoff, tidal current and wind waves on the spatial and temporal distribution of suspended sediment concentration in the Yangtze estuary, China.

2. FIELD EXPERIMENT SITE AND METHOD

Xuliujing station locates at the bifurcation node of south-north branches in Yangtze estuary, China (31°44′54″N, 120°55′12″E), 140 km far away from the mouth; Hengsha station locates in the turbidity maximum area (31°17′36″N, 120°50′54″E), which is 53 km from the mouth; Sheshan station locates at the -5 meter isobaths out of north-channel(31°25′12″N, 120°14′18″E), where exists a lot of shoals (Fig.1). Each station represents different nature characteristics. Dynamic condition of Xuliujing dominates by runoff; Hengsha station locates in the mixing area of fresh water and salt water; Shesha is in the mouth, which is often influenced by wind. Surface suspended sediment samples were collected at the stations between Aug. 1998 and Jan. 1999. Suspended sediment concentrations were measured by filtration, drying and weighing in lab.

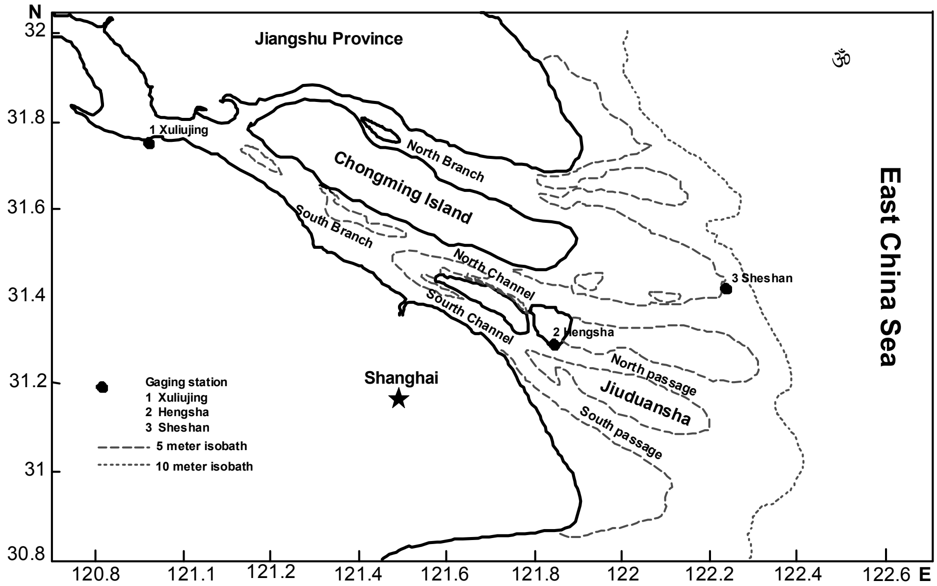

Fig. 1 Sketch map of gauging stations in the Yangtze estuary, China

3. SURFACE SUSPENDED SEDIMENT CONCENTRATION

Data of surface suspended sediment concentration which were measured everyday at Xuliujing, Hengsha and Sheshan respectively between Aug. 1998 and Jan., 1999, show the influences by runoff, tidal current and wind waves on the spatial and temporal distribution in the Yangtze estuary, China.

Fig. 2 is the monthly averaged value of SSC which was sampled at Xuliujing, Hengsha and Sheshan gauging stations. It shows us that the monthly averaged value of SSC of Xuliujing station, located at upper reach of south branch in Yangtze estuary, is the lowest one among the three stations. The highest value of SSC reaches 0.2616 kg/m^3 in August at this station. The monthly averaged SSC decreases with time and drops to the lowest one, 0.098 kg/m^3 in Jan. 1999. The monthly averaged SSC of Hengsha gauging station is higher than that of Xuliujing most of the time. It represents the averaged SSC of upper reach of north passage and the highest monthly averaged SSC 0.3364 kg/m^3 appears in January 1999. For Sheshan gauging station, the lowest monthly averaged SSC appears in August with value of 0.3507 kg/m^3, and the other monthly averaged SSC of Sheshan are all larger than 0.40 kg/m^3. The highest value 0.4922 kg/m^3 appears in November 1998. The characteristics of monthly averaged SSC of Sheshan gauging station, located at outside the north-channel and the end reach of Chongming East Shoal, is totally different with the Xuliujing station.

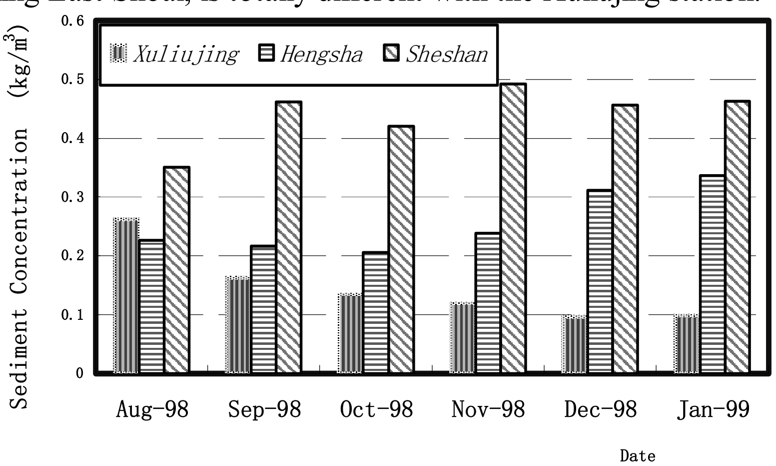

Fig. 2 Monthly averaged surface SSC at the Xuliujing, Hengsha and SheShan gauging stations, Yangtze estuary, 1998-1999

The SSC also changes with the alternation of spring and neap tides and the flood and dry seasons. Figure 3 shows SSC of spring and neap tides in flood season (Aug.-Sep.) and dry season (Dec.-Jan.) at Xuliujing（Xu）, Hengsha(Heng) and Sheshan(She). Except the Xuliujing station, the SSC of spring tide is lower than that of neap tide in flood season, all the other SSC of spring tide are larger than that of neap tide no matter what season (flood or dry season). For the Hengsha station, the SSC of the spring tide is double of the neap tide.

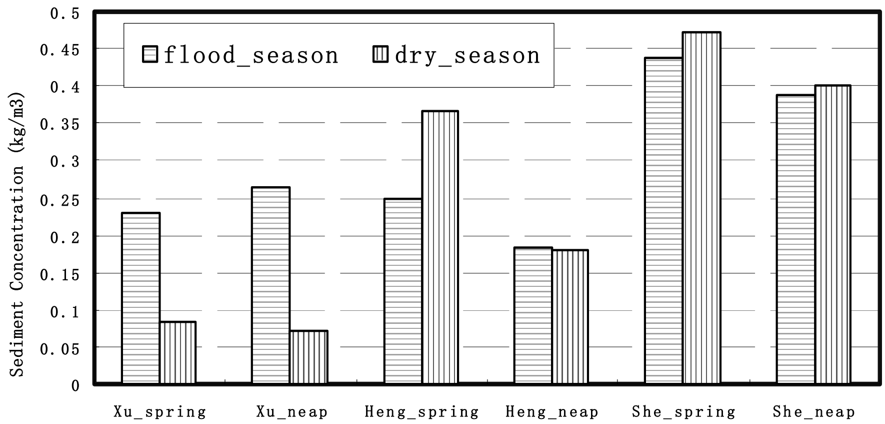

Fig. 3 Surface SSC of spring and neap tides in flood season (Aug.-Sep.) and dry season (Dec.-Jan.) at Xuliujing, Hengsha and Sheshan gauging stations, Yangtze estuary

The highest SSC happened different time at different stations. At Xuliujing, it is 1.84 kg/m^3 in August; secondly high concentration is 0.7190 kg/m^3 in October. At Hengsha station, the highest SSC is 1.3762 kg/m^3 in October and the second one is 0.9037 kg/m^3 in January. At Sheshan station, outside of north-channel, the SSC are very high during the whole observation period. Statistic results for all data set show that there are 26 times which the SSC is over 1.0 kg/m^3 and 7 times exceeding 1.5 kg/m^3. Among the above high SSC events, there are 19 times (about 73%) along with strong northward wind. The highest SSC is 3.021 kg/m^3 in September; secondly is 2.439 kg/m^3 in November, The SSC of Sheshan are higher than that of Hengsha.

4. WIND-WAVE EFFECT ON SUSPENDED SEDIMENT CONCENTRATION

Based on the wind data between August 1998 and July 1999 and the wave data between June and November, 1999 at Sheshan station, the wind and wave conditions are summarized in Table 1 to Table 4. The normal wind direction is Northward (N), secondly is SE (Table1). The maximum values of average wave height and maximum wave height are all at NNE direction (Table3). The averaged wave height is 0.98 meter with 3.5 second wave period; the maximum wave height is 3.5 meter. These data also provide that the 60% of the wave heights are less than 1 meter, 16.8% larger than 1.5 meter.

Table 1 Statistics of wind at SheShan gauging station (1998-1999)

Wind direction	N	NNE	NE	E	ESE	SE	S	SW	W	NW	NNW	C	Total
Count	295	2	18	18	3	165	74	16	5	28	13	51	688
Frequency %	42.9	0.3	2.6	2.6	0.4	24.0	10.8	2.3	0.7	4.1	1.9	7.4	100
Averaged wind speed	7.5	4.5	6.3	6.0	8.0	6.6	5.6	5.6	4.6	7.6	9.8	0	6.4

Based on criterion of seaport hydrologic measurement and the method of Li Yucheng (Li, 1991; Li 1993), depths of breaking wave are given in Table 4. The underwater shoal with isobaths of -2~3 meters is influenced intensively by the wave, especially, when the wave heights are larger than 1.5 meter. The sediments on shoal are re-suspended under the condition. The SSC in the water column increases obviously at the same time.

Table 2 Statistics of frequency of wave height at Sheshan (June-Nov., 1999)

Wave height	<0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5
Frequency (%)	19.3	42.2	21.7	9.4	5.2	1.8	0.4

Table 3 Statistics of wave and wind direction at Sheshan

Wave height	N	NNE	NE	ENE	E	ESE	SE	SSE	S
Frequency %	8.6	17.3	6.9	6.0	13.1	6.3	7.6	6.5	6.4
Averaged wave height	1.2	1.4	0.9	0.9	0.9	0.9	0.8	0.7	0.9
Maximum wave height	2.9	3.5	2.7	2.5	2.7	2.1	2.2	2.0	2.0

Table 3 continued

Wave height	SSW	SW	WSW	W	WNW	SW	NNW	C	Total
Frequency %	1.5	1.1	0.4	0.3	0.4	1.0	3.9	12.8	100
Averaged wave height	0.8	0.9	0.7	1.3	0.9	0.9	1.1		
Maximum wave height	1.5	2.2	1.1	1.6	1.8	1.5	2.1		

Table 4 Relationship between water depth of breaking wave and wave height at Sheshan

Wave height ($H_{1/10}$) (m)	Frequency (%)	Water depth of breaking wave	
		The criterion of harbor	Ref. Li Yucheng
0~0.5	19.3	0.77	0.65
0.5~1.0	42.2	1.54	1.33
1.0~1.5	21.7	2.31	2.05
1.5~2.0	9.4	3.08	2.74
2.0~3.0	7.0	4.62	4.23
3.0~3.5	0.4	5.38	___

Fine sediment deposited on the shoal transported into the channel. Coarse sediment deposited on the shoal and easy to be kept. By this way, the shoal is coarsened. Comparing the variation of the grain size distribution of the sediment on the shoal located at the north side of Jiuduansha (Fig.1), Table 5 shows clearly the action of wind wave on the sediment re-suspension on the shore. The process of sediment re-suspension and transportation into the main channel is one of the major contributions for the turbidity maximum in the Yangtze estuary. It is a big different for median size changing from 0.05 to 0.103 mm corresponding to the wind speed changing from 10.4 to 3.6 m/s respectively. Table 6 is the wind condition and the surface suspended sediment concentration at Shesha gauging station. We can clearly notice that the wind had important effect on the high suspended sediment concentration of the Sheshan area. The surface maximum suspended sediment concentration reached to 2.8 kg/m^3 and the corresponding wind speed was 8.9 m/s on Aug. 3, 1999 and 1.86 kg/m^3 and 8.6 m/s of the same year on November 25.

Table 5 Variation of grain size on the shoal of north side of Jiuduansha

Sampling time	Wind conditions			Grain size parameters	
	Wind direction	Averaged wind speed (m/s)	Maximum wind speed (m/s)	D_{50} (mm)	<0.005 mm (%)
April 6, 2000	SW	3.6	7	0.05	13
July 11,2000	S-SW	10.4	12.0	0.103	0

Based on yearly measuring data, it happened 46 times that the surface suspended sediment concentration are over 1.0 kg/m^3. Among them, 76% of the wind speeds are larger than 6 grades (8.0 m/s) and the wind direction are usually northward (N). Therefore, wind wave is one of the main dynamic factors that re-suspend the fine particle sediment on the shoal and it is also the major reason of the high suspended sediment concentration at Hengsha and Sheshan gauging stations.

Table 6 Wind conditions and surface SSC at Shesha gauging station

Sampling time	Wind conditions			Surface SSC
	Wind direction	Averaged wind speed (m/s)	Maximum wind speed (m/s)	kg/m^3
August 3, 1999	NNW	8.9	16.7	2.8
November 25,1999	N-NNW	8.6	15	1.86

5. SUMMARY AND COCLUSIONS

The observation results of surface suspended sediment concentration at the Xuliujing, Hengsha and Shesha gauging stations show that the suspended sediment concentration increases from upper station Xuliujing, passing through the Hengsha in the North Passage to the Sheshan, outside of the Yangtze estuary. That the monthly averaged suspended sediment concentration in the flood season is larger than that in the dry season at the Xuliujing. It is because that the suspended sediment concentration is influenced mainly by the runoff. On the contrary, the monthly averaged suspended sediment concentration in the dry season is higher than that in the flood season at the Hengsha and Sheshan gauging stations. It is because of the wind conditions. The wind wave disturbed the sediment near the bed and re-suspended the sediment.

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