Seasonal variation of suspended-sediment transport through the southern Bohai Strait, China

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How much sediment is transported from the Bohai Sea to the Yellow Sea annually ?

The Bohai Strait connects the Bohai Sea and the Yellow Sea (Fig. 1) and is the pathway for material exchange between the two seas. The strait is roughly divided into two parts by North Huangcheng Island. Yellow Sea water flows into the Bohai Sea through the northern Bohai Strait, and Bohai Sea water flows out to the Yellow Sea through the southern part . Thus, the southern Bohai Strait is the primary pathway for sediment transport from the Bohai Sea to the Yellow Sea.

The Huanghe suspended sediment transported eastward to the Yellow Sea through the southern Bohai Strait is considered a major source of the muddy deposits (e.g., mud wedge or distal subaqueous delta off the eastern Shandong Peninsula) in the Yellow Sea. However, the quantity of sediment that is transported from the Bohai Sea to the Yellow Sea through the southern Bohai Strait is still under debate due to the absence of long-term and multistation observations, especially in winter.

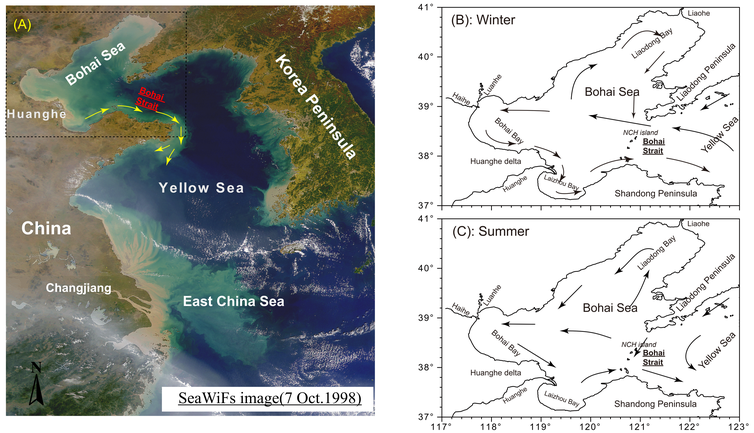

Fig. 1. (A) Location of the Bohai Sea and Bohai Strait and the schematic map of sediment transport through the southern Bohai Strait (after Yang and Liu, 2007) and general pattern of the circulation in the Bohai Sea and the Bohai Strait in (B) winter (after Fang et al., 2000) and (C) summer (after Guan, 1994) and . NCH indicates northern Chenghuang Island.

Field observational data and monthly averaged MODIS data were used

Hydrographic surveys at a time-series station (A28) near the southern Bohai Strait were conducted on November 13, 2006, and July 7, 2007 (Fig. 2). The observations in summer (July 2007) were conducted when wind speeds were relatively low (~4 m /s); the winter (November 2006) observations were made 4-5 days after stormy weather with wind speeds of ~15 m/s. In addition, SSC data were collected at eight time-series stations (sampled for 13- or 25-h periods) and on a twenty-four grid stations off the Huanghe delta and in the adjacent Bohai Sea on cruises during June 29–July 7, 2007 and November 7–13, 2006 to establish models of SSC retrieval from the MODIS data.

Cloud-free MODIS L1b data with spatial resolutions of 250 m and 500 m were obtained for days corresponding to the field surveys. Reflectance data were extracted from pixels centered on the in-situ measurements to establish the MODIS retrieved SSC model (Fig. 3) if the time gaps between the acquisition of MODIS imagery and field sampling were less than 30 minutes in coastal areas within the 15-m isobath and 3 hours in offshore areas deeper than 15 m. Moreover, daily cloud free MODIS imageries in 2007 were collected to yield composite monthly averaged MODIS data.

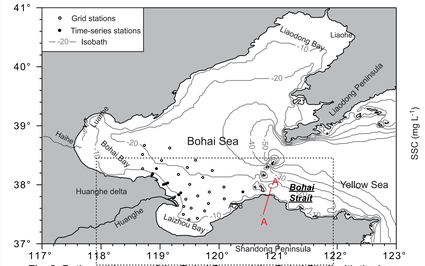

Fig. 2. Bathymetric map of the Bohai Sea and the Bohai Strait with the locations of the survey stations in 2006 and 2007. The dashed box indicates the area of interest for retrieval of SSC from MODIS imageries. Transect A-A' indicates the locations for WF and SSF calculations.

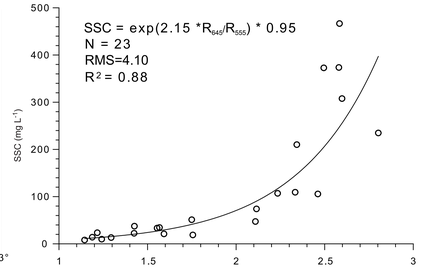

Fig. 3. The SSC as an exponential function of the ratio of reflectance values of band 4 to band 1. R_{645} and R_{555} indicate the reflectance values of band 1 and band 4, respectively.

Significant seasonal variation of suspended sediment transport through the southern Bohai Strait was detected

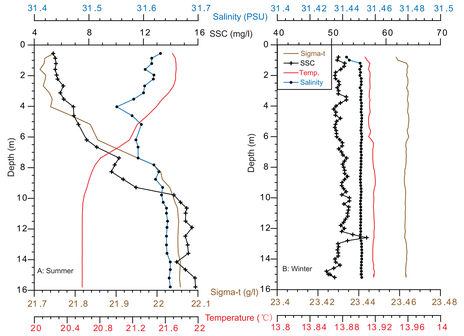

Fig. 4. Vertical profiles of sigma-t, SSC, temperature and salinity in (A) summer and (B) winter at station A28.

Table 1. Comparison of salinity, SSC, WF and SSF at station A28 during two surveys, one in summer 2007 and the other in winter 2006.

Item	Summer			Winter		
	Maximum	Minimum	Average	Maximum	Minimum	Average
Salinity	31.65	31.59	31.63	31.41	31.20	31.36
SSC (mg l^{-1})	40	4	11.55	20	100	48.1
Water flux [a] (m^3 s^{-1})	/	/	1.91	/	/	2.37
Sediment flux (kg m^{-1} s^{-1})	/	/	0.3	/	/	1.5

[a] The directions of the water and sediment fluxes are flowing out of the Bohai Sea to the Yellow Sea.

The observational data shows that the water column is well mixed vertically for the physico-chemical parameters (e.g., salinity, density, and SSC) (Fig. 4). The depth-averaged SSC is 48 mg/L, more than 4 times that in the summer. The WF and SSF are estimated to be 2.37 m^3/s and 1.5 kg/m/s, equal to 1.2 and 5.0 times those in summer (Table 1).

The intermonthly variation of the MODIS-derived surface SSC indicates that highly turbid waters are formed off the Huanghe delta starting in January and disperse eastwards through the north-middle Laizhou Bay some distance off its south coast. They are then driven along the coast of Shandong Peninsula, with the SSC decreasing gradually towards the Yellow Sea through the southern Bohai Strait. After April, the extension of highly turbid waters is narrowed and limited to the nearshore area close to the coast of the Huanghe delta. As a result, the highly turbid water belt in the southern Bohai Strait disappears gradually. During the flood season of the Huanghe (July–September), the turbid river plume extends seaward and becomes more identifiable than it is for April-June, but it has little impact on the SSC distributions in the southern Bohai Strait. The same distribution pattern of highly turbid waters for January–March is formed again in November. The waters are more turbid in December, with an enlarged extension of highly turbid waters that almost covers the whole area of this study (Fig. 5).

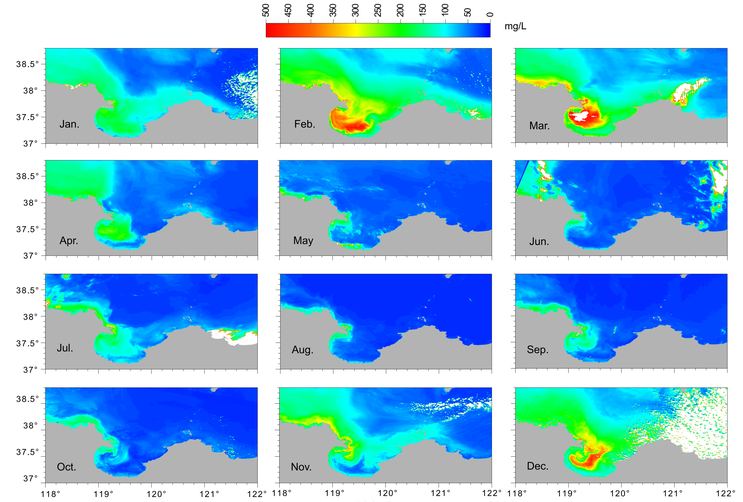

Fig. 5. Seasonal and spatial variations of monthly averaged SSC based on the model of SSC retrieval. The white areas indicate clouds.

The annual sediment flux through the southern Bohai Strait was reestimated to be approximately 40.0 Mt/yr

According to the seasonal variation of the monsoon activity, the year can be simply divided into two seasons, namely summer (April–September), when southerly and southeasterly winds prevail, and winter (October–March), when northerly and northwesterly winds dominate (Liu, 2006). During the winter, the water column is well mixed and the SSC has little variability with depth (Fig. 4). Thus, the MODIS retrieved SSC is used as the depth-averaged SSC in the present study. The averaged SSC in the summer in the present study is taken to be 10.5 mg/L calculated by Martin et al. (1993) based on 6 cruises data collected from 1985-1991. It indicates that winter is the major season for sediment transported from the Bohai Sea to the Yellow Sea through the southern Bohai Strait.

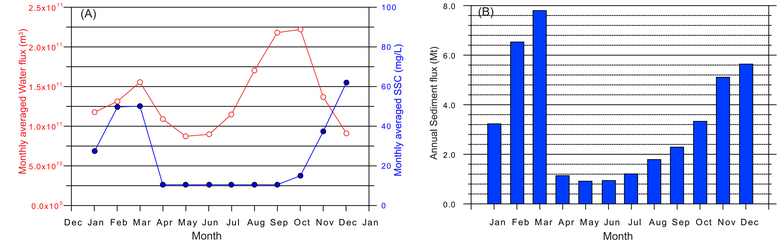

Fig. 6. Seasonal variations of (A) monthly averaged water discharges (Lin et al., 2004), SSC, and (B) SSF in the southern Bohai Strait. Note that the averaged SSC from April to September is from Martin et al. (1993), while those from January to March and October to December were calculated from the MODIS-retrieved SSC along transect A-A' (Fig. 2).