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Diurnal Changes Monitoring and Analysis of the Total Suspended Matters in Bohai Sea Using Geostationary Ocean Color Imager

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Abstract. Since the launch of the world's first geostationary satellite ocean color sensor, the Geostationary Ocean Color Imager (GOCI), it is possible to realize the hourly observations and trace the diurnal changes of color matters in target waters. In this paper, we first developed an empirical TSM retrieval algorithm of Bohai Sea based on in situ spectral data. Then we applied the algorithm to the GOCI images on September 13, 2015. Results showed that TSM concentration in Bohai Sea had a good relationship with band five of GOCI. The concentrations of TSM were high along the coast and low in the offshore areas. The concentrations were extremely high around Huanghe Reiver Delta, such as Bohai Bay and Laizhou Bay. The deviation analysis also showed a great diurnal changes around the north part of Bohai Bay and Laizhou Bay. This paper highlight the feasibility of using geostationary ocean color remote sensing to monitor short-term and regional color matters in coastal waters.

1. Introduction

As a pollutant tracer agent, the suspended matter is extremely important for the study of the spread and distribution of the terrigenous sediment in the sea area, and it is also an important indicator for the quality assessment of marine waters. Bohai Sea is a semi-enclosed inland water in China with the average depth of 18m. Yellow River, Liaohe River, Weihe River and other rivers enter the sea, bringing a large amount of suspended matters. The study on the distribution characteristics of the suspended matters concentration in Bahai Sea has important scientific value for the study of biogeochemical system material and energy cycle [1], which can provide data security for the ecological environment protection of Bohai Sea [2][3][4][5]. Since the 1960s, scholars have begun to study the concentration distribution and seasonal variations of suspended matters in Bohai Sea. Qin et al [6] qualitatively analyzed the distribution of suspended matters in Bohai Sea by using the field survey data. Cao et al. [7] made numerical simulation of the transport value of suspended matters in Bohai Bay based on tidal waves. Jiang et al. [8] analyzed the relationship between hydrodynamic conditions and suspended matters distribution based on actual observations. Cui et al. [9] carried out the remote sensing inversion analysis for the distribution of suspended matters in Bohai Sea by using the measure data of Bohai Bay and Laizhou Bay. With the development of satellite, remote sensing of suspended matters in Bohai Sea have become more and more mature. In general, the previous remote sensing inversions of the suspended matters in Bohai Sea [2][10][11][12] were based on a small number of voyage data in one or two regions, and some inversion values in the estuary area were significantly lower. The algorithm results could not characterize the distribution of suspended matters in the whole Bohai Sea. Most of the existing studies have analyzed a certain phase or inter-annual scale of Bohai Sea [13][14], and few studies have been conducted on the dirunal variation of suspended matters.

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In this paper, the remote sensing inversion algorithm of suspended mattes in Bohai Sea was studied by using the measured spectroscopy and suspended matters concentration data of several voyages in Bohai Sea from 2008 to 2017. The inversion algorithm was applied to the satellite data received by the geostationary ocean color imager (GOCI) to obtain the spatial distribution pattern of the diurnal eight phases of suspended matter concentration in Bohai Sea. The variation characteristics of the suspended matters in Bohai Sea were also discussed.

2. Data and Methods

From 2008 to 2017, a number of voyage surveys were conducted in the Liaodong Bay, Bohai Bay, Laizhou Bay and the central Bohai Sea, with the data covering the different seasons. Through data quality control, a total of 153 sets of data were selected, including ship water body spectral data, laboratory measured suspended matter concentration, etc. The station distribution is showed in Figure 1. The remote sensing data used in this paper is the GOCI data of Korean static water color satellite COMS, with the ground resolution of 500m, a total of 8 bands (6 visible light bands, 2 near-infrared bands). The time range of the daytime imaging is 08:15-15:45. If the observation is carried out once every one hour, 8 times of data covering the most of the sea area of China can be obtained every day.
Spectral data is based on the NASA SeaWiFS marine optical measurement specification. The portable ground spectrometer (350-1050) was used to measure the water body above the surface [15]. In order to ensure the quality of the acquired spectral data, the spectral acquisition of each site was performed in 3 parallel measurements. The final water body remote sensing reflectance was calculated from the measured ASD spectral radiation. Before the algorithm is established, it is necessary to determine the validity of the spectral data, eliminating the abnormal data, and calculate the band equivalent value according to the spectral response function of each band according to the GOCI bands setting. The surface water samples were collected synchronously during the on-site spectral measurement, and the suspended matter concentration was obtained by the electronic balance weighing method [16]. the FLAASH atmospheric correction module was used to perform atmospheric correction on the GOCI data.

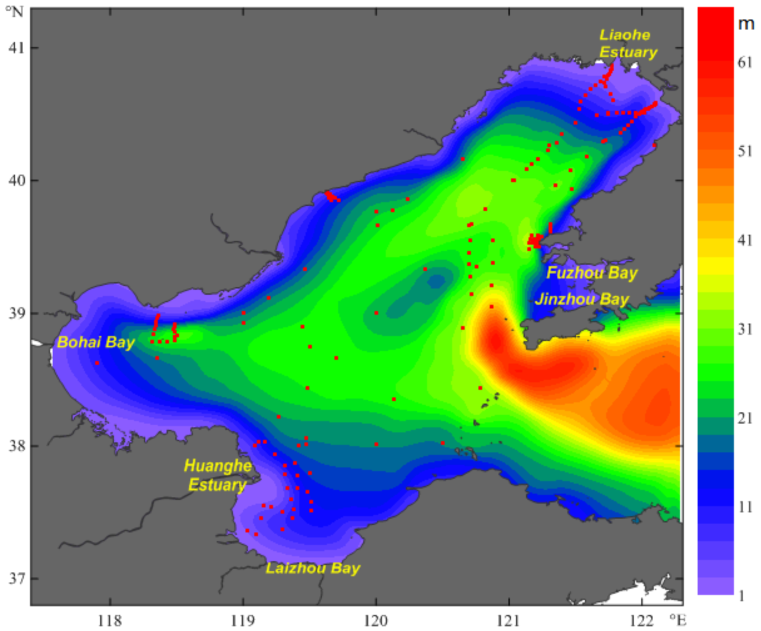

Fig. 1. The location of in situ sampling stations. The color bar indicates the different water depth.

3. Results and Discussion

3.1 Inversion of the Total Suspended Matters in Bohai Sea

According to the measurements, the overall suspended matters concentrations are comparatively low. 50% of the values are within 0-10 mg/L, and most of them are less than 30 mg/L. The single-band algorithm can be used to carry out remote sensing inversion of suspended matters concentration in Bohai Sea. Specifically, the band five of GOCI (630~690, center wavelength 660) is more appropriate to establish the inversion model. The scatter points in Figure 2 show a preferable relationship with suspended matters concentration. Based on the 153 sets of data, the inversing algorithm is established to estimate total suspended matters as follows:

$$\lg TSM = 0.371 + 51.342 * R_{rs}(660) \quad (\mathbf{1})$$

where TSM stands for the concentration of total suspended matters, and $R_{rs}(660)$ is the remote sensing reflectance at 660 nm.

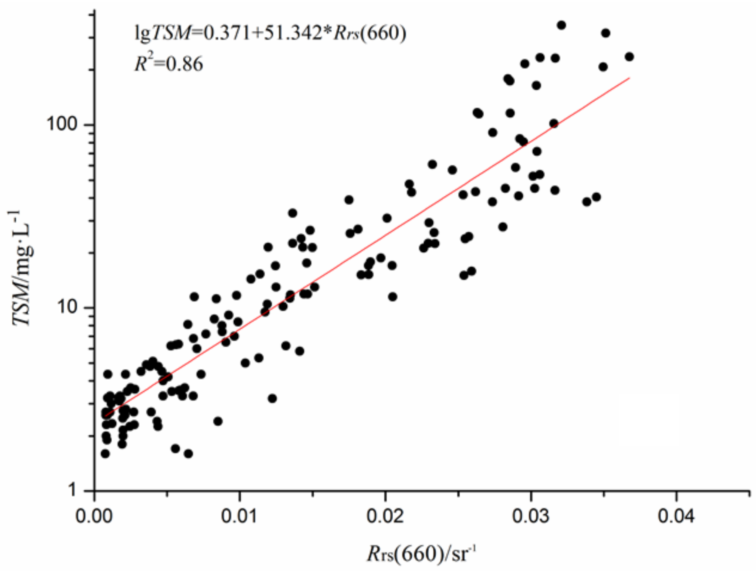

Fig. 2. The relationship between TSM and $R_{rs}(660)$ based on in situ data.

3.2 Diurnal Variations in GOCI-derived TSM

According to the inversion model in Figure 2, we obtained the TSM distribution in Bohai Sea based on the GOCI images on September 13, 2015. Figure 3 shows the inversion results of eight phases from 08:16 to 15:16 on that day. Generally speaking, the concentrations of TSM were high along the coast and low in the offshore areas. Most areas of Bohai Sea have a low concentration of TSM no more than 10 mg/L. High values mainly distributed in Bohai Bay and Laizhou Bay (Up to 300 mg/L). In addition, the estuary regions of Liaohe River, Fuzhou Bay and Jinzhou Bay also had the comparatively high concentrations. The overall spatial distribution pattern of TSM was consistent with the results obtained by Jiang et al [8]. The high concentrations were primarily caused by the imput of suspended sediments and other substances from terrigenous rivers, especially the imput from Yellow River. Besides, the resuspendsion of sediments deposited during historical periods also made the TSM concentrations in the Yellow River delta significantly higher than that in other areas of Bohai sea. The high concentration in the estuary reflected the rapid deposit charcaterristics of TSM after entering the sea. On the other hand, there was a low TSM concentration in Bohai Strait (0~3mg/L). The concentration gradient displayed in the northwest direct along the Strait denoting the influence path of Yellow river when it entered Bohai Sea.

The diurnal variations of TSM concentration was mainly related to ocean currents, because the wind speed was only 5m/s on September 13, 2015 in Bohai Sea. Figure 3 indicates that Fuzhou Bay and

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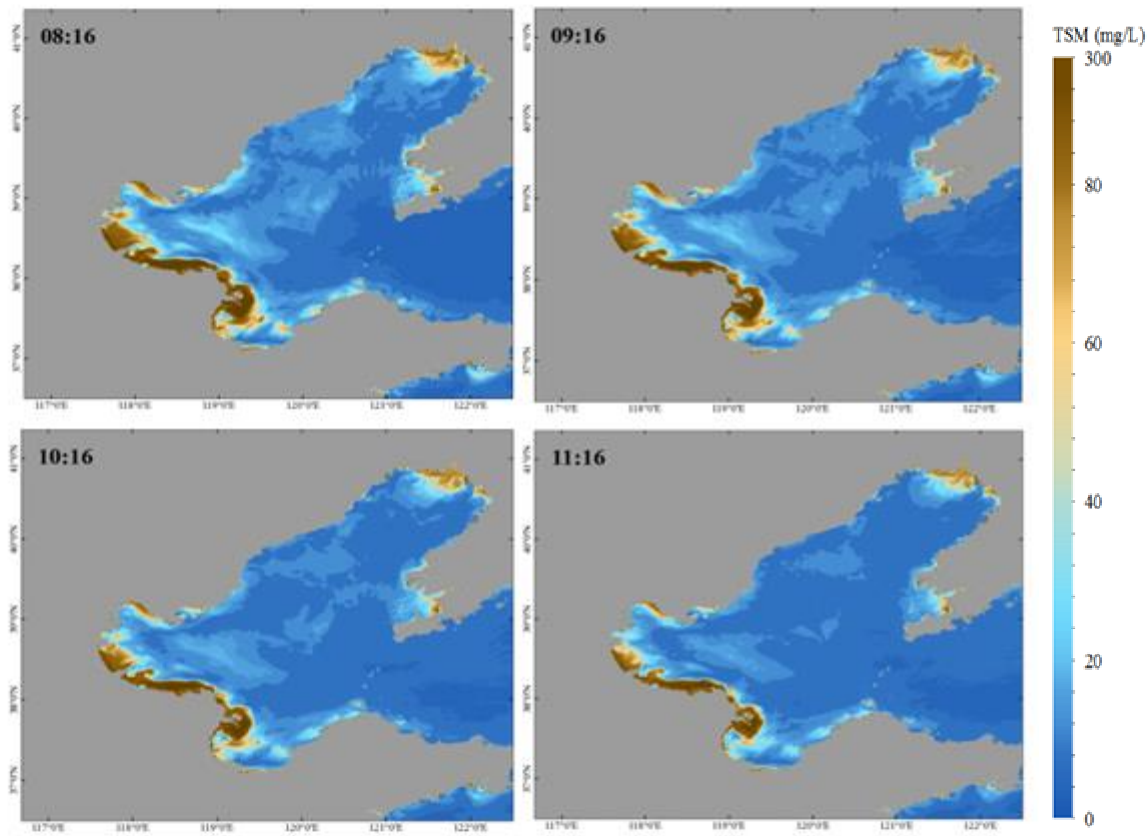
Jinzhou Bay ranked second only to Yellow River estuary as having the most obvious diurnal variations of TSM. According to the tide table of Weifang Port in Laizhou Bay (Figure 4), the time of full tide was 12:58. Therefore, the eight phases of remote sensing images spaned from high tide to low tide. Figure 4 shows a corresponding relationship between TSM concentration and tidal level. There was a significant hysteresis between the extreme values of TSM concentration and tital level. Specifically, the time of maximum/minimum value of TSM was later than that of lowest/highest tital level for 1-2 hours.
In order to analyse the variation degree of TSM in Bohai sea, we calculated the standard deviation (SD) and coefficient of variation (CV) in Figure 5. It is showed that the amplitude of TSM variation around Bohai Bay and Laizhou Bay was above 60mg/L with highest value of 200mg/L, wihle the figure was about 30mg/L in Liaohe River and 40mg/L in Jinzhou Bay. The overall change in the remaining area was small. On ther other hand, Liaohe River had a comparatively big value of SD but a small value of CV indicating a small diurnal variation. In terms of Yellow River Delta, its amplitude of TSM variation was also significant due to the large TSM concentration and drastic resuspension of its silt sediment.



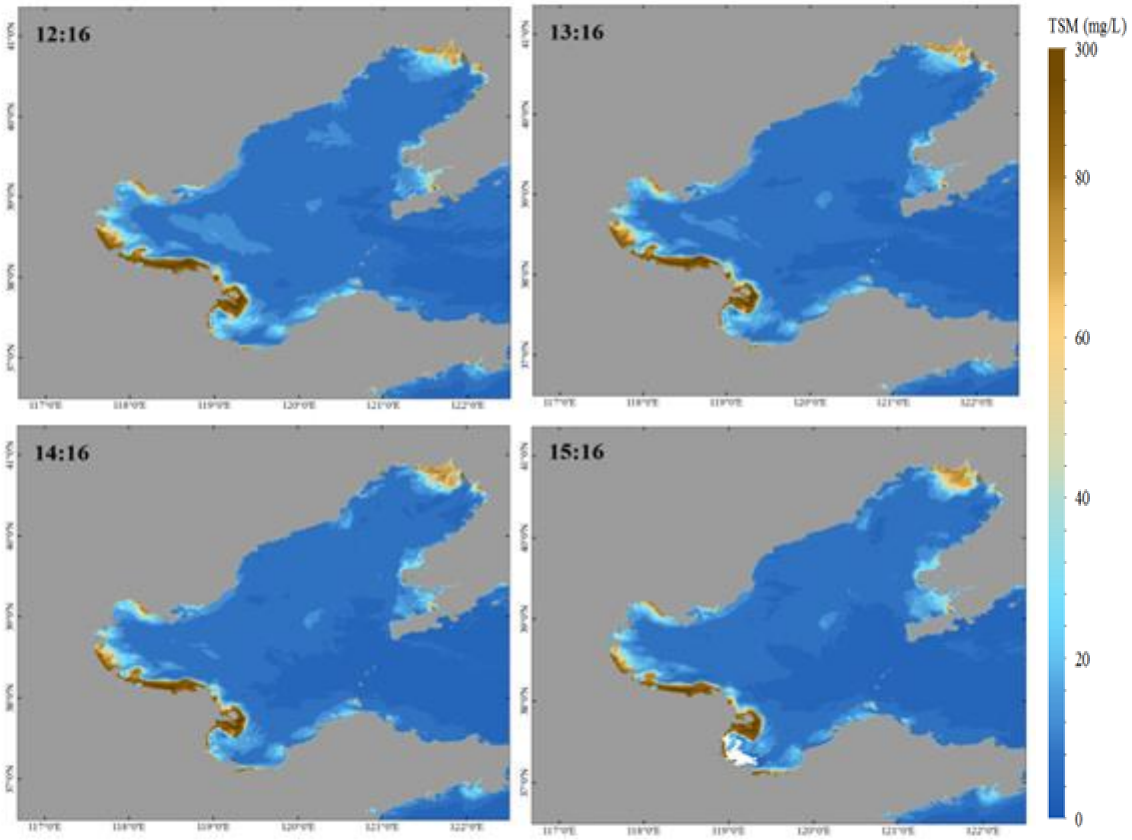


Fig. 3. Hourly maps of TSM in Bohai Sea retrieved by GOCI on September 13, 2015.

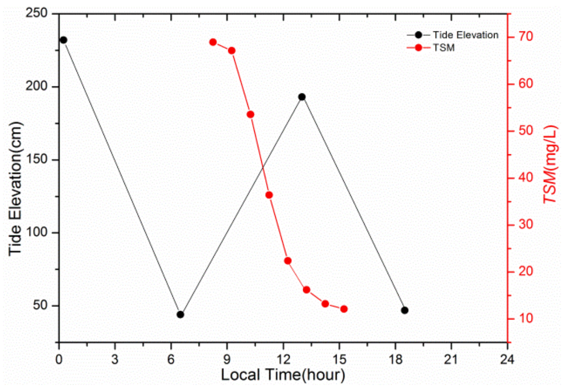


Fig. 4. The relationship between TSM and tide level based on the tidal table of Weifang Port.

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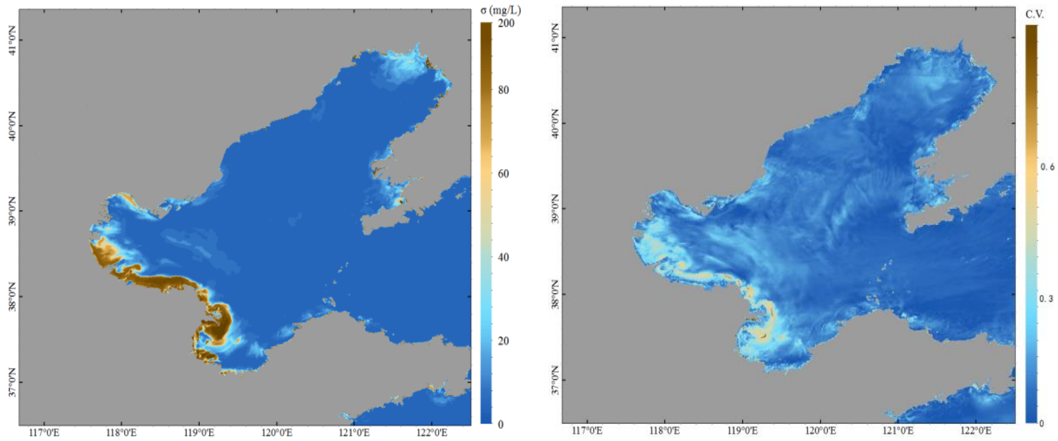

Fig. 5. The standard deviation (SD) and coefficient of variation (CV) of TSM concentration in Bohai Sea, the left map shows SD and the right map shows CV.

4. Conclusion

Most satellites in the world have a revisiting period of at least several days. Since the launch of the world's first geostationary satellite ocean color sensor, the Geostationary Ocean Color Imager, it is possible to trace the diurnal changes of color matters in target waters. Therefore, In this paper, we first establishd a retrieval model of TSM concentration for Bohai Sea based on the in situ spectral data corresponding to the band setting of GOCI. Results showed that TSM concentration in Bohai Sea had a good relationship with band five of GOCI. Applying the model to the images on September 13, 2015, we analyzed the diurnal spatio-temporal variations of TSM. Generally, the diurnal variations of TSM concentration was mainly related to ocean currents on that day. The concentrations of TSM were high along the coast and low in the offshore areas. Especially in the areas around Huanghe Reiver Delta, such as Bohai Bay and Laizhou Bay, the figure could be up to 300 mg/L. The deviation analysis also showed a great diurnal changes around the north part of Bohai Bay and Laizhou Bay. To sum up, the superior characteristics of GOCI data were well-suited for the diurnal tracing of water color matters, which could provide important elements to explain some chemical or phisical processes in near-real-time.

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