Continental Shelf Research 135 (2017) 86–91

Contents lists available at ScienceDirect

Continental Shelf Research

journal homepage: www.elsevier.com/locate/csr

Declining riverine sediment input impact on spring phytoplankton bloom off the Yangtze River Estuary from 17-year satellite observation

Cheng Chen[a,*], Zhihua Mao[b], Fuping Tang[c], Guoqi Han[d], Yazhou Jiang[a]

[a] Key and Open Laboratory of Marine and Estuary Fisheries, Ministry of Agriculture of China, East China Sea Fisheries Research Institute, Chinese Academy of Fisheries Sciences, Shanghai 200090, China

[b] State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, State Oceanic Administration, Hangzhou 310012, China

[c] The Second Surveying and Mapping of Zhejiang Province, Hangzhou 310012, China

[d] Biological and Physical Oceanography Section, Fisheries and Oceans Canada, Northwest Atlantic Fisheries Centre, St. John's NL A1C 5X1, Canada

ARTICLE INFO

Keywords:
Water turbidity
Riverine sediment input
Spring phytoplankton bloom
Yangtze River Estuary
Satellite ocean color
Anthropogenic impact

ABSTRACT

Off the Yangtze River Estuary and its adjacent waters (the YRE) are one of the fastest changing regions in the world in terms of the effects of anthropogenic disturbance. Here we address quantitative analysis whether reducing river to sea sediment may cause declining water turbidity then a better light available condition for the algal growth, therefor increasing phytoplankton bloom magnitude in the YRE in the bloom season. An area of high phytoplankton productivity zone is estimated by theoretical and satellite data analysis, which matches well with the spatial distribution of accumulative times of the reported algal bloom events at the decadal time scale. We present 17-year (1998–2014) satellite and hydrological data to reveal an increasing trend in Chlorophyll-a concentration (Chl-a) in the spring bloom season (May to June), which has strong correlation with the decreasing in the sediment discharge from the Yangtze river to the East China Sea. Changes in Chl-a and the sediment load are inversely related in terms of both temporal variation and their corresponding magnitudes (R^2=0.38, p=0.008, n=17). Furtherly, this relationship is not sensitivity to one-year time lag analysis. On the other hand, euphotic depth in the bloom period shows no significant change, which reflects a balance between the increasing phytoplankton biomass enhancing water turbidity and declining riverine sediment decreasing turbidity. Finally, a stepwise multiple linear regression is used to determine which of the five relatively independent environmental variables most significantly contribute to the interannual variability of the bloom magnitude. The most significant effect (p=0.00007) is also found in the riverine sediment load. Therefor, our results suggest that anthropogenic derived riverine sediment change has been significantly impacted spring phytoplankton production in the YRE.

1. Introduction

Estuarine regions global-wide are experiencing fast changes due to anthropogenic disturbance (Cloern et al., 2016). Although humans have increased riverine sediment load within the watershed due to increased soil erosion, the actual amount of sediment reaching the sea has decreased mainly due to dams block (Bianchi et al., 2014). The Yangtze River (Changjiang River) is one of the largest rivers in the world in terms of both water and sediment discharge. Its fresh water discharge and sediment loads account for over 90% of the total riverine input into the East China Sea (ECS) (Yang et al., 2015). Over the past few decades, more and more giant reservoirs on the Yangtze river basin have had little impact on net water discharge, but have drastically reduced the annual sediment flux to sea, especially entering 21 Century (Fig. 1) (Yang et al., 2005, 2006). Sediment retention behind the Three Gorges Dam (TGD) reduced the sediment discharge of the Yangtze River by ~70% (Yang et al., 2011). Over the past 20 years, annual surface suspended sediment concentration off the Yangtze River Estuary and its adjacent coastal waters (the YRE) also have been decreased by 30%, due mainly to upstream dam construction (Li et al., 2012; Liu et al., 2014).

In the future decades, the influences of new dams, the Water and Soil Conservation Project and the South to North Water Diversion Project in the Yangtze River basin will propably cause the river to sea sediment to continue to decline. An important question that needs to be addressed then is: how does marine

* Corresponding author. Tel.: +86 21 65803266.
E-mail address: frankchen1978@aliyun.com (C. Chen).

http://dx.doi.org/10.1016/j.csr.2017.01.012
Received 12 May 2016; Received in revised form 12 December 2016; Accepted 22 January 2017
Available online 23 January 2017

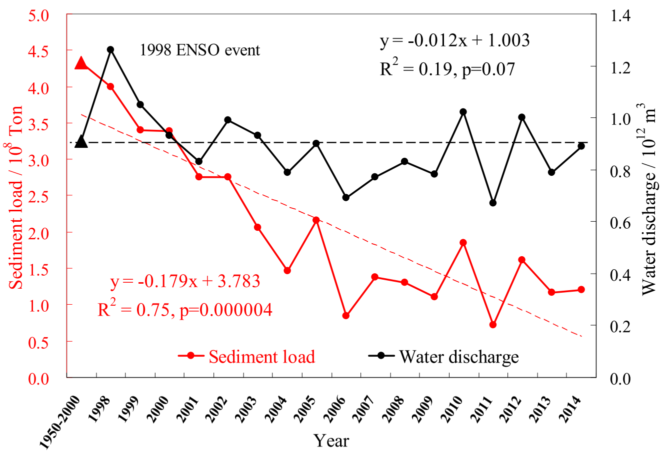

Fig. 1. Temporal variation of the annual water and sediment discharge at the Datong Hydrographic Station on the Yangtze River. The annual river discharge shows small variation from 1998 to 2014 (excluding the effect of 1998 ENSO event), while the sediment load decreased significantly during the period. The triangle indicates the long-term mean (1950–2000) transports for comparison with the last decadal trend.

phytoplankton activity quantitatively respond to such environmental changes (Chen et al., 2003; Zhou et al., 2008; Gao and Wang, 2008; Jiang et al., 2014)? Therefore in this study we address to test and quantitative analysis whether reducing river to sea sediment may cause declining water turbidity, then a better light available condition for the algal growth, therefor increasing phytoplankton bloom magnitude (biomass) in the YRE in the bloom season. Previous concerned quantitative studies at the basin scale are few not only because of the cost of traditional ship survey, but also due to the high spatial and temporal variations in patchy algal bloom water (Song, 2009; Jiang et al., 2014). Furthermore, algal bloom and its associated productivity are such large-scale yet short-lived phenomenon, there is simply no way to survey large enough areas to fully capture their evolutions using in-situ measurements (Platt et al., 2009). Thus, here we use the 18-year (1998–2015) continuous satellite ocean color observation of Chlorophyll-a concentration (Chl-a) in concert with hydrological data (1998–2014) from the Datong hydrometric station to investigate the relationship of them based on the analysis of their interannual variability in the spring bloom season. Therefore, these results will help to illuminate how anthropogenic watershed activities impact estuarine phytoplankton production, because the YRE is one of the fastest changing areas in the world in terms of the effects of anthropogenic induced marine disturbance.

2. Materials and methods

2.1. Satellite and hydrological data

The Sea-viewing Wide Field-of-view Sensor (SeaWiFS) and the MODerate resolution Imaging Spectroradiometer (MODIS)-Aqua Chl-a level-3 product (OC4 and OC3M algorithm, respectively) are used as proxies for the sea surface phytoplankton biomass (O'Reilly et al., 1998; Carder et al., 2003). Their other oceanic products are also used, including the Photosynthetically Available Radiation (PAR), Sea Surface Temperature (SST, daytime) and Zeu (Euphotic depth). PAR is defined as the quantum energy flux from the sun in the spectral range of 400–700 nm. This satellite PAR product is an estimate of daily-averaged cloudiness corrected incident photosynthetically active solar irradiance fields reaching the ocean surface (Frouin and Pinker, 1995). Zeu is the depth at which light intensity falls to 1% of the value at the surface water. It refers to the vertical extent of the water column in which photosynthesis can take place. Zeu at the bloom season in the YRE is mainly determined by the sea surface PAR, phytoplankton induced pigment concentration (Chl-a), and the riverine sediment derived water turbidity.

The SeaWiFS and MODIS 8-day composite Chl-a, PAR, SST and Zeu data at 4 km×4 km resolution were downloaded from the NASA/Goddard Earth Science Data and Information Services Center Interactive Online Visualization and Analysis System (Giovanni) for January 1, 1998 to December 31, 2015. While most of the missing images occur in winter time (from November to February) due to cloudy conditions, fortunately there are few algal blooms during these months. We have used these multi-sensor data from SeaWiFS during 1998–2007 and MODIS at period of 2003–2015, respectively, and furtherly compared them to determine data consistency and to look for longer term interannual trends over the 1998–2015. Annual (1998–2014) water discharge and sediment load measurements from the Datong Hydrographic Station are used in this study. The Datong Station is the last predominated hydrological station in the downstream of the Yangtze River, which has no tidal influence, and is 624 km upstream from the river mouth. These data come from Ministry of Water Resources of China.

2.2. Consideration of satellite data precision in the YRE

Although annual surface suspended sediment concentration has been decreased, the YRE still remains a high turbidity coastal zone nearly all year round, due to the huge amount of sediment input from the river. However, most particulate materials transported from the Yangtze River and Hangzhou Bay into the ECS settles in the area west of 122°E (Fig. 2b). As affected by the monsoon climate, resuspended sediments are prevalent in winter and early spring when strong seasonal winds cause mixing of the water column. With the flow of the Yangtze River dilution plume extending towards the northeast in May, suspended in the water are observed to sink continuously and water clarity is improved (Chen et al., 2006). Furtherly, in May-June water usually begins to be strongly stratified and as a result light condition and water column stability become more suited for algal growth (Zhou et al., 2008; Zhu et al., 2009). In this study, we define May to June as the spring phytoplankton bloom season, which is consistent with reported algal bloom events frequency in the Bulletin of Marine Environmental Quality of China (Fig. 3).

So we suggest that satellite derived Chl-a should be mainly from phytoplankton production during the spring bloom season in the YRE, although that signal may also include other non-biogenic pigments in other non-bloom seasons from these typical Case 2 waters. Furtherly, Level-3 Chl-a concentrations are derived from SeaWiFS and MODIS Level-1A raw radiances determined by applying the sensor calibration, atmospheric corrections, and bio-optical algorithms to the raw signal measured by the satellites. Level-3 data processing quality control (QC) tests for 15 different factors known to degrade data accuracy and generates a QC flag if any are present. All flagged pixels are excluded from the analysis in the creation of Level-3 Chl-a products (Acker et al., 2005). Multiple images for which at least 70% of the study area is cloud free are extracted from 8 day intervals and composited into a single image to produce 8-day composite data. It must be cautioned that these composite images are not 8-day mean values because a different number of data points may be used for each pixel. These 8-day composite values are then used to calculate monthly averages for the analysis of the seasonal and interannual variance of Chl-a. The spring bloom is the strongest signal in the annual variation of Chl-a, especially since large-scale algal blooms typically last for more than two months from late April to early July in the YRE (Zhou et al., 2008). Therefore, although in theory 8-day averaging degrades the ability to resolve events on short time scales, algal blooms in the YRE evolve over a long enough period so that this is not a serious problem.