Analysis of the seasonal variation of the Yellow River flux and the chlorophyll concentration in Laizhou Bay in 2007

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Abstract —**The estuary influenced by land and sea is the area frequently exchanged of matter and energy. respond very sensitively in global changes. Therefore, the estuaries and the shallow areas are the focus in research project of the interaction between the terrestrial and marine. Laizhou Bay is one of the three bays in Bohai sea. It's located at the mouth of the Yellow River and is the typical estuarine area. the Yellow River hold sway the delivery of the substances into the Bay. And because of the extra nitrogen, phosphorus, organic carbon and other chemical ozone-depleting substances taken into by the river, Laizhou Bay presents eutrophication, and then brings environment problems, for example, red tide. Thus the study of changes about the Yellow River has very important significance on the management of the Laizhou Bay. Based on the measurement on the runoff of the Yellow River Lijin Station and the images of the SeaWiFS remote sensing data in 2007, this paper applies the OC4 algorithm to calculate the chlorophyll concentration, which has obvious regional and seasonal features. The basic principle is the chlorophyll shows the "fan" decline from the estuary to the gulf center, the estuaries grows and the chlorophyll distribution increases with the season, then the chlorophyll concentration bears obvious correlation with the flux of the Yellow River. This study can estimate the primary productivity in the estuary, and provide a reference to the effectively development of ocean resources.**

Keywords-estuary; river flux; chlorophyll concentration; Laizhou Bay

I. INTRODUCTION

The flux of river into sea is the key factors affecting the ocean environment, especially in the adjacent coastal zone, such as the coastal estuary [1]. It not only determines the shape of the sea water line, but also the degree of the delta influenced by the tide and coastal runoff. This article focuses on the impact of the estuary on the nutrients, which are closely related to the growth and reproduction of the living things and balances the entire estuary ecosystem. Knox (1986) pointed out that the sediment, the circulation and salinity distribution of the mouth makes it play the role of the capturer and collector of the nutrients [2]. The distributions and the changes are related not only with the interface dynamics process of its source, the transport ,vertical mixing and sediment, but also with the bacteria, phytoplankton, zooplankton. The dynamic study of the estuarine nutrient is one of the key processes, while it plays an important role in the research of the causes and its control of the red tide and eutrophication[3]. The physical input of the estuary nutrients mainly includes river input, sewage directly input, offshore input and atmospheric deposition input. Estuary nutrients and sewage make up the vast majority, for example, in the Narragasett estuary [4], about 99.5% nitrogen and 99.7% phosphorus come from the input of the estuary nutrients and sewage; though atmospheric deposition and underwater supply can also play the role of the exchange of materials and nutritional supplements with the water, its contribution is less compared with the runoff.

Based on the analysis on the monitoring data of the Germany Estuary from November 1989 to May 1992, we can find that the runoff makes up 70%, while the atmospheric deposition about 30% [5].

After the research of the relation between the river runoff and the average concentration of nitrate in the Wales River in 1984, Brooker and Johnson found that there's the negative correlation between the river flow and the nitrate in the 12 rivers, but now it's positively related in a few rivers [6]. In studying the relationship between the nutrients in the Yangtze River and the river flow, Shen pointed out that the seasonal changes are related to the flow, nitrogen concentration of the nitrate are higher in wet period than in dry period, whereas the concentration of inorganic phosphorus is mostly controlled by the activities of the living things [7,8].

In the time scale, when the amount of flow is large, the ratios of the nitrogen and phosphorus increased, when it's small, the ratio also becomes low, the seasonal changes of the flow lead to the seasonal change of the input of nutrients [9]. It affects the condition of the living things in the estuary by the influences on the hydrological factors and the nutrients. The seasonal and annual changes of the runoff can affect the primary productivity and the distribution of species of the phytoplankton in the estuarine ecosystem. The mechanisms contain: (1) change the transportation of the nutrients in the water; (2) change the rate of the dilution or take the algal cells to the estuary; (3) make impacts on the light usage of the planktonic plants by the changes of the water stratification, gravity circulation and the location of the biggest turbidity zone [10].

The input of the freshwater in the upstream of the Neuse River made the chlorophyll a decrease, if the high runoff lasts for several months, it can affect the distribution of primary production [11].

In addition, the largest primary production areas of estuarine were also controlled by the change of river runoff. Filardo (1985) found that the peak concentration of chlorophyll a occurred in the James River erosion area of United States, with the increasing of runoff, the biomass of the part phytoplankton transferred to the downstream, the

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maximum production of phytoplankton centered in the estuary [12].

Guo and Yang (1992) found that the relationship between the phytoplankton's seasonal changes in the Yangtze River estuary and the runoff of Yangtze River's Seasonal change is also of tightness, during July to September[13], Yangtze River is in flood season, Yangtze River Estuary has the highest density of phytoplankton. By the strong influence of Runoff, low-Salt and brackish water species and inshore species proliferated, forming the peak of the number of phytoplankton in the year. The number of phytoplankton is positively correlated with the runoff in one year, and between years, the number of phytoplankton in water-sufficient period is also positively correlated with the runoff, all the above studies show that the change of runoff has impact on the distribution and number of the phytoplankton.

Form ground based observational data and remote sensing data, the seasonal variation of the Yellow River flux and the chlorophyll concentration in Laizhou Bay of Bohai sea in China was analyzed in this paper, and the relation between the flux and the chlorophyll concentration was also researched.

II. THE GEOGRAPHICAL FEATURES OF THE RESEARCHED REGIONS

Laizhou Bay is adjacent to the estuary of the Yellow River, it locates in the north of Shandong Peninsula in china, south of the Bohai Sea, with a total area of 1590.25Km^2. Compared with the other two bays of Bohai Sea, Laizhou Bay has the strongest water refreshing ability. Infect with the monsoon, Laizhou Bay costal area is cold and dry in winter, while hot and wet in summer. The temperature variation is clearly of continental climate, the average temperature is lowest in January and highest in July. The rainfall is mainly concentrate in June to August. As a result of the monsoon circulation and general circulation, the water resource distribution of this region is uneven, the runoff vary a lot during the year, the water and sediment comes from different source areas and sediment concentration is high, these all produce important influence to the ecological system of Laizhou Bay.

In the remote sense image, the sediment diffusion of the Yellow River delta which lies in the west bank of Laizhou Bay presents fan-like along the mouth, obviously, the influence of the Yellow River to the coast development and coast process can not be ignored. According to the yearly runoff data provided by Yellow River Water Resource Commission, Shandong chapter, the average flux of Yellow River in 1951-2001 in Lijin is $331.15\times10^8 m^3$, it dominates the material import of Bohai Sea. The annual runoff of Yellow River account for over 90% of all the river annual runoff of the Laizhou Bay, it's the main phosphorus resource of the marine phytoplankton, the nutrient CODmn, ammonia nitrogen, nitrate and nitrite enter Laizhou Bay mainly through the river runoff. Many phenomenons in the ocean has close relations with the distribution and variation of the salinity, Rainfall and runoff is the fresh water supplement, and is the key to salinity variation. In Tianjin and Tanggu sea area, the salinity has risen for about 0.3% in last 30 years, but the rainfall of the area varies not much [14], the river flux plays an important role in the variation of the nutrients. Liao and Liu (2005) estimated that in normal flow year, the ground water of Yellow River delta area that flows to the sea is between $7.0*104m^3/a$ and $9.5*104m^3/a$, in 2001, this number is $8.717*104m^3$, together with the average nutrients concentration, the amount of the nutrients brought to the sea by the ground water in this year is derived, of which NO_3-N,NO_2-N and NH_4^+-N are about 0.0002%, 0.0005% and 0.01% of the amount that brought to the sea by the Yellow River respectively. This indicates that the contribution of the nutrients that brought to the sea by the ground water of the researched area to the Bohai Sea is minor [15]. Through the analysis of the statistics of the estuary runoff of Yellow River and Xiaoqing River, Ma et al (2004) showed that the estuary runoff of Xiaoqing River is about 4% of the Yellow River. Compared with Xiaoqing River, the annual average amount of CODmn, ammonia nitrogen, nitrate, nitrite and Ar-OH brought to the sea by the Yellow River is 1.83 times of than that of the Xiaoqing River [16]. Yellow River plays a leading role in the import of continental material into Laizhou Bay.

III. THE RESEARCH METHODS OF FLUX IMPACTS ON ESTUARINE ENVIRONMENT

The related studies on estuarine environment focus on analysis of the changes in river runoff to estuarine ecosystems, material recycling, etc. Research methods mainly include two categories. One way is by analyzing the field test survey to determine the correlation between changes in river runoff and ecological systems. Jassby etc through analysis of large amounts of related data, San francisco Bay freshwater input and salinity gradients and the distribution of biological species is closely related[17].The Three Gorges Project and the ecological environment of the Yangtze Estuary; project through the analysis of biological species, distribution and runoff changes in the corresponding relationship of the Three Gorges Project on the changes in runoff into the sea and its ecological environment of the estuary of the index [18];With the recent construction of the transfer project feasibility studies, changes in runoff affect the ecological environment of the Yangtze River estuary study has been further developed[19].Another is through the establishment of mathematical model of the ecosystem material and energy transformation process, determined the quantitative relationship between runoff enter and State of the ecosystem change. This method also requires a lot of field measurement data for the model checking verification. Because of the shortage of relevant ecological data and the complexity of the mathematical model, this method was relatively less used in the study of estuarine ecosystems. Ecological information shortage is the facing problems in the estuarine ecosystem at home and abroad. So we take the first research method, the combination of satellite remote sensing and field experiments investigating.

From lijin hydrological station, which is the nearest station of the Yellow River to the Laizhou Bay, and located in Dongying city, Shandong Province, Longitude 118.3 °,latitude 37 .517°, 103.6 km far from the sea, the year flux data of the yellow River in 2007 were acquired, the corresponding concentration of chlorophyll data were collected from SeaWiFS remote sensing data. From Lijin station to the estuary, there is less water interception, so water and sediment flux was used to represent the actual

flux into the sea. Daily, sediment and water flux data were measured at around 8 in the morning, Monthly and seasonal flux were acquired according to the daily statistic data, Since the measurement of sea surface phytoplankton of the region only through the acquisition of discrete sample points, it is difficult to overall grasps, we can use remote sensing method to obtain the chlorophyll concentration, with water–leaving radiance to retrieve chlorophyll concentration. Chlorophyll concentration data of this article are acquired from SeaWiFS L3, its calculation of chlorophyll concentration usually by a four polynomial OC4 algorithm [20].

OC4 algorithm for polynomial equation:

$$C = 10^{a0+a1R+a2R^2+a3R^3+a4R^4} \quad (1)$$

R=lg[max(R(443), R(490), R(510))/R(555)]

$[a_0,a_1,a_2,a_3,a_4]=[0.366,-3.067,1.930,0.649,-1.532]$

C is the chlorophyll concentration, R is the water – leaving radiance .OC4 algorithm is a four-band ocean chlorophyll concentration estimation method, it use the maximum of $R_{rs}(443)$ / R_{rs} (555), R_{rs} (490) / R_{rs} (555) and R_{rs} (520) / R_{rs} (555) to create the polynomial algorithm.

TABLE I. RIVER FLUXES:Q（M^3/S）, CHLOROPHYLL CONCENTRATIONS:C (MG/M^3)

	1	2	3	4	5	6	7	8	9	10	11	12
Q	316.84	257.07	433.41	250.51	268.25	873.31	1303.0	1779.0	772.03	861.68	643.04	334.45
C	3.814	4.533	5.168	3.773	4.123	3.931	4.080	4.771	4.112	4.360	4.090	3.830

IV. RESULTS AND ANALYSIS

A. seasonal variation of the yellow river flow

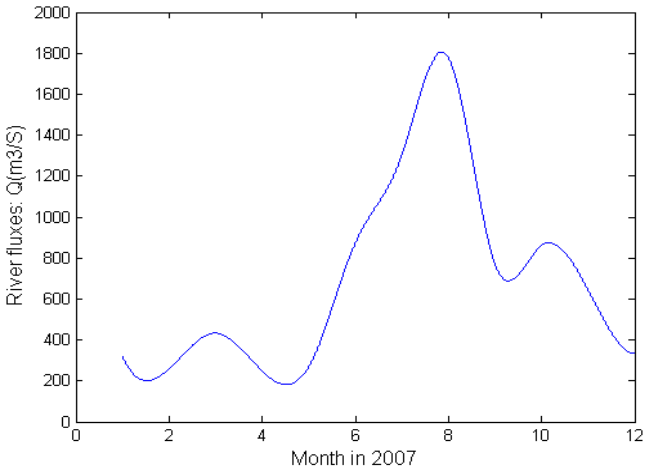


Figure 1. Monthly average fluxes of the Yellow River in 2007

As can be seen from Figure 1, the flux of the Yellow River has staggered variation, and there is no cutoff, generally there are two flood seasons in the spring and summer, respectively. Flux variation during the year mainly influenced by seasonal rainfall, temperature and watershed management. River flow in the valley present large-capacity in summer, low in winter, flux is focused on June to September. Also there is a small flood In March, Maybe for the spring thaw formation of ice and snow melt which are result by temperature increment.

Presently, five reservoirs in the river mainstream have enough impoundment. Xiaolangdi Reservoir has increased the flow discharge since it completed in 2001.1000 cubic water per second can release since late February, this will extend the flood-carrying capacity for the lower watercourse of the Yellow River. Many places of Shandong province along the Yellow River stop water diversion, About 700 cubic per second of River diversion when spring irrigation in the past, In recent years, the amount is less than one seventh, Most of the water has the chance rush into the sea [21].

In April and May, River downstream has less water flux, Especially in recent years, for erosion alluvial channel, The Local River Bureau done many consecutive man-made floods and sand drainage, in this period, Xiaolangdi reservoir start to save water, lower watercourse release little, however, when it is not in flood period, the flux of yellow river maybe fall into the most low value scope because of less rainfall and drought. From June it gradually enter into the rainy season, with the increase of rainfall, runoff augment, July to August the flux reached to peak value and continues to prediction of end-date of pluvial period, November it began to low water period.

B. seasonal variation characteristics of Chlorophyll concentration

Generally, chlorophyll concentration of Laizhou bay seasonal changes obviously, two peaks respectively in March and August. With the seasons alternation, the temperature rises, chlorophyll concentration increases; higher in Autumn and Winter, Lower in late Spring, eutrophication is obvious in the entire coastal waters [22].

Analysis of reasons: Mid-February to mid-March, The chlorophyll concentration peak appeared for two main reasons: First, The effect of Coastal upwelling. Second, the reservoir's discharged flow and the ice and snow melt replenishment. Most of the Laizhou bay area is shoal water, Nutrient salt enrichment, hybridization Strongly, unsuitable for phytoplankton growth. The reservoir's discharged flow and the ice and snow melt replenishment increased the flux of the yellow river, it takes amount of margin substance which contain abundant nutrient salt, especially upwelling makes salt in the bottom to the ocean surface, which is the supplement of phytoplankton. However, there is little difference between the chlorophyll concentration in each of laizhou bay Regional , it showed that the period leading role is the coastal upwelling[23].The reservoir's discharged flow draw to a close, contemporaneously, because of spring drought, the river flux and the Nutrient salt both cut down, and bring a low concentration of the chlorophyll. It reached to another peak In August and distribution with average.

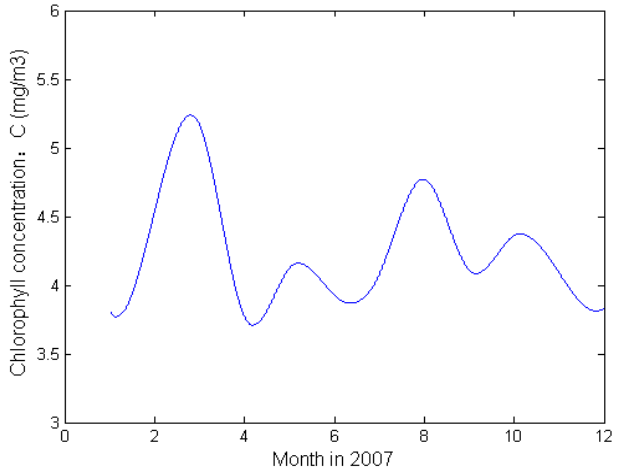


Figure 2. The curve of monthly average chlorophyll concentrations of Laizhou Bay in 2007

From the figures we know the changes of them are not synchronized, chlorophyll concentration changes lag behind. According to the factors of phytoplankton growth about light, water temperature, Nutrient salt, Yang and Chen Comprehensive analysis the Influence of different conditions on growth and community structure of phytoplankton, of these factors affect the physiological characteristics of phytoplankton growth and structural change in the characteristics of their clusters. Of light, temperature and nutrients on growth of phytoplankton in the mechanism and process to determine their significant impact on the growth of phytoplankton in the order of :light, temperature and nutrients [24].About 10 days at the peak of river flux the nutrient concentrations remain basically unchanged, this period phytoplankton growth factor is mainly decided by the sea temperature. Maximum sea temperature in August, but the Light intensity is lag behind. So the chlorophyll concentration reach maximum in August. After the water temperature dropped in October, lower light intensity; chlorophyll concentration during the period controlled by the nutrients, along with changes in river flows.

V. THE CORRELATION OF RIVER FLUX AND CHLOROPHYLL CONCENTRATION

The change of river flux which is composed of Nutrient salt, bedload and fresh water can affect the growth of phytoplankton near the estuary. Therefore, the author propose to study the estuary of the chlorophyll concentration through changes of the yellow river flux. Based on the 2007 yellow river flux data from lijin station and chlorophyll concentration data retrieval from satellite remote sensing for lazhou bay, we study The changes of river flux Influenced in the chlorophyll concentration in the estuary and adjacent waters, Analysis the Laizhou Bay chlorophyll concentration on the response of flux changes. We found that the annual change in chlorophyll concentration of Laizhou Bay and the Yellow River flow months showed a strong correlation, and more obvious in autumn and winter .

One of the main source of nutrients is from land-carriage supplied by surface water and groundwater. The Yellow River is the main river in Laizhou Bay area, carrying a large number of freshwater and nutrients into the sea every year, plays an important role on the maintenance of the Laizhou Bay (in particular, near the Yellow River Estuary) ecosystem. But the River flux

obviously present seasonal changes, Monthly changes more in water, chlorophyll concentration changes little, it indicate that there is a stable supply source in laizhou bay, such as Groundwater and atmospheric deposition. when the flux to the smaller period in Winter and spring, the role of groundwater transport of nutrients to the Bohai Sea is even more important to the ecological environment of the Bohai Sea, But the cause of changes in chlorophyll concentration is still surface water. Chinese scholars do some research on the relationship between nutrients of flux and phytoplankton mainly on the forms of nutrients, transformation, distribution and adsorption in the sediment and release and so on, but little on the total nutrient of the river transport to the sea ,mainly about Chen's preliminary study through the Yangtze River flux of nutrients, found a formula about the nutrients of flux into the sea is[25]:

$$F = \frac{1}{n}\sum_{i=1}^{n} CQ \qquad (2)$$

(C is Nutrient concentrations, Q is river fluxes)

And analysis the fluxes of nutrient has seasonal changes as the river runoff. Most of the Nutrient salt has a linear positive correlation with the Yangtze flux. Except NO_2-N in winter and PO_4-P、NO_2-N、NH_4-N in summer, their relevance in more than 99%.based on study monitoring data about the water quality and flux of the Hai river, liu found that the changes of various pollutants is impacted on the river flux[26].

Now we mainly through the seasonal changes of nutrients, fresh water and sediment transport, To investigate the effects of these vectors to chlorophyll concentration alterative. Because of laizhou bay has a Strong upwelling, which hybridization strongly makes salt in the bottom to the ocean surface, and is the supplement of phytoplankton. It is the main reason for chlorophyll concentration changes. Not representative for our study, so we take a year's flux and chlorophyll concentration for the study except Feb and Mar.

First we use SPASS to analysis statistical correlation of river flux and chlorophyll concentration.

River fluxes: Q(m^3/S), Chlorophyll concentrations: C (mg/m^3) .E(Q) is Annual average Fluxes, E(C) is Annual average chlorophyll concentrations.

TABLE II. DESCRIPTIVE STATISTICS

	average	Standard deviation	Samples
C (mg/m^3)	4.088 E(C)	0.29939	10
Q（m3/S）	740.21 E(Q)	499.465	10

TABLE III. CORRELATION

correlation coefficient	Significant correlation (sig.)	Cross deviation	Covariance
0.799	0.006	1074.898	119.433

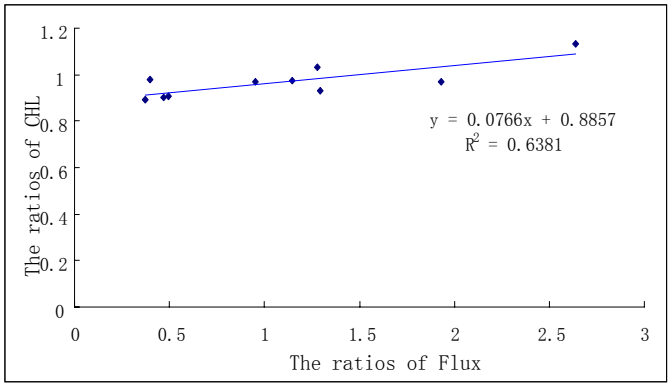
Pearson correlation is the correlation coefficient, which reflects the correlation and asymptotic ,The greater the absolute number is present the more asymptotic of the

two, if it is negative shows a negative correlation between the two. Sig is the Significant correlation, if sig.<0.05,Note that there is statistically disciplinarian. if sig.>0.05,there is little statistically disciplinarian.

The correlation coefficient between Chlorophyll concentration and the Yellow River flux is 0.799, significant correlation is 0.006 much less than 0.05,so we can know that the chlorophyll concentration in the Laizhou Bay is much impacted by the Yellow River flux, as the mount of river flux chlorophyll concentration added.

As to study the impact of flux changes to Chlorophyll concentration, we take the ratio of each month to the average as the horizontal axis, the ratio of each concentration to the average l as the vertical axis, fitting a straight line. Basically, this is the linear relationship between the two:

$$Y=0.0766X+0.8857 \qquad (3)$$



VI. CONCLUSION

This article assumes that the runoff of Lijin port equals the flow of the Yellow River estuary, but Lijin also has some distance from the estuary, so they are not equal in fact. In addition, although the OC4 algorithm retrieval chlorophyll concentration of the magnitude in Bohai bay, it still has the deviation. we had only studied the relationship between the Annual runoff in 2007 and the chlorophyll concentration, parameters , such as sediment in the runoff, nutrients, water quality was changing, and these factors affected the changes of the chlorophyll, To a certain extent, they have impact on the result, so further studies are needed in the future.

Laizhou Bay has high chlorophyll concentration and it's under the control by Case-Ⅱ water all around the year. The images indicated the changes of the river flux and distribution of chlorophyll concentration are very correlative, From winter to early spring of the second year, with less river flow and feeble impact of vertical mixing of sea water, it leads to a reduction of nutrients, so the chlorophyll concentration is low. In the middle February, the situation changes, In addition, the reservoir's supply also contributes to it. The above factors makes Chlorophyll concentration reaching a peak values in March, with the rainy season's drawing near, As the River runoff increase, the nutrients are sufficient, the temperature is suitable, so that with the keeping value, the chlorophyll concentration reaches another peak. Totally, the river flux changes obviously with the seasons, and the changes and distribution of chlorophyll concentration have a correlation with these factors, so the chlorophyll concentration presents an obvious seasonal change, which maybe helpful to estimates the primary productivity in the coastal zone.

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