

CONTRIBUTION OF THE YANGTZE RIVER TO ECOSYSTEM OF THE EAST CHINA SEA

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ABSTRACT

The Yangtze River of the China main land has recorded the decrease of sediment load in these 10 years because of construction of dams in the upstream region. The Three Gorgeous Dam, partly started its operation since July of 2003, has a significant contribution to reduce the sediment load with sedimentation. According to the Yangtze River hydrological report, the amount of discharge and the sediment concentration exhibit a clear migration in season and temporal changes. The seasonal and annual variations of discharge and sediment concentration are expected to have a strong contribution to the ecosystem in the East China Sea. In this study, a primary productivity in the East China Sea, especially over the offshore region of the Yangtze River mouth, is estimated with satellite monitoring of chlorophyll-a concentration, sea surface temperature, photo-synthetically available radiation, which are observed by MODIS on the polar orbiting satellite AQUA. The depth resolved primary productivity model was implemented to estimate the primary productivity where sufficient amount of nutrients are supplied and the variation of environments by the river compounds. In-situ measurements are also conducted at the entrance of the Kuroshio into the East China Sea, at one exit of the Kuroshio into the Pacific and at another exit of the Kuroshio into the Japan Sea to monitor effects of the Yangtze River. The in-situ measurements were conducted to evaluate the extensions of diluted water into the Kuroshio in the spring, when the discharge exhibits lower value, and in the summer, when the discharge exhibits the maximum value through the year. This paper discusses the contribution of the Yangtze River to the ecosystem of the East China Sea through the primary productivity and the effects of the diluted water into the Kuroshio.

1. INTRODUCTION

1.1 Change of river discharge from the Yangtze River

The Three Gorges Dam (TGD) is one largest project in the world to build a hydroelectric dam on the Yangtze (Changjiang) River, which is the world's third longest river. The TGD project may exhibit an unknown environmental contribution along the Yangtze River and to the East China Sea (ECS) in the very near future following to the operation of the Dam since 2003.

The Yangtze River exhibits a seasonal variation of outflow and discharge tongue on ECS (Ning and Cai, 1998). Fig. 1 shows a mean discharge of the Yangtze River for each month over all years from 1978 to 1986. In contrast, the Yangtze River exhibits a response to the climate change as the increase of the summer rainfall over the Yangtze River valley in 1979 because of the regime shift (Gong and Ho, 2002). A discharge of the Yangtze River affects the physical, chemical, and biological environment on ECS. Physical observation examined an offshore extension of the freshwater plume. The freshwater plume tends to move northeast along the Chinese coastal area with southerly winds and to move eastward over 400 km offshore across the western shelf of the northern ECS in the summertime (Lie et al., 2003). The freshwater has a contribution to change sea surface salinity with exhibiting a drought signal (1997) or a flooding one (1998 – 1999) over the catchment area of the Yangtze River (Delcroix and Murtugudde,

2002). From Fig. 1, it is obvious that the summer time exhibits 4.5 times discharge of the winter time and it suggests that TGD has a significant control in the discharge through the year except the summer time with its capacity as a reservoir. It will not be a natural seasonal variation of discharge from TGD but an artificial variation is expected on the discharge and its expansion on ECS.

Based on those discharge from the Yangtze River, nitrogen is supplied to ECS and the amount of nitrogen is a significant concern for us especially from the point of eutrophication and biological fixation on ECS. A nitrogen input from the Yangtze

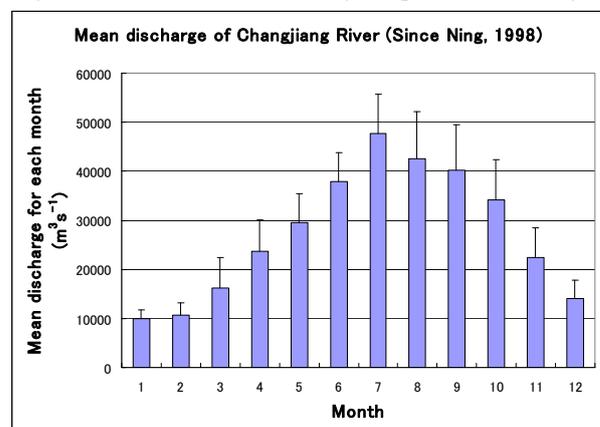


Figure 1. Mean discharge of the Yangtze River for each month over all years from 1978 to 1986 since Ning (1998).

River to the Yangtze basin shows a significant increase of a total N input from 2.2×10^9 kg.year⁻¹ in 1968 to 7.8×10^9 kg.year⁻¹ including a fertilizing effect by human activity, although a similar N fixation capability around 2.0×10^9 kg.year⁻¹ through those periods (Yan and Zhang, 2003). The eutrophication over ECS results a formation of phytoplankton blooms under a complex interplay of physical, geological, biological, and chemical processes associated with the Yangtze River discharge, sediment deposition, and the Taiwan Warm Current (Chen et al., 2003).

TGD may significantly influence an environmental and ecosystems of the Yangtze River in its reservoir region and downstream area, and in the adjacent shelf region and offshore region of ECS. Environmental concerns are a change of water level in the front reservoir area (Wang, 2000) and a time-variable gravity signal along the Yangtze River during a water impoundment (Boy and Chao, 2002). Authors concern goes to a chemical and biological change by the discharge of TGD and following results over ECS and especially over our down stream region. Zhang et al. (1999) suggested retention of nutrients in the reservoir region with an overall decrease in its concentration, and a removal of sediments within a reservoir region with an influence on the load of dissolved silica. Similarly, Chen et al. (2003) suggested a reduction in sediment discharge due to TGD and warned an ecosystem disaster with possible downstream contamination of Korea and Japan, unless the nutrient loading from Shanghai and surrounding cities and aquaculture activities along the coast are reduced. On the other hand, Chen (2000) suggested a control of TGD with reducing an upwelling and productivity in ECS. An on-shore nutrient supply would be reduced proportionately with a reduction outflow of the Yangtze River by TGD, and the new production, primary production and fish catch in ECS would also be reduced proportionately (Chen, 2000).

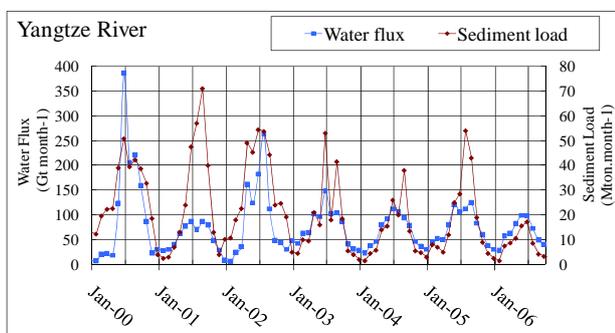


Figure 2. Water flux and sediment load observed at Datong station from 2000 to 2006

	Water flux	Sediment load
	(Gt/y)	(Mt/y)
2000	1280	350
2001	660	290
2002	1000	380
2003	930	210
2004	780	150
2005	900	220
2006	690	85

Table 1. Water flux and Sediment load per year.

According to the recently reported data of sediment flux of the Yangtze River from 2000 to 2006 (<http://www.cjh.com.cn>), it is possible to observe a sudden decrease of the sediment flux since June of 2003 (Figure 2). Table 1 shows the annual water flux and sediment load observed at the Datong Station. The water flux has decreased slightly to 2006, but the level of water flux is almost constant. In contrast, the sediment load has decreased drastically since 2003 and it has decreased to 1/4 from 2000 to 2006. It is suggested that the water in the upstream region of the Three Gorges Dam have a possibility to reduce sediment by a slower running and a sinking to river bottoms.

1.2 Satellite monitoring of the East China Sea

Now, satellite based ocean color sensing systems provide chlorophyll *a* distribution continuously since 1996. The Ocean Color Temperature Scanner (OCTS) provided a global coverage of chlorophyll *a* distribution from November of 1976 to June of 1997 (Shimada et al., 1999). The Sea-Viewing Wide Field-of-View Sensor (SeaWiFS) continues its observation since September of 1997 (McClain et al., 1992). This series of ocean color observation has a possibility to study contribution of phytoplankton to climatological change for these 10 years, although there is a discontinuity of two months between two programs. OCTS and SeaWiFS provide a similar specification with bands, full-width half-maximum of wavelength, maximum radiance, and signal to noise ratio, which are based on some experience in the Coastal Zone Color Scanner (CZCS). In contrast, the Moderate Resolution Imaging Spectrometer (MODIS) and the Global Imager (GLI) have a narrow bandwidth with 36 bands, to establish multi-purpose missions on ocean, land, atmosphere, and cryosphere. It is an urgent mission for space agencies to exhibit a consistency in geophysical values among different sensors indicating deferent characteristics. The consistency is necessary to analyze a long-term observation. Even a small inconsistency among systems, a combination of remote sensing parameters may exhibits amplified inconsistency in the final geophysical value in time.

1.3 Primary productivity model

Estimates of global primary productivity from the ocean color measurement are one approach to discuss a contribution of the oceanic biota to a global warming or a climate change, and also a response of phytoplankton in a regional study like in ECS. Morel (1991) discussed the light field in the water relative to photosynthesis, which is extended to a wavelength resolved primary productivity model. Behrenfeld et al. (1997) and Falkowskie et al. (1998) proposed a light and temperature dependent primary productivity model based on the satellite measurement. Arrigo et al. (1998) implied a possibility of a primary productivity model in Southern Ocean waters. In partly, those models worked in some extent, but some failures were observed, in which an over-estimate is observed in the middle latitude and an under-estimate is observed in the lower latitude. Photosynthetically available radiation (PAR) dependent depth and time resolved primary productivity model was proposed to recover those failures (Asanuma et al. 2000, Asanuma et al., 2001a, Asanuma et al., 2001b). A vertical distribution of PAR is defined by an empirical equation as a function of the chlorophyll *a* concentration in the surface, which is observed by ocean color sensors. A vertical distribution of chlorophyll *a* concentration is also defined by an empirical equation as a function of the vertical distribution of PAR. A carbon fixation rate is defined as a function of PAR and temperature.

2. PRIMARY PRODUCTIVITY ESTIMATED BY SATELLITE DATA

2.1 Satellite data

In this study, a series of chlorophyll *a* and PAR estimate by OrbView/SeaWiFS and AQUA/MODIS, sea surface temperature by NOAA/AVHRR and AQUA/MODIS were combined to estimate the primary productivity in ECS. Those data were resampled into 4 km by 4 km and a monthly average to reduce a cloud presentation from daily observations. All data were processed using the user defined function of the SeaWiFS Data Processing System, SeaDAS, which is provided by the Goddard Space Flight Center, GSFC, of the National Aerospace Agency, NASA (<http://seadas.gsfc.nasa.gov>) and is easily realized on the personal computer based Linux system. The user defined function of SeaDAS provides an opportunity for end users to calculate the primary productivity by combining arithmetic functions on the image buffered for display.

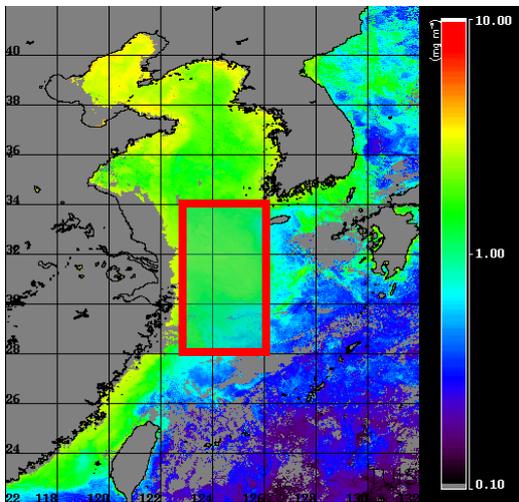


Figure 3. A region to estimate a primary productivity

The bold rectangle in Figure 3 shows the region of interest for this study covering between 28 and 34 degree N and between 123 and 126 degree E. This region was selected to exclude a high productive region at the river mouth and along the coastal region. The region along the coast exhibits a high chlorophyll *a* concentration, where the algorithm to estimate chlorophyll *a* concentration fails because of high sediment and CDOM concentration.

2.2 Statistics of observation and model estimate

Figure 4 shows a monthly variation of primary productivity estimated by the depth and time resolved primary productivity model with chlorophyll *a* concentration, SST, PAR. In this model calculation, a primary productivity is given by $\text{mgC m}^{-2} \text{day}^{-1}$, which is an amount of carbon fixation by phytoplankton on a unit area per day. We could observe a lower primary productivity in 1999, 2000, 2001, and 2005 with the maximum primary productivity less than $1400 \text{ mgC.m}^{-2}.\text{day}^{-1}$. A slightly decreasing trend is observed from 2002 to 2005, which could be considered as the effect of the construction of the Three Gorgeous Dam. But the primary productivity is recovered from 2006 to 2007. The minimum primary productivity was almost same through all years around $300 \text{ mgC.m}^{-2}.\text{day}^{-1}$.

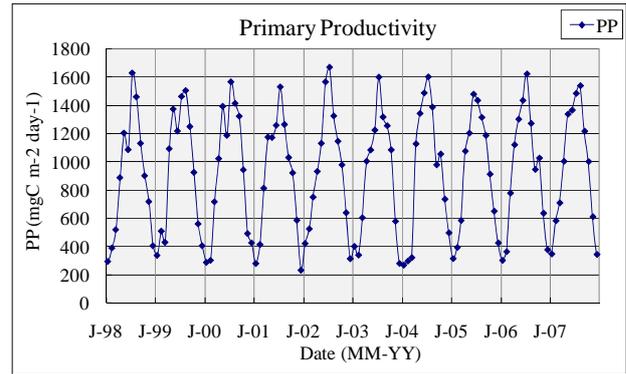


Figure 4. Primary productivity estimated with satellite observation.

It is still difficult to identify a relationship between a river discharge or a sediment one from the Yangtze River and primary productivity estimated from satellite observation. Although we need longer time series data to lead a conclusion, the primary productivity since 2002 exhibited a slightly decrease to 2005 as well as a reduction of sediment discharge. As we have a sufficient nitrate on ECS because of the river discharge (Yan and Zhang, 2003), the decrease of primary productivity is expected related to the decrease of sediment discharge.

Figure 5 shows the scatter plots between the water flux and the sediment concentration calculated from the water flux and the sediment load for each month from 2000 to 2006. The monthly deviation from winter to summer was strongly observed in the summer time from 2000 to 2002, but its deviation was obviously small since 2003, which suggests the artificial control of the water flux being under control at the Three Gorgeous Dam.

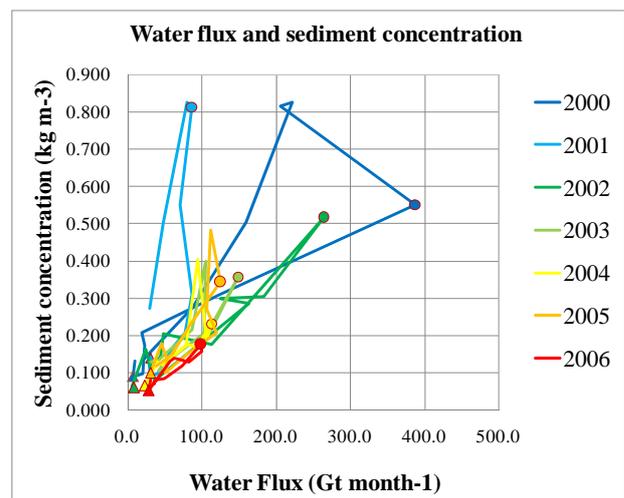


Figure 5. Sediment concentration and water flux.

3. SUMMARY

This study reported our current analysis on the primary productivity, satellite observation, and statistics of river discharge and sediment discharge. Although there is a

possibility of high nutrients low chlorophyll, it is difficult to identify a relationship among parameters with currently available data.

We are able to propose hypothesis on the interaction between the discharge from the Yangtze River and the water in ECS on the point of primary productivity as the primary productivity will be decreased because of reduction of silicate following to the decrease of sediment load. But the primary productivity has recovered since 2006 to 2007, and it is difficult to explain a contribution of the river discharge from the Yangtze River. It may be suggested that the ecosystem in the East China Sea has adapted the change of water quality and an optimum ecosystem has established.

As we have started an in-situ observation at the Yonaguni Island, which is located at the entrance of the Kuroshio to ECS, at the Yakushima Island, which is located at one exit of the Kuroshio to the Pacific Ocean, and at the Tsushima Island, which is located at one exit of the Kuroshio to the Japan Sea since 2005, we may be able to discuss further relationship among primary productivity and environmental parameters in the near future.

REFERENES

- Arrigo, K.R., D. Worthen, A. Schnell and M.P. Lizotte, 1998. Primary production in Southern Ocean waters. *J. Geophys. Res.*, 103, C8, 15587-15600.
- Asanuma, I., T. Tanaka, K. Matsumoto, T. Kawano, 2000: Primary productivity model based on photosynthetically available radiation. *Hyperspectral Remote Sensing of the Ocean, Proc. of SPIE*, V4154, 153-158.
- Asanuma, I., K. Matsumoto, T. Kawano, H. Kawahata, 2001a. Satellite estimated primary productivity and carbon flux. *Sixth International Carbon Dioxide Conference*, 505-508.
- Asanuma, I., K. Matsumoto, T. Kawano, 2001b. Validation of photosynthetically available radiation estimated from satellite data for primary productivity model. *Proc. Of the CEReS Interna. Symp. on Remote Sensing of the Atmosphere and Validation of Satellite Data*, 62-67.
- Behrenfeld, M. and P. G. Falkowski, 1997. Photosynthetic rates derived from satellite-based chlorophyll concentration, *Limnol. Oceanogr.*, 42(1), 1-20.
- Boy, J. P. and B. F. Chao, 2002. Time-variable gravity signal during the water impoundment of China's Three-Gorges Reservoir, *Geophys. Res. Lett.*, 29(24), doi:10.1029/2002GL016457.
- Chen, C. A., 2000. The Three Gorges Dam: Reducing the Upwelling and thus Productivity in the East China Sea, *Geophys. Res. Lett.*, 27(3), 381-383.
- Chen, C., J. Zhu, R. C. Beardsley, and P. J. S. Franks, 2003. Physical-biological sources for dense algal blooms near the Changjiang River, *Geophys. Res. Lett.*, 30(10), 1515, doi:10.1029/2002GL016391.
- Delcroix, T. and R. Murtugudde, 2002. Sea surface salinity changes in the East China Sea during 1997-2001: Influence of the Yangtze River, *J. Geophys. Res.*, 107(C12), 8008, doi:10.1029/2001JC000893.
- Falkowski, P.G., and M.J. Behrenfeld, W. Balch, J.W. Campbell, R.L. Iverson, D.A. Kiefer, A. Morel, and J.A. Yoder, 1998. Satellite Primary Productivity Data and Algorithm Development: A Science Plan for Mission to Planet Earth, *SeaWiFS Technical Report Series*, Vol.42, 37pp.
- Gong, D. and C. Ho, 2002. Shift in the summer rainfall over the Yangtze River valley in the late 1970s, *Geophys. Res. Lett.*, 29(10), 1436, 10.1029/2001GL014523.
- Lie, H., C. Cho, J. Lee, and S. Lee, 2003. Structure and eastward extension of the Changjiang River plume in the East China Sea, *J. Geophys. Res.*, 108(C3), 3077, doi:10.1029/2001JC001194.
- McClain, C., W. E. Esaias, W. Barnes, B. Guenther, D. Endres, S. B. Hooker, B. G. Mitchell and R. Barnes, 1992. SeaWiFS Calibration and Validation Plan, *NASA Technical Memorandum* 104566, 3, 43pp.
- Morel, A., 1991. Light and marine photosynthesis: a spectral model with geochemical and climatological implications. *Prog. Oceanog.*, 26, 263-306.
- Ning, X., and Y. Cai, 1998. Physicobiological oceanographic remote sensing of the East China Sea: Satellite and in situ observations, *J. Geophys. Res.*, 103(C10), 21,623-21,635.
- Simada, M., H. Oaku, Y. Mitomi, H. Murakami, and H. Kawamura, 1999. Calibration of the Ocean Color and Temperature Scanner. *IEEE Trans. Geoscience and Remote Sensing*, 37, 3, 1484-1495.
- Wang, H., 2000. Surface vertical displacements and level plane changes in the front Gong and Ho (2002) reservoir area caused by filling the Three Gorges Reservoir, *J. Geophys. Res.*, 105(B6), 13,211-13,220.
- Yan, W. and S. Zhang, 2003. How do nitrogen inputs to the Changjiang basin impact the Changjiang River nitrate: A temporal analysis for 1968-1997, *Global Biogeochem. Cycles*, 17(4), 1091, doi:10.1029/2002GB002029.
- Zhang, J., Z. F. Zhang, S. M. Liu, Y. Wu, H. Xiong, and H. T. Chen, 1999. Human impacts on the large world rivers: Would the Changjiang (Yangtze River) be an illustration?, *Global Biogeochem. Cycles*, 13(4), 1099-1105.