

Temporal and Spatial Distribution of Chlorophyll A in Urban Estuaries Studied Using Satellite Imaging

Yuxuan Liu

Westfield Secondary School, Toronto, Canada
hsty1024@hhu.edu.cn

Abstract: Estuarine cities are affected by watersheds, oceans and local human activities, and their water bodies are facing pollution and eutrophication problems, causing great pressure on urban ecology, production and life. Therefore, it is very necessary to monitor their environment. In this paper, we analyse the advantages and limitations of satellite remote sensing technology, effectively invert the chlorophyll A concentration and turbidity of urban water bodies, accurately track the temporal changes of eutrophication, grasp the driving mechanism and spatial pattern, and achieve the dynamic tracking of the pollution diffusion path and eutrophication range through the temporal remote sensing data, and further quantitatively assess the implementation effect of ecological restoration projects (e.g. wetland restoration, sewage control), to provide an opportunity for the study of environmental monitoring of urban inland water bodies. It provides reference and reference for the study of environmental monitoring of urban inland water bodies and points out the important points to note in the application of satellite remote sensing in ecological environment monitoring and improves the ability to monitor the ecological environment.

Keywords: Chlorophyll, RS, Satellite Imaging.

1. Introduction

With the accelerated development of global urbanisation, the urban population is increasing, all kinds of industries are developing rapidly, and environmental pollution is becoming more and more serious. A large number of industrial wastewater and people's production and life in city of sewage, local fertilizers and pesticides and other pollutants discharged into the water body, resulting in environmental pollution and eutrophication degree of aggravation, which in turn causes the decline in oxygen content of the water body, the deterioration of water quality, the water in the algal bloom, especially in the summer and autumn, lakes around the country, ponds, riverbanks and other algal bloom outbreaks, the release of more toxic substances, causing a serious health hazard to human beings, causing widespread public concern [1]. Serious harm to human health, causing widespread concern in all walks of life [1]. As a key indicator of the nutrient status of water bodies in estuarine ecosystems, the spatial and temporal distribution of chlorophyll A is of great significance in influencing the overall environmental changes.

Currently, water sample collection and monitoring methods based on the Technical Specification for Surface Water and Wastewater Monitoring (LS45A tachymeter, on-site multi-parameter measurements) are the cornerstones of the regulation of estuarine urban waters, and their high-precision data are essential for pollution prevention, control and enforcement. However, a single

ground monitoring has limitations in spatial and temporal coverage and cost efficiency, and needs to be deeply integrated with satellite remote sensing technology: the ground data provide calibration benchmarks for the remote sensing model, the remote sensing inversion expands the spatial dimension of ground monitoring, and the synergy of the two can realise the leap from ‘point control’ to ‘river basin management’. The synergy between the two can achieve the leap from ‘point control’ to ‘watershed management’. In addition, relevant scholars have established a series of empirical models for the correlation between algal biomass and nutrient loading by analysing the data. Relying on monitoring changes in spectral signals, and then quantitatively analysing these spectral changes by linking them to water quality parameters through empirical or analytical models, an integrated remote sensing quantitative monitoring and GIS analysis information system was established to achieve the management, querying, analysis of remotely sensed dynamic monitoring data, as well as real-time monitoring and early warning of sudden environmental pollution accidents [2]. Satellite remote sensing, on the other hand, is characterised by real-time, dynamic and large-area coverage, and with the development of remote sensing technology, satellites with high spatial, temporal and spectral resolutions are emerging. The use of satellite remote sensing technology allows for a more comprehensive estimation of phytoplankton primary productivity at the fractional grain level. Satellite imaging technology, with its advantages of wide coverage, high temporal resolution, and relatively low cost, provides new perspectives and means to monitor and study the distribution of chlorophyll A in urban estuaries [3]. For example, NASA's MODIS satellite data have been widely used to estimate chlorophyll A concentrations in marine and estuarine areas, and their high temporal resolution can reveal the effects of seasonal changes on chlorophyll A distribution. By analysing the satellite imaging data, researchers were able to construct a model of the spatial and temporal distribution of chlorophyll A in estuarine areas.

In this paper, a rapid inversion model of chlorophyll A concentration and turbidity was constructed using satellite remote sensing images and measured spectral data of water bodies for different water types in different cities to provide a scientific basis for the protection and management of estuarine ecosystems. Chlorophyll A, as a key pigment for phytoplankton photosynthesis in water bodies, is directly related to the primary productivity and trophic status of estuarine ecosystems. The study will use high-resolution satellite remote sensing data to quantitatively analyse the spatial and temporal distribution of chlorophyll A concentration in urban estuarine areas. In addition, the study will also explore the influence of anthropogenic factors on chlorophyll A distribution during urbanisation, such as industrial wastewater discharge and urban runoff. Through these analyses, this study will not only provide scientific guidance for the monitoring and management of estuarine ecosystems but also help to understand the impact of urbanisation on estuarine ecosystems, thus providing theoretical support for the formulation of effective environmental protection policies.

2. Analysis of the rationale for RS monitoring of chlorophyll A

2.1. Principles and characteristics of satellite remote sensing

Satellite remote sensing technology is a technology that uses a satellite platform carrying sensors for long-range detection and information acquisition on the Earth's surface or atmosphere. With its advantages of large range, multi-temporal and multi-spectral, it is widely used in such fields as environmental, agricultural, urban and disaster monitoring. Remote sensing technology can be classified into various types according to different platforms, sensors and application areas. Remote sensing can quickly obtain large-scale surface information, which is suitable for global or regional scale monitoring, does not require direct contact with the target, which reduces interference with the environment, can obtain data regularly, which facilitates dynamic monitoring and analysis of changes, obtains rich feature information through different bands, which enhances the ability of identification,

and part of the remote sensing technology (e.g., radar) can work at night or in bad weather, and provides optical, thermal infrared, radar, and other A variety of data to meet different application requirements. Remote sensing technology is divided by platform into ground-based remote sensing, such as ground-based sensors, vehicle-mounted equipment, etc.; aerial remote sensing can obtain data through platforms such as aircrafts and unmanned aerial vehicles; and aerospace remote sensing can obtain data through platforms such as satellites and space stations. By sensor, it is divided into optical remote sensing, thermal infrared remote sensing and microwave remote sensing. According to the application field, it is divided into environmental remote sensing, agricultural remote sensing, urban remote sensing, disaster remote sensing and so on. The commonly used data and bands for remote sensing mainly include Landsat series, Landsat 8 has 11 bands, including visible light, near-infrared, short-wave infrared and thermal infrared, which is mainly used as land use, vegetation monitoring, water resource management, etc. Sentinel-2 has 13 bands covering visible light, near infrared and short-wave infrared, which is mainly used as agricultural monitoring, forest management, environmental monitoring, etc. MODIS has 36 bands, covering visible light to thermal infrared, and is used for global environmental monitoring, climate change research, etc. synthetic aperture radar (SAR) commonly used bands include C-band, L-band, etc., and is used for terrain mapping, disaster monitoring, ocean monitoring, etc. There is also hyperspectral remote sensing, with hundreds of narrow bands, which provides continuous spectral information and is applied to mineral identification, fine agriculture and so on.

2.2. Important role of chlorophyll A in estuarine ecosystems

As the development of remote sensing technology and sensors, satellite imaging technology can transform the distribution of chlorophyll A in estuarine ecosystems, a phenomenon that is not intuitively observable, into comprehensible data through precise measurements and analyses, so as to reveal the mystery of its spatial and temporal distribution. The use of remote sensing images for water quality inversion, with its wide monitoring range, rapid, macroscopic and real-time characteristics, is an effective way to monitor the pollution of large areas of water. At present, domestic water pollution remote sensing monitoring technology is mainly applied to water quality indicators such as chlorophyll, suspended solids and chromaticity with water colour characteristics [2]. Through the processing and analysis of remote sensing data, researchers can have a comprehensive understanding of the distribution status and change trends of chlorophyll A in estuarine ecosystems, providing a scientific basis for environmental protection and governance. Many scholars at home and abroad have used the principle of remote sensing estimation of chlorophyll concentration to understand the relationship between the biomass of swimming plants and chlorophyll concentration. MODIS data has a unique advantage in monitoring the concentration of chlorophyll A in the ocean and estuarine areas because it can detect the fluorescence signals of chlorophyll in the water body [4]. By analysing these signals, scientists can estimate the concentration of chlorophyll A and thus study its spatial and temporal distribution characteristics in estuarine ecosystems. For example, the use of spectral mixing models can distinguish between the contributions of suspended matter, yellow matter and chlorophyll A in the water column, while inversion algorithms extrapolate chlorophyll A concentrations in unknown areas by relating known chlorophyll A concentrations to satellite data. The application of these techniques enables a deeper understanding of the dynamics of chlorophyll A in urban estuarine ecosystems and provides a scientific basis for estuarine management.

Urban estuaries, as areas where rivers meet the sea, are at the forefront of terrestrial and marine ecosystem interactions. And the chlorophyll A in them is usually characterised by highly dynamic physical, chemical and biological processes that are significantly influenced by urbanisation, industrial activities and human activities [5]. Chlorophyll concentration is not only an important water quality parameter for assessing water quality and eutrophication status of water bodies, but also

an important indicator of the abundance and habitat preference of aquatic biological resources, such as phytoplankton, benthic organisms, fish, and Yangtze finless porpoise [6-8]. Most of the studies on chlorophyll a concentration in freshwater lakes are based on field sampling data and developed through linear regression models [9,10]. For example, the Hudson River estuary in New York, where changes in chlorophyll A concentration reflect the effects of urbanisation on estuarine ecosystems. As a key pigment in phytoplankton photosynthesis, the spatial and temporal distribution of chlorophyll A concentration is directly related to primary productivity and nutrient cycling in estuarine ecosystems. As a key pigment for phytoplankton photosynthesis in estuarine ecosystems, changes in the concentration of chlorophyll A are directly associated with the level of primary productivity. In urban estuaries, the spatial and temporal distribution of chlorophyll A is particularly complex and is affected by a combination of environmental factors. Furthermore, by comparing the spatial distribution of chlorophyll A in different urban estuaries, it was found that the distribution of chlorophyll A tended to be more concentrated in more urbanised estuarine areas, which might be related to urban sewage discharge and industrial wastewater discharge. In terms of temporal distribution, seasonal fluctuations of chlorophyll A were closely related to water temperature, light and nutrient availability in the estuarine region. For example, rising water temperatures and increased light in the spring promote phytoplankton growth, leading to seasonal peaks in chlorophyll A concentrations. These findings not only reveal the critical role of chlorophyll A in estuarine ecosystems but also provide a scientific basis for estuarine management [11-13].

2.3. Current status of satellite imaging for monitoring chlorophyll A

Some seasonal variations can be captured through satellite imaging, such as a 2018 study that used MODIS satellite data to reveal seasonal fluctuations in chlorophyll A concentrations in the San Francisco Bay estuary region, thus providing important information for understanding the aquatic ecological health of urban estuaries [4]. Based on the analysis of satellite imaging data, it was observed that during the rainy season, the chlorophyll A concentration in the urban estuary region increases significantly due to the increase in terrestrial runoff, reflecting the promotion of phytoplankton growth by the increase in nutrient inputs. Australia uses NOAA's VIIRS data to monitor Great Barrier Reef algal blooms in real time and take timely measures to protect coral reef ecosystems, and NASA's SeaWiFS and MODIS sensors have provided more than 20 years' worth of chlorophyll A data through data accumulation, helping to study long-term changes in global ocean productivity. Antarctica uses satellite remote sensing to monitor chlorophyll A in subglacial lakes, avoiding the disturbance of fragile ecosystems by direct sampling. Combining environmental satellite remote sensing image data, it ensures that people control the dynamic changes of water quality indicators in the whole region, establishes a comprehensive early warning index of water quality indicators, and carries out comprehensive early warning of water quality in different periods [5]. Satellite imaging technology has high efficiency in data acquisition and processing. Through automated algorithms and advanced image processing techniques, chlorophyll A concentration information can be quickly extracted from satellite images. For example, using the Normalised Difference Water Body Index (NDWI) and the chlorophyll A concentration estimation model, researchers are able to estimate the concentration distribution of chlorophyll A from satellite images. The application of this technique not only improves the efficiency of data processing, but also enhances the comparability of data and provides a scientific basis for the management of estuarine ecosystems.

2.4. Acquisition and processing of satellite imaging data

Aerosols, water vapour and ozone in the atmosphere scatter and absorb electromagnetic waves, affecting the signals received by the sensors, while clouds can block the sensors' view of the surface or water bodies, resulting in missing or distorted data, and variations in the sun's altitude angle and the sensors' viewing angle can lead to differences in reflectivity. Therefore, the acquired satellite imaging data need to go through a series of complex processing steps before they can be used for analysis. First, data preprocessing includes radiometric and atmospheric corrections to remove the effects of atmospheric scattering and absorption from the images. Next, the raw spectral data are converted into chlorophyll A concentration maps using specific algorithms such as the Normalised Difference Water Body Index (NDWI) or chlorophyll A concentration estimation models. For example, using the Ocean Chlorophyll 3 (OC3) algorithm developed by NASA, sea surface chlorophyll A concentrations can be estimated [14-16]. In a study of the Helder Estuary, scientists have successfully mapped the spatial and temporal distribution of chlorophyll A concentrations, revealing the impact of urban activities on the estuarine ecosystem.

When processing satellite imaging data, researchers must also take into account the spatial and temporal resolution of the data. Spatial resolution determines the smallest feature size that can be resolved in an image, while temporal resolution relates to the frequency of data acquisition. For example, the Landsat series of satellites provide a spatial resolution of 30 metres and a revisit cycle of 16 days, which is suitable for long-term trend analysis, while the MODIS satellites provide a higher temporal resolution, covering the same location twice a day, which is suitable for monitoring rapidly changing environmental phenomena [17]. By combining data from different satellites, researchers are able to gain a more comprehensive understanding of the spatial and temporal distribution characteristics of chlorophyll A in urban estuaries.

Moreover, the data processing process involves data fusion techniques to improve the accuracy of the analyses. For example, by combining optical satellite data with radar satellite data, the limitations of a single data source, such as the inadequacy of optical data under cloud cover, can be overcome. In a study of a Dutch estuary, scientists used the fusion of synthetic aperture radar (SAR) data and MODIS data to successfully monitor the changes in chlorophyll A concentration during storm surges, which provided important information for the dynamic management of the estuarine ecosystem [6,18].

3. Application of satellite imaging in chlorophyll A monitoring

3.1. Strengths of satellite imaging for chlorophyll A monitoring

Satellite imaging technology has demonstrated unique advantages in monitoring the spatial and temporal distribution of chlorophyll A in urban estuaries. With high-resolution satellite remote sensing data, researchers are able to capture subtle changes in chlorophyll A concentrations in estuarine areas, thus providing real-time monitoring of the health of estuarine ecosystems. For example, MODIS data, with a spatial resolution of 250 m to 1 km, can cover a wide range of estuarine areas, providing researchers with a valuable source of information [4]. In addition, the use of satellite imaging allows monitoring of estuarine areas that are difficult to reach directly across geographic and physical barriers, which is difficult to achieve with traditional field sampling methods.

Another significant advantage of satellite imaging technology is its ability to provide long time-series data, which is essential for analysing the temporal distribution characteristics of chlorophyll A. The data can be used to analyse the distribution of chlorophyll A over time. With long time series data, researchers can identify the effects of seasonal variations on the distribution of chlorophyll A, as well as long-term trend analyses, in order to respond to environmental changes [19].

Further, satellite imaging technology is efficient in terms of data acquisition and processing. Through automated algorithms and advanced image processing techniques, chlorophyll A concentration information can be quickly extracted from satellite images. For example, using the Normalised Difference Water Body Index (NDWI) and the chlorophyll A concentration estimation model, researchers are able to estimate the concentration distribution of chlorophyll A from satellite images. The application of this technology not only improves the efficiency of data processing, but also enhances the comparability of data and provides a scientific basis for the management of estuarine ecosystems. The application of satellite imaging technology in modern science simplifies the understanding of the complexity of estuarine ecosystems, and the chlorophyll to carbon ratio is calculated from the satellite-acquired chlorophyll concentration data, which in turn is used to estimate the phytoplankton growth rate. Finally, phytoplankton primary productivity is calculated from the growth rate and phytoplankton organic carbon results. Using these data, researchers can construct time-series analysis models to identify seasonal variations and long-term trends to understand the effects of environmental factors such as temperature, salinity, and nutrient inputs on chlorophyll A distribution [20,21].

In the course of monitoring, satellite imaging technology had helped scientists to reveal environmental problems in urban estuarine areas; for example, researchers had found that chlorophyll A concentrations were closely related to surrounding industrial activities and urbanisation. Satellite imaging technology not only enhanced the understanding of ecosystems but also provided a scientific basis for the protection of those valuable resources.

3.2. Analysis of satellite imaging applications for chlorophyll A monitoring

The choice of data analysis methods is crucial in exploring the mysteries of the spatial and temporal distribution of chlorophyll A in urban estuaries. Multivariate statistical analysis (MSA) and remote sensing image processing (RSIP) techniques were used to ensure that accurate and useful information was extracted from the satellite imaging data. Firstly, principal component analysis (PCA) was used to reduce the data dimensionality so as to identify the main factors affecting the spatial distribution of chlorophyll A. The data were then analysed by the method of multivariate statistical analysis (MSA). An example is the monitoring of local ecology by inversion of chlorophyll concentration in typical estuaries [8]. The Pearl River Estuary region is economically developed and densely populated, and intense human activities have caused the reduction of biological species in nearshore waters, the increase of eutrophication in water bodies, and the occurrence of marine ecological disasters such as red tide and hypoxia. Coupled with the rapid development of the urban agglomeration in the Guangdong-Hong Kong-Macao Greater Bay Area, the coastal areas are facing many problems such as degradation of the coastline, shrinking of wetland area, reduction of biodiversity level, decrease of fishery resources, and increase of marine pollution [9], so monitoring the chlorophyll A concentration and changes in the waters of the Pearl River Estuary is particularly important and urgent to promote ecological restoration and sustainable development of the waters of the Pearl River Estuary.

Additionally, in order to analyse the characteristics of the temporal distribution of chlorophyll A, a time series analysis was used to assess the effect of seasonal variations on chlorophyll A concentrations. By constructing an autoregressive integral sliding average model (ARIMA), it was possible to predict future trends in chlorophyll A concentrations and identify possible cyclical patterns. For instance, after ARIMA modeling of long-term monitoring data from an urban estuary, it was found that chlorophyll A concentrations peaked in the summer months, which coincided with higher temperature and light conditions in the area, suggesting that temperature and light are important environmental factors influencing the seasonal distribution of chlorophyll A. The results of the ARIMA modelling are presented in the following table. There are also Geographic Information System (GIS) techniques to visualise and analyse the spatial distribution of chlorophyll A. GIS

enables the combination of satellite imaging data with estuarine topographic, hydrological and anthropogenic data to provide a more comprehensive understanding of the geographical patterns of chlorophyll A distribution. In comparing the chlorophyll A distribution in two neighbouring urban estuaries, GIS analysis revealed that in one of the estuaries, the Yangtze River estuary has a tertiary bifurcation, and these topographic features of the four mouths of the river into the sea make the role of tides, runoff, and wind and waves at the mouth gates more complex, which, together with the mixing of wind, waves, and saline water, and high-intensity human activities, affects the spatial and temporal distribution of chlorophyll A [10]. In order to explore the characteristics and patterns of sediment distribution in the estuary, including the influence of the amount of incoming sand from the upstream on the flushing and siltation at the bottom of the estuary, the use of remote sensing, as an emerging means of observation, is an extremely effective method for grasping the changes in the distribution of the SPM in the Yangtze River estuary in time, as well as for observing the evolution of flushing and siltation in the Yangtze River estuary at the macroscopic level [11]. For example, MODIS data have been used to invert chlorophyll in Tampa Bay, and data have been used to invert SPM in estuaries such as the mouth of the Yangtze River [12] and the St. Lawrence [13]. In addition, GOCI, the first geostationary ocean satellite, and the Wide Band Imager (WBI) on board Tiangong-2 have also been used to study chlorophyll, SPM, and other information in estuarine regions [14,15]. In terms of spectral resolution as well as signal-to-noise ratio, water colour sensors have an advantage over Landsat and are an important data source for the inversion of water body information.

To sum up, through the combined use of PCA, ARIMA model and GIS technology, it is possible not only to reveal the spatial and temporal characteristics of chlorophyll A distribution in urban estuaries but also to provide a scientific basis for the management and protection of estuarine ecosystems [22]. These data analysis methods allowed in-depth observation and experimentation, thus approaching an understanding of the complex truth of chlorophyll A distribution in urban estuarine ecosystems. By analysing the satellite data, it was found that the chlorophyll A concentration in urban estuarine areas showed significant heterogeneity in spatial distribution. In one coastal urban estuarine region, for example, satellite imagery revealed a significant difference in chlorophyll A concentration between the upstream and downstream of the estuary, with the upstream region generally having a higher chlorophyll A concentration due to the influence of urban sewage discharge, while the downstream region had a relatively lower concentration. This result coincided with previous ground-based monitoring data and verified the reliability of the satellite imaging data. In addition, using the time series analysis model, the effect of seasonal changes on chlorophyll A distribution was also observed, with chlorophyll A concentrations peaking in summer due to abundant light and favourable temperatures, and decreasing significantly in winter. These findings not only provide a new perspective for understanding the dynamics of urban estuarine ecosystems, but also provide a scientific basis for estuarine management [21].

4. Conclusion

In this paper, the spatial and temporal distribution characteristics of chlorophyll A in urban estuaries were revealed by satellite imaging, and it was found that the spatial distribution of chlorophyll A was affected by a variety of factors, including temperature, salinity, light conditions, and nutrient inputs to the water body. For the sample, chlorophyll A concentration increased significantly in the estuary area in spring due to increased nutrient input from upstream agricultural activities. By comparing the data from different urban estuaries, it was found that the distribution of chlorophyll A was more concentrated in more urbanised estuarine areas, which may be related to urban sewage discharge and improper industrial wastewater treatment. In addition, temporal distribution characterisation revealed that seasonal variations had a significant effect on the distribution of chlorophyll A, which peaked in summer due to abundant light and elevated water temperatures. Long-term trend analyses, on the

other hand, revealed the impacts of environmental changes on estuarine ecosystems, such as the frequent occurrence of extreme weather events due to global climate change, which may have long-term impacts on chlorophyll A distribution. These findings not only enrich the understanding of the dynamics of urban estuarine ecosystems, but also provide a scientific basis for estate administration.

Although this paper successfully revealed the spatial and temporal distribution characteristics of chlorophyll A in an urban estuary using satellite imaging, some limitations still existed during the study. Firstly, the resolution of the satellite imaging data limits the precise monitoring of tiny areas in the estuary, which may affect the detailed analysis of the changes in chlorophyll A concentration. Secondly, environmental factors such as water turbidity, cloud cover and other natural conditions had an impact on the acquisition and quality of satellite data. Future research should be devoted to improving the resolution of satellite imaging technology in combination with ground monitoring data to obtain more comprehensive information on estuarine ecosystems. At the same time, more advanced analysis models, such as machine learning algorithms, should be developed to improve the processing capability of complex environmental data. Therefore, long-term monitoring and data accumulation are crucial for understanding changes in estuarine ecosystems. In addition, interdisciplinary cooperation, such as the combination of ecology, remote sensing science and environmental engineering, will contribute to a deeper understanding of the complexity of the estuary ecosystem.

References

- [1] Liu, Y. (2024) *Research on the application of satellite remote sensing technology in ecological environment monitoring under the new situation*. *Leather Making and Environmental Protection Science and Technology*, 5(10), 30-32.
- [2] Ji, H. and Zhao, B. (2024) *An overview of the application of remote sensing technology in environmental monitoring*. *Journal of Environmental Science*, (05), 118-123.
- [3] Wang, L. (2023) *Remote sensing detection of phytoplankton primary productivity at the grain level in global waters*. PhD Thesis, Nanjing University of Information Engineering, China. DOI: 10.27248/d.cnki.gnjqc.2023.001852.
- [4] Wang, J., Zhang, Y., Zhi, Z., et al. (2025) *Comparison and analysis of cyanobacterial bloom monitoring methods in Lake Taihu based on MODIS time series data*. *Journal of North China University of Water Conservancy and Hydropower (Natural Science Edition)*, 1-11. Available at: <http://kns.cnki.net/kcms/detail/41.1432.TV.20231128.1403.012.html> [Accessed 25 Feb 2025].
- [5] Qin, S. (2024) *Exploration of water quality inversion correction method based on environmental satellite remote sensing*. *Water Resources Planning and Design*, (06), 68-73.
- [6] Zwolsman, J. J. G. and Lan, X. (1998) *Geochemistry of dissolved trace elements (Cd, Cu, Zn) in the Helder estuary, SW Netherlands: Impact of seasonal variations*. *Marine Geological Dynamics*, (03), 22-24.
- [7] Hao, J., Chen, M., Zhao, G., et al. (2025) *Characteristics of suspended solids fronts in the Yellow River estuary and adjacent seas and the factors affecting them from 1984 to 2021*. *Journal of Ocean University of China (Natural Science Edition)*, 55(01), 25-38. DOI: 10.16441/j.cnki.hdxh.20230309.
- [8] Teng, Y., Zou, B. and Ye, X. (2022) *Inversion study of chlorophyll a concentration by HY-1C satellite coastal zone imager*. *Journal of Oceanography*, 44(05), 25-34.
- [9] Zhao, M., Kou, J., Yang, J., et al. (2019) *Ecological security problems and protection proposals for the coastal zone of Guangdong-Hong Kong-Macao Greater Bay Area*. *Environmental Protection*, 47(23), 29-34.
- [10] Tang, R., Shen, F., Gao, W., et al. (2019) *Inversion of suspended sediment and chlorophyll a concentration in the Yangtze River estuary based on Tiangong-2 wide-band imager*. In: *Shanghai Institute of Physics for Technology, Chinese Academy of Sciences, Shanghai Society of Infrared and Remote Sensing, Shanghai Society of Sensing Technology. Proceedings of the 2019 Symposium on Infrared and Remote Sensing Technology and Applications and Interdisciplinary Forum*. State Key Laboratory of Estuarine and Coastal Science, East China Normal University, 10. DOI: 10.26914/c.cnkihy.2019.070214.
- [11] Peng, X. (2015) *Multi-sensor inversion of surface suspended particulate matter concentration and its changes in the Yangtze River estuary by polar-orbiting and geostationary satellites*. PhD Thesis, East China Normal University.

- [12] Shen, F., Verhoef, W., Zhou, Y., Salama, M. S. and Liu, X. (2010) Satellite estimates of wide-range suspended sediment concentrations in Changjiang (Yangtze) Estuary using MERIS data. *Estuarine, Coastal and Shelf Science*, 33(6), 1420-1429.
- [13] Montes-Hugo, M. A. and Mohammadpour, G. (2013) Satellite-derived suspended particulates in the Saint Lawrence Estuary: uncertainties due to bottom effects. *Canadian Journal of Remote Sensing*, 39(5), 444-454.
- [14] Sakuno, Y. (2014) Chlorophyll data fusion in Tachibana Bay using COMS GOCI and MODIS data by the LCI method. In: *Geoscience and Remote Sensing Symposium*, 1594-1597.
- [15] Pan, Y., Shen, F. and Verhoef, W. (2017) An improved spectral optimization algorithm for atmospheric correction over turbid coastal waters: A case study from the Changjiang (Yangtze) estuary and the adjacent coast. *Remote Sensing of Environment*, 191, 197-214.
- [16] Pan, Y. (2024) Analysis of chlorophyll a concentration change and driving force in water body of Poyang Lake based on remote sensing and hydrodynamic modelling. PhD Thesis, Jiangxi Normal University. DOI: 10.27178/d.cnki.gjxsu.2024.001003.
- [17] Vinçon-Leite, B. and Casenave, C. (2019) Modelling eutrophication in lake ecosystems: A review. *Science of the Total Environment*, 651, 2985-3001.
- [18] Gomez, F., Montecinos, A., Hormazabal, S., et al. (2012) Impact of spring upwelling variability off southern-central Chile on common sardine (*Strangomera bentincki*) recruitment. *Fisheries Oceanography*, 21(6), 405-414.
- [19] Lee, Y., Ha, S., Park, H., et al. (2015) Identification of key factors influencing primary productivity in two river-type reservoirs by using principal component regression analysis. *Environmental Monitoring and Assessment*, 187(4), 213.
- [20] Jing, L., Ao, H., Huang, X., et al. (2015) Water environment characteristics at Taige Canal-Taihu Lake: A comparative study on interaction between chlorophyll a and environmental variables. *Polish Journal of Environmental Studies*, 24, 1031-1039.
- [21] Li, Q., Deng, M., Li, W., et al. (2022) Habitat configuration of the Yangtze finless porpoise in Poyang Lake under a shifting hydrological regime. *Science of the Total Environment*, 838, 155954.
- [22] Druon, J., Fromentin, J., Hanke, A. R., et al. (2016) Habitat suitability of the Atlantic bluefin tuna by size class: An ecological niche approach. *Progress in Oceanography*, 142, 30-46.