Research Progress of Remote Sensing Technology in Lake Water Environment Monitoring in China

Ping He, Xueya Chen, Yuanxing Cai, Yue Zhou, and Yan Chen

***Abstract*—This paper analyzes the research progress of remote sensing technology in lake water environment monitoring in China in recent years, including the research progress of suspended matter concentration in water, the research progress of bloom characteristics and the research status of chlorophyll concentration A.Although great progress has been made in lake water environment monitoring, the use of remote sensing to capture the spectral characteristics of water remains to be strengthened. It is necessary to improve the lake remote sensing algorithm for long time series and large range.**

***Index Terms*—Remote sensing monitoring, remote sensing of water environment.**

I. Introduction

Lakes are important fresh water resources on earth, which have multiple functions such as water source, agricultural irrigation, flood control and storage, aquaculture, tourism and recreation, and regional climate regulation. China is a country with many lakes. According to the latest survey results, there are 2,693 lakes with an area of more than 1km2, covering a total area of 81,414.6 km2, or 0.9 percent of the country's total area [1], [2].

Water quality monitoring and early warning are the main basis for water quality assessment and pollution prevention [3], [4]. The traditional field sampling-laboratory analysis method requires a large number of observation stations to be set up on site, which has the disadvantages of time-consuming, labor-intensive and high cost. For such a large area of water as inland lakes, the traditional method is difficult to meet the requirements of large-scale, rapid and long-term dynamic water quality monitoring [4]. Remote sensing technology has the advantage of long-term, real-time and rapid water quality monitoring, and can accurately explore the pollution spreading trend that cannot be explained by traditional methods [5].

The purpose of this paper is to introduce the research progress of remote sensing technology in lake water environment monitoring in China in recent years, including the research progress of suspended matter concentration in water, the research progress of bloom characteristics, and the research status of chlorophyll concentration A.

II. Main Research Progress

A. Study on Concentration of Suspended Matter in Water Body

Suspended solids in water are widely distributed and are one of the parameters for water environment monitoring and evaluation. They have a direct impact on water transparency and color, and then affect the water ecosystem. Therefore, the monitoring and control of suspended solids concentration in water is of great significance to the protection of ecological environment [6][7]. Scholars at home and abroad usually use remote sensing technology to extract suspended matter concentration by two methods, namely empirical method and semi-analytical method [7].

Empirical method is used to establish the relationship between the performance optical quantity and the measured suspended matter concentration. The empirical methods are mainly represented by single spectral band method, band ratio method and BP neural network prediction system.

The semi-analytical method relates the natural optical quantity of water to the concentration of suspended matter. The semi-analytical method usually uses the radiative transfer model of water body to calculate the intrinsic optical quantity information from the optical quantity and construct the remote sensing inversion method of suspended matter concentration. The semi-analytical method is used to establish the relationship between the natural optical quantity of water and the concentration of suspended matter. The semi-analytical method is a remote sensing inversion method for the concentration of suspended matter by using the radiation transfer model of water body to calculate the intrinsic optical quantity information from the optical quantity. Taking Hongze Lake as the research area, Lei Shaohua constructed a remote sensing estimation model for vertical distribution of inorganic suspended solids, and calculated the concentration of suspended solids particles at different depths of water by using remote sensing information on water surface [8]. Yu Zhexiu *et al.* took the suspended matter in Dianchi Lake, Yunnan province as the research object, collected water samples on the spot, measured the concentration of suspended matter in water samples by filtration drying method, and established an estimation model of suspended matter content based on HJ-1A hyperspectral remote sensing image data [9]. Yang rong *et al.* took dianchi lake as the research area and studied the remote sensing quantitative inversion of suspended matter in dianchi lake by using the CCD1 data of hj-1a satellite. The research results showed that bands 2, 3 and 4 of CCD1 data had the best correlation with the concentration of suspended matter in dianchi lake, and the best band combination for constructing the inversion model of suspended matter concentration was :(b2+b3)/(b2/b3) [10].

B. Study on the Characteristics of Blooms

Bloom phenomenon mainly refers to the phenomenon that algae (mainly composed of blue algae and green algae) prolifically after a large amount of nitrogen, phosphorus and other nutrients in wastewater from domestic and industrial

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and agricultural production enter fresh water, which is a typical feature of lake trophication. Bloom has always been one of the important indicators to evaluate the water quality of lakes [11]. How to monitor and control algal blooms is the key and difficult point in lake eutrophication research [12]. He Yunling *et al*. analyzed the temporal and spatial distribution of NDVI in Dianchi Lake area by using MODIS data, and discussed the distribution area and spatial variation characteristics of cyanobacteria blooms of different grades [13]. Li Xuwen *et al*. calculated the concentration of chlorophyll-A, the distribution of floating algae, suspended algae and aquatic grass in Taihu Lake on typical dates by using THE MPH algorithm based on OLCI image data from Sentinel-3 satellite. The paper points out that compared with MODIS, VIIRS and other commonly used cyanobacteria blooms remote sensing sensors, OLCI shows better water ecological remote sensing monitoring ability and can improve the early warning and forecast level of cyanobacteria blooms [14]. Jiang Dalin used MODIS remote sensing images from 2000 to 2014 to extract the algal bloom area of Dianchi Lake by FAI, estimated the algal bloom area, analyzed the spatio-temporal variation characteristics of the algal bloom in Dianchi Lake, studied the driving factors affecting the spatio-temporal variation of the algal bloom, and provided theoretical support for dianchi Lake water pollution prevention and control [15].

C. Study on Chlorophyll Concentration A

Chlorophyll A concentration is an important parameter reflecting the degree of eutrophication in water [16].There are many researches on water quality inversion of chlorophyll A concentration, mainly using statistical analysis methods and models [16]. Li Xuwen et al. used OLCI images of Sentry 3 satellite and C2RCC algorithm to compare and analyze the inversion results of chlorophyll A and total suspended matter in the South Yellow Sea. The results showed that remote sensing inversion of chlorophyll A had not yet reached operational application, and the spatial distribution of remote sensing inversion results of total suspended matter was relatively consistent with measured values [17].Based on APPLE method, Feng Honge et al. constructed a cooperative inversion model of chlorophyll A concentration with GF-1 WFV and Landsat8 OLI data as objects, and differentiated the dominant effects of spectral resolution and spatial resolution in the inversion process of chlorophyll A concentration, so as to improve the inversion accuracy of chlorophyll A concentration. Thus, the application value of high-resolution satellite data in water color remote sensing is improved [18].Based on dianchi Lake water quality monitoring data, Hou Pengfei analyzed the variation characteristics of dianchi Lake water quality parameters and the spatio-temporal variation characteristics of Chal concentration in dianchi Lake under the background of urbanization in the past 20 years, and discussed the influence of internal and external factors on Chal concentration [19]. Zhang Lihua et al. used the least-squares support vector machine model to invert the concentration of chlorophyll A in dahuofang reservoir area, and used stepwise regression analysis to explore the influence of chlorophyll A concentration on environmental factors and predict the change of chlorophyll A concentration [20]. Xu Pengfei et al. took Qiandao Lake as the research object, established water quality inversion model by using GF-1 satellite data images and combined with the measured water quality results of ground sampling points to invert the concentration of chlorophyll A in water and evaluate its accuracy [21]. Taking Qinglong Photolake in Guizhou province as an example, Huang Linfeng made a preliminary estimation and analysis of chlorophyll A concentration in photolake by using GF5 hyperspectral remote sensing monitoring images [22]. Xu Yifan et al constructed an inversion model of chlorophyll A concentration in Taihu Lake by using the three-band algorithm based on GOCI image data [23]. Zhu Bingchuan et al. used GOCI remote sensing data to construct a three-band model for chlorophyll A inversion in Taihu Lake, and used normalized vegetation cover index (NDVI) to monitor cyanobacteria blooms and conduct eutrophication evaluation [24]. Fan Guangli took Taihu Lake as an example and constructed a prediction model of chlorophyll A concentration based on ELM model based on environment 1 remote sensing image, and compared the prediction results with the traditional BP artificial neural network and SUPPORT vector machine SVM [25]. Yu Zhexiu et al. took the suspended matter in Dianchi Lake, Yunnan province as the research object, collected water samples on the spot, measured the concentration of suspended matter in water samples by filtration drying method, and established an estimation model of suspended matter content based on HJ-1A hyperspectral remote sensing image data [26].Yue Chengpeng et al. took Wuliangsuhai as the research area, used Landsat8 OLI remote sensing data, combined with chlorophyll A mass concentration data measured in water, adopted regression analysis to build a phytoplankton bioinversion model in Wuliangsuhai, and verified the accuracy and universality of the inversion model [27].Using MODIS satellite images as data sources and ground measured data, Chong Dan et al realized inversion of chlorophyll-A concentration in nine plateau lakes in Yunnan Province [28].Taking Chaohu Lake as the research area, Dong Dandan et al. used MODIS image data and quasi-synchronous surface water quality monitoring data to invert the water chlorophyll A information and build a chlorophyll remote sensing extraction model, which can provide data support for the control of cyanobacteria blooms in the lake[29].Liu Weihua et al. took river water in Bayanbulak Wetland in Xinjiang as the research object, and constructed a variety of spectral index models by using water reflection spectrum and water quality parameters. Finally, the paper analyzed the spatial distribution characteristics and seasonal pattern of chlorophyll concentration A of river water in wetland by using Sentinel-2 images. The seasonal variation of chlorophyll content in this water area was obtained [30].Han Yiwen etc. In the gulf of zhanjiang lit for the study area, according to the characteristics of the feature spectrum using spectral index, normalized difference vegetation index method to extract the lit bay mangrove plant area, the distribution of the chlorophyll a inversion of the water of the gulf, prove that water around the chlorophyll a concentration and distribution of mangrove plants have obvious change law [31].Chang Jingjie et al. used uav equipped with hyperspectral imaging equipment to detect representative water areas in combination with hydrological

and water quality characteristics of Bali Lake. The collected spectral data and the laboratory test data of the sampled water were compared and analyzed, and the concentration of water quality parameters was estimated through the quantitative model, providing data support for the subsequent application and promotion of this technology in water quality monitoring [32].Jiang Qian calculated the FUI index of water body by using multi-temporal GF-1 WFV data of 17 lake and reservoir water sources in Shandong Province. The CI index of reference was used to modify the consistency of FUI of different simultaneous terms. FUI time series and synchronous surface water quality online monitoring data were constructed, and the effectiveness evaluation index of water quality remote sensing monitoring was constructed. The effectiveness of water quality remote sensing monitoring was evaluated from two aspects: the significance of water FUI change and the synchronization of FUI change with the change of surface water quality online monitoring data [33].Feng Lian et al. pointed out four problems that should be paid attention to when using remote sensing to study lake blooms: (1) sediment and other signals in lake water would interfere with algal blooms; (2) atmospheric radiation and water-land boundary would affect the extraction results of algal blooms; (3) the effective observation frequency of satellite data would affect the spatial-temporal variation characteristics of algal blooms. Fourth, it is difficult to achieve accurate inversion of chlorophyll concentration in algal bloom outbreak area by satellite remote sensing [34].Jian-chao li tai lake as the study area, the use of 2017 field measured data and in situ observation sentry 3 a OLCI and MERIS image, build the applicable to taihu total remote sensing estimation model of microcystin algae toxin concentration, including empirical model and analysis model, and evaluate the accuracy of each model validation, finally choose three band model is applied to the image, The spatial and temporal distribution maps of TMC in Spring, summer, autumn and winter of 2017 and from 2003 to 2011 were obtained, and the driving factors of TMC in Taihu Lake were analyzed [35].Taking Taihu Lake and other inland water bodies as research objects, Du Chenggong Constructed an empirical estimation model of total PHOSPHORUS concentration based on wide-band remote sensing and an estimation model of total phosphorus concentration based on hyperspectral remote sensing, respectively, to explore the spatial and temporal distribution and change rule of total phosphorus concentration in Taihu Lake, and analyzed the influence mechanism of climate change on the spatial and temporal distribution of total phosphorus concentration at different time scales in different lakes of Taihu Lake. At the same time, the total phosphorus load of surface source input was estimated, and the response law of total phosphorus concentration in Taihu lake to terrestrial inflow was analyzed [36].Taking Taihu Lake as the research area, Yan Fuli et al established a specific emissivity model based on the concentration of cyanobacteriaceae and suspended matter through laboratory measurement of the specific emissivity of water component samples in Taihu Lake, and carried out a study on the response law of the specific emissivity of MODIS channel 31 and channel 32 to the concentration of water component. In addition, the split window algorithm was further used to compare the changes of surface temperature of Taihu Lake before and after the correction of specific emissivity, and finally the authenticity test was carried out through the measured data [37].Liu Ge builds a kind of optical characteristics of 2 kinds of water can be used in different concentration of chlorophyll a estimate analysis model (UMOC), and a more stable atmospheric correction models (DDV - WC), so as to improve the applicability of the model in the second type water body remote sensing monitoring, for the country and the world second class will provide technical support for remote sensing monitoring [38].Taking Chaohu Lake, Taihu Lake and Dianchi Lake as the study area, Wu Zhiming constructed remote sensing estimation models for CDOM concentration and composition of inland lakes suitable for OLCI images, including empirical model and semi-analytical model, by means of optical parameters and related water quality parameters obtained in the field for many times at different times and with reference to band Settings of Sentinel-3A OLCI images. Machine learning model and deep learning model, and compares the precision of each model, the final choice will be the best random forest model is applied to the precision OLCI images, obtained in 2017 in taihu lake, spring, summer, autumn, winter four seasons of CDOM concentration and spatial distribution, and discusses its space-time distribution rule, understand its evolution features [39].

III. Conclusion

In recent years, great progress has been made in the study of remote sensing technology in lake water environment monitoring, especially in the study of suspended matter concentration, bloom characteristics and chlorophyll concentration A, and some mature remote sensing monitoring models have been established.

Although great progress has been made in lake water environment monitoring, the use of remote sensing to capture the spectral characteristics of water remains to be strengthened. It is necessary to improve the lake remote sensing algorithm for long time series and large range.

Conflict of Interest

"The authors declare no conflict of interest".

Author Contributions

Xueya Chen,and Yuanxing Cai have collated the data.Yue Zhou and Yan Chen reviewed and revised the first draft.

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