Application of High-resolution Satellite Imagery in Water Quality Monitoring of Rivers and Lakes

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Abstract. The traditional water quality monitoring needs a lot of manpower and financial resources, but with the advantage of high time efficiency and other advantages of high-score data for information extraction, analysis and monitoring can be timely, large-scale monitoring of specific water, make up for the shortcoming of traditional water quality environmental monitoring. This paper introduces the theoretical method and technical process of monitoring surface water body with high score data. First, the original remote sensing data are preprocessed by radiometric calibration, geometric correction, atmospheric correction and water extraction, and then an inversion model is established to invert the chlorophyll a concentration, and then the main monitoring indicators are established, such as suspended matter, transparency and eutrophication index.

1. Introduction
With the rapid economic development of our country, living standards have been greatly improved, industrial wastewater, domestic sewage discharge lead to environmental pollution of water bodies, some cities appear eutrophication or even black water. Water bodies in many areas are irreversibly damaged, so the establishment of a highly time-efficient, large-scale, dynamic monitoring mechanism can detect pollution problems as early as possible and establish prevention mechanisms. High score data can be used to obtain more accurate water quality status over a wide range, used to estimate suspended matter concentration and algal biomass, to provide continuous reflectance spectral values and high spatial or temporal resolution to monitor water quality characteristics, such as suspended particulate matter or chlorophyll a concentration and water transparency. On the basis of reading a large number of literatures, this paper summarizes the processing flow of high score data and its application, and makes evaluation and analysis.

2. Preconditioning
In order to use the remote sensing image for research, we should initially preprocess the remote sensing image. The traditional preprocessing technology flow of remote sensing image generally includes radiometric calibration, geometric correction, atmospheric correction and water extraction.

2.1. Radiometric calibration
Radiometric calibration is the process of converting digital quantization values (DN values) recorded by sensors into absolute radiometric brightness values, and different remote sensing images correspond to different system gains and offsets, and the relevant data are regularly updated with the use status of remote sensing sensors, thus ensuring the accuracy of image processing\cite{1}. Radiometric
calibration was done by ENVI software. The radiometric calibration formula is $L_\lambda = \text{Gain} \times \text{DN} + \text{Bias}$, where: Gain is the calibration slope; DN is the satellite load observation value; Bias is the calibration intercept, and $L_\lambda$ unit is W/(2 * um * sr)$^{[2]}$.

2.2. Geometric correction
Geometric correction refers to that in the process of remote sensing imaging, due to the comprehensive influence of various factors, the characteristics of ground objects on the original image such as geometric position, shape, size, size and orientation are often inconsistent with the characteristics of their corresponding ground objects, and this inconsistency is geometric deformation, also called geometric distortion$^{[3]}$. We can correct the deviations of the original image where produced by any reason to reduce errors via geometric correction. The commonly used geometrical correction models for remote sensing images are: polynomial model, rational function model and parametric model$^{[4]}$. In the construction of parametric model, topographic factors, instrument imaging factors and satellite location factors should be considered. Ji Gang$^{[1]}$ uses the workflow module in ENVI for correction, and the geometric correction accuracy is within 0.5 pixel. Liu Zhonghua$^{[5]}$ uses georeferencing module in ArcGIS to correct geometry, takes the topographic map of the study area as the reference image, and completes the geometric precision correction of remote sensing image data by selecting control points around the remote sensing image, which effectively eliminates the geometric distortion.

2.3. Atmospheric correction
A large part of the signal received by the sensor is output by the atmosphere, and the proportion of water is not high. Therefore, atmospheric correction is needed to reduce the error caused by the influence of atmosphere, gas in the atmosphere and other impurities, and try to form an image that can truly reflect the surface. Atmospheric correction methods for remotely sensed images include 6S model, MODTRAN model, ATCOR model and FLAASH model based on radiation transmission model, dark pixel method, and reflectance inversion method based on statistical model$^{[6]}$. Among the above models, the calibration accuracy of 6S model is relatively high, the ATCOR model is relatively stable, the error of FLAASH in the blue band is relatively large, and the versatility is relatively strong. Besides atmospheric correction, the problem of proximity effect should be considered. Cheng Chunmei$^{[7]}$ used the 6S model to remove the atmospheric attenuation, and uses the kernel function to express the atmospheric point spread function, to correct the proximity effect, restore the original surface, the edge of the object becomes clearer, image contrast has been significantly improved. Ma Xiuqiang$^{[8]}$ used the mid-latitude summer MLS model in FLAASH and obtained more accurate results, which is conducive to accurate identification. Zhou Yu$^{[9]}$ used the atmospheric calibration method based on the FLAASH model, which is based on the MODTRAN4 + radiative transfer model. After the correction, it can reflect the real surface information more accurately. FLAASH atmospheric correction method was developed by the Institute of Spectroscopy Science with the support of the United States Air Force Research Laboratory atmospheric correction module. The FLAASH atmospheric correction model can effectively remove the aerosol scattering effect, simultaneously correct the cross radiation of adjacent pixels and reduce the spectral noise. In addition to the true surface reflectance, information such as water vapor content and visibility in the study area can be obtained from the FLAASH atmospheric correction$^{[8]}$.

2.4. Water extraction
Water extraction is a step after radiometric calibration, geometrical correction and atmospheric correction. Different methods have different characteristics. Generally speaking, there are three common methods to extract water information from remote sensing data: spectral relationship method, water index method and single band threshold method. Chen Peng$^{[9]}$ used single-band threshold method, threshold-based multi-band spectral relationship method and threshold-based water body index method to extract water bodies from FY3A/MERSI images in the study area. Based on the confusion matrix method, the extraction results were compared with the Land-Sat-ETM + image base
map, respectively, and concluded that the overall accuracy of the normalized difference water body index method in the threshold-based water body index method to extract water bodies in the study area was high. Shen Mengjun \(^{[10]}\) conducted experiments using four different extraction methods: single-band threshold, normalized difference vegetation index (NDVI), normalized difference water body index (NDWI), and principal component analysis, and finally concluded that single-band threshold extraction method and NDVI extraction method were less accurate than other methods, and NDWI extraction method was affected by urban areas and partial shadows. Wan Peixuan \(^{[11]}\) used four bands of near-infrared, green, red and blue light for extracting the surface water. The normalized vegetation index, normalized water index and mixed water index are calculated by using these four bands, and the shape factor combined with water index is used to find an effective method for extracting decent water. Different methods also have certain limitations, so specific analysis is also needed to use an efficient and convenient way.

3. Chlorophyll a (Chl-a) Concentration Retrieval Based on High Score Image

Chlorophyll-a (Chl-a) concentration is an important parameter of water quality and eutrophication degree. By estimating the concentration of chlorophyll-a, we can quantitatively understand the basic ecological information of water bodies and assess the impact of human activities and external environmental changes on water ecosystems \(^{[12]}\). Due to the complexity of water body and the interaction of various water color elements, it is necessary to select a suitable inversion model. The basic inversion models are empirical model, semi-empirical model and analytical model \(^{[5]}\). Empirical model is simple and efficient, and it has good inversion effect for water body in a single area. But the water quality conditions in different areas are different, so it is difficult to establish a unified chlorophyll a concentration inversion model using empirical model. The semi-empirical and semi-analytical model has a small deviation and is widely used at present. Analytical model is difficult to establish inversion model, and the mechanism is too complex, but the universality is good after the establishment.

3.1. Empirical model

Empirical method is widely used in remote sensing monitoring of chlorophyll concentration. Empirical method is to establish the statistical relationship between remote sensing data and ground monitoring of chlorophyll concentration to achieve quantitative inversion of water chlorophyll concentration. For Dahuofang Reservoir with clear water quality, Xia Xiaoyun et al. \(^{[13]}\) combined the satellite image data to analyze the sensitive band combination of chlorophyll a, established a linear regression model and least squares support vector machine (LS-SVM) model for quantitative inversion of chlorophyll a concentration in Dahuofang Reservoir. The model can also be used to retrieve other water quality indicators. Li Suju \(^{[14]}\) used band ratio and first order differential model to retrieve the chlorophyll concentration of Chaohu Lake water, and achieved good results. In the preliminary stage of the inversion of chlorophyll a concentration, the empirical method is used to retrieve the chlorophyll a concentration of Jiuhu Lake. Although the optimal wave band is selected and compared, it is mainly based on statistical analysis and has some limitations.

3.2. Semiempirical semi-analytical model

Semi-empirical semi-analytical method is a common method of water quality remote sensing monitoring since the 1990s, which has a certain physical meaning by analyzing the measured water spectral data and then determining the best band or band combination to establish a relationship with water quality parameters for remote sensing inversion of water quality parameters \(^{[5]}\). Aiming at Taihu Lake water body, Wen Jianguang \(^{[16]}\) proposed the mixed spectral decomposition model as the water body chlorophyll a concentration estimation model on the basis of analyzing the traditional empirical and semi-empirical water quality remote sensing model. Empirical semi-empirical model is limited by time and space, and hybrid spectral model is more superior and reliable than empirical semi-empirical model. Liu Zhonghua \(^{[5]}\) used the linear function model and quadratic function model in the single-
band model, the first-order differential model, the band ratio model, the three-band model and the four-band model, and made a comparison for this purpose. For RapidEye high-score satellite data, the inversion results showed that the quadratic function model, the multi-band combination model and the three-band model in the single-band model all had high accuracy and stability, with an average relative error of 12.53%. For the ALOS high score satellite data, the inversion results show that the quadratic function model can effectively retrieve the chlorophyll concentration of the western Taihu Lake and its major polluted rivers into the lake, with an average relative error of 14.27%. Zhang Minghui et al. [17] used the machine learning method random forest (RF) and the traditional characteristic band ratio (BR) method for the inversion of chlorophyll a concentration near the coast of Fujian for small sample data, combined with the time sequence buoy observation data, and used the modeling strategy of "continuously replenishing spatial sparsity with time" to perform remote sensing inversion of chlorophyll a concentration in different phases near the coast of Fujian, and verified and analyzed the inversion results. This method is an effective monitoring method for areas where water bodies generally deteriorate and there are few observation points. Luo Jianmei et al. [18] determined (B3/B1) as the best band combination for the inversion of chlorophyll a concentration in the coastal waters of the northern Luanhe Estuary, and constructed a reciprocal model based on this band combination, which could be used for the inversion of chlorophyll a concentration.

3.3. analytical model
The analysis method is to use the bio-optical model to simulate the relationship between the absorption coefficient and backscattering coefficient of each component in water and the irradiance ratio of remote sensing, and use the radiation transmission model to simulate the propagation process of light in the atmosphere and water, and use the remote sensing data to retrieve the concentration of each component in water. Cao Hongye [19] used RBF (Radial Basis Function) neural network to establish the inversion model of chlorophyll a concentration and synchronous image data in this study area. This model is easier to popularize and use. Li Yunmei et al. [20] established a reflectance simulation model using Gordon model based on the measured data of Taihu Lake water body, and then used the method of optimization function to retrieve the chlorophyll concentration of water body. Wu Jiansheng [21] used Matlab R2012a software to construct two BP (error back-propagation) neural network models to retrieve the concentration of chlorophyll a in Shenzhen sea area.

4. Discussion and Prospect
High application is of great significance for the environmental monitoring data, using the high score data inversion of chlorophyll (chlorophyll-a) concentration, transparency and a suspended solids concentration, water quality parameters, such as working for the degree of urban water body black smelly remote sensing discriminant provides a possibility, but the model applicable to the different conditions of water quality is different, we need to strengthen the analysis of chlorophyll a inversion method research, improve the universality of the inversion model. At present, there are many inversion models for specific waters, but there is no universally applicable inversion model. It will be greatly convenient for environmental monitoring if we can explore the personality and commonness of all kinds of water inversion models and obtain models suitable for different waters.

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