

Remote Sensing Monitoring of Taihu Lake Based on Small Environment Satellite

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Abstract: Taking the results of Taihu Lake, using the relationship between water spectral characteristics and the mathematical model and quantitative remote sensing technology, we realize the high frequency, large-range and quasi-real time monitoring to improve the pollution and protect the natural environment.

1. Introduction

Water is the source of life, and the water quality status is closely related to the survival and development of human society. Therefore, various countries in the world attach great importance to the research and monitoring of water quality status. As a large population country with poor water resources and urgent economy, the research and monitoring of water quality is of great practical significance.

Since the early 1990s, remote sensing technology has been gradually applied to the research on land water bodies, and has gradually developed from simple water recognition to remote sensing monitoring, mapping and prediction of water quality parameters. With the continuous development of remote sensing technology and the study of spectroscopic characteristics and algorithms of water quality parameters, the monitoring method experienced the development of analytical methods (before 1980s, mainly for open oceans) -empirical methods (1980s-1990s) -semi-empirical methods (after 1990s). Various remote sensing data, including Landsat MSS, TM, SPOT, MODIS, IRS-1C, NOAA/AVHRR, and various aviation hyperspectral data, such as AVIRIS data, CASI data, AISA data, and CIS data, are widely used in water quality remote sensing monitoring research [1-7] The water quality of remote sensing monitoring has gradually developed from qualitative to quantitative, and the types of water quality parameters through remote sensing monitoring has gradually increased, including chlorophyll a, suspended object and yellow substance, the inversion accuracy is also improving. But there are no forming models and algorithms with high accuracy and good versatility [2-3].

The main research content of this paper is to monitor the water quality parameters of Taihu Lake water quality, chlorophyll a, and reverse the water quality parameters according to the relationship of the water spectral characteristics and the concentration of water quality parameters. Starting from the

original CCD data, after a series of data preprocessing under ENVI, obtain Taihu water surface data with correct geographical coordinates and real spectral information, combined with mathematical model and quantitative remote sensing technology, reverse the concentration of Taihu chlorophyll, thus obtaining the concentration achievement map of Taihu chlorophyll.

2. Research Area and Research Methods

2.1 Study Area Overview

Taihu Lake is the third largest freshwater lake in China, and one of the more serious eutrophication lakes. This study, Taihu Lake was selected as the experimental area mainly for the following two considerations: (1) Taihu Lake is located at the mouth of the Yangtze River, is the third largest freshwater lake in China and plays an important role in freshwater supply and aquatic product aquaculture; (2) it is an important water source of the Yangtze River Delta. Therefore, the research of the water quality of Taihu Lake is of great practical significance. In addition, in the past decade, with the rapid economic development of Taihu Lake, Taihu water body has been polluted to varying degrees, especially the degree of water eutrophication is increasingly serious, and most of the water bodies are in a moderate, or even extreme nutritional state. For example, in the Mailiang Bay Lake District in the north of Taihu Lake, large-scale blue algae blooms occur almost every year and month. Floating algae, suspended objects and yellow substances are the three main substances affecting the spectral characteristics of Taihu Lake water bodies. Taihu Lake is a shallow lake, average water depth, area, average east and west wide, the widest of. The terrain at the bottom of Taihu Lake is very flat, with small capacity and weak adjustment and storage capacity, but it is conducive to the mixing of the lake water and averaging the cultural characteristics and chemical composition of the whole lake. The typical characteristic of Taihu water is the high content of plankton algae and nonbiological suspended objects. Therefore, Taihu Lake is suitable for the object of water environment remote sensing research.

2.2 Data Source

CCD-1B data of the small environment satellite, download for free in the Satellite Environmental Environment Application Center of the Ministry of Environmental Protection, CCD data download address: Read patch of the www.secmeep.cn environment small satellite download address:http://blog.sina.com.cn/s/blog_764b1e9d0101a9dh.html

The TM data download address is: www.gscloud.cn

Ammission small satellite data spectral response function used for atmospheric correction Download address: <http://www.cresda.com/n16/n1115/n1522/n2118/index.html>

2.3 Research Methods

First, a series of data preprocessing of the obtained environmental small satellite CCD data under ENVI: data processing, radiation calibration, geometric correction (environmental small satellite data processing patch) geometric correction (reference image), atmospheric correction (spectral response function), Taihu District Cutting (Taihu Vector Data), Get Taihu water surface data with correct geographic coordinates and real spectral information; Combining mathematical models and

quantitative remote sensing techniques, chlorophyll inversion: establish the inversion model to modify the inversion model and apply the water surface image of Taihu Lake; Counterperformance of chlorophyll a concentration throughout the Taihu Lake, Results map of Taihu Lake chlorophyll concentration was obtained; The results are analyzed and applied.

Main steps of the research method: obtain CCD data under ENVI, chlorophyll inversion, chlorophyll concentration distribution map, and result post-processing and application.

See Figure 1 for the processing process:

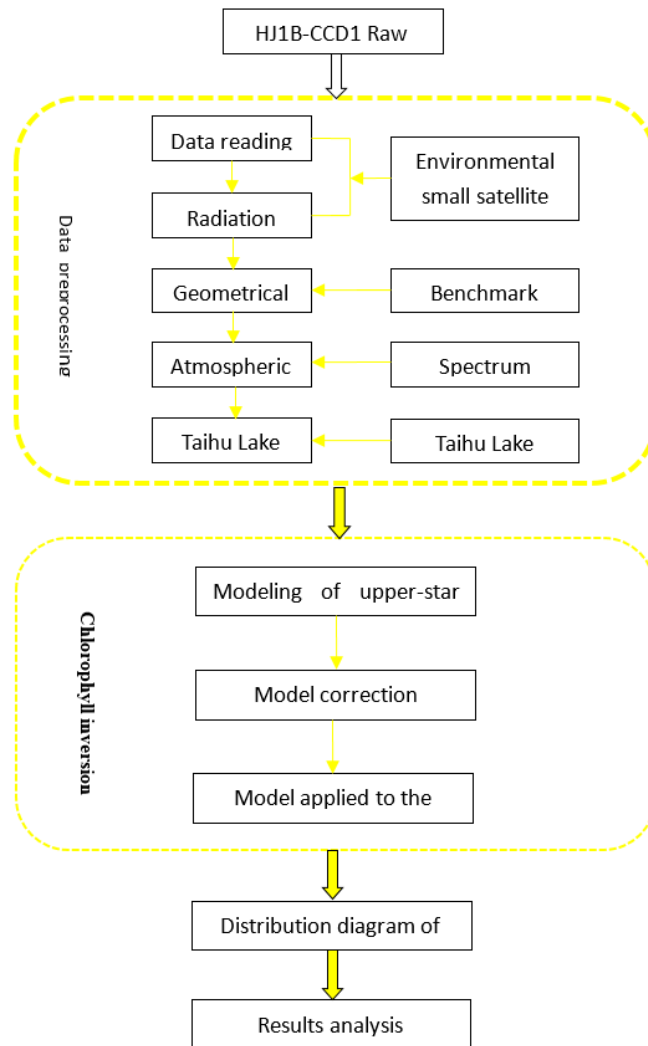


Figure 1: Process Flow Chart

3. Remote sensing monitoring of lake water quality based on small environmental satellite

3.1 Data Preprocessing

- (1) Install the environment small satellite data reading and calibration patch
- (2) Data reading and calibration

Open the main menu in ENVI-File-Open As-HJ-1A1B, with the following figure:

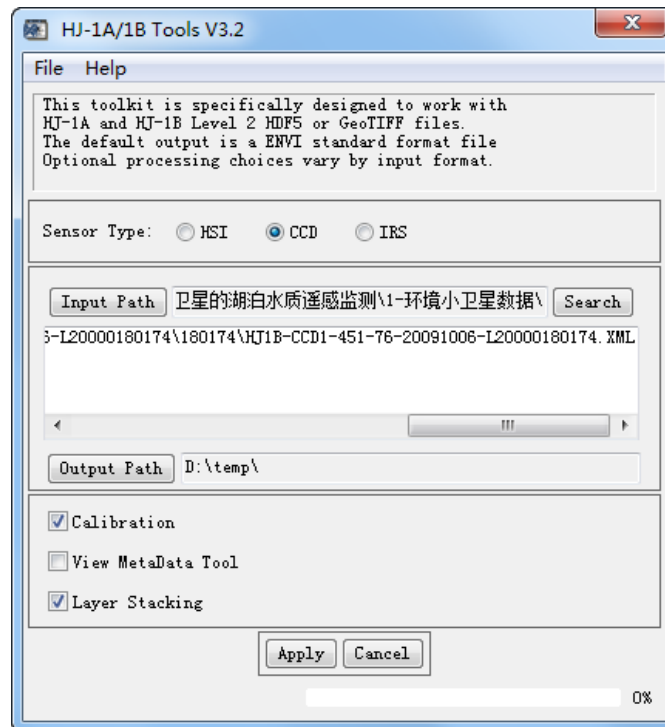


Figure 2: Caliation Processing

3.2 Geometrical correction

3.2.1 Purpose of the geometric correction

Geometric correction of environmental data is conducted to have accurate geographical information. The reference image can be a topographic map or other medium and high resolution images that have been corrected. The overcorrected TM data is used as the reference image. The purpose is to make environmental small satellite images have accurate coordinates and can match other data directions, such as measured GPS data.

3.2.2 Engineering crop

Because the landscape data range is very large, and our engineering area is only a small part of them, so the Taihu Lake and the surrounding area are cut out before the geometric calibration.

Cutting method:

Open the picture file of Taihu Lake in ENVI, File-Save as, File Selection dialog box appears, click Spatial Subset option, enter from 6638 to 10145 total 3508 pixels, rows in columns, click OK, to cut out Taihu Lake and surrounding areas:



Figure 3: Cropping Results of Taihu Lake Area

3.2.3 Image registration

Registration is the calibration of another image (reference image) in the same area to align the same image in the two images.

Image registration procedure: Open the ENVI, Search for the Image Registration, in the toolbar Open the image registration dialog box, Select the TM Image in the Base Image, Select the Taihu Lake image in the Browse Image, Click on the Next, Select the Band 4, in the Advanced bar Point selection 300, Search Window Select 121, Click on the Next, Warping - Resampling Select Cubic Convolution, in the new appear dialog box Click on the Next, The output window appears, Click on the Finish, Outputs are shown as follows:



Figure 4: Image registration

3.3 Atmospheric correction

Obtaining the real spectral information of earth is the premise of remote sensing inversion, and atmospheric correction can eliminate atmospheric influence and restore the real information of earth, which is an essential link in the preprocessing of quantitative remote sensing data.

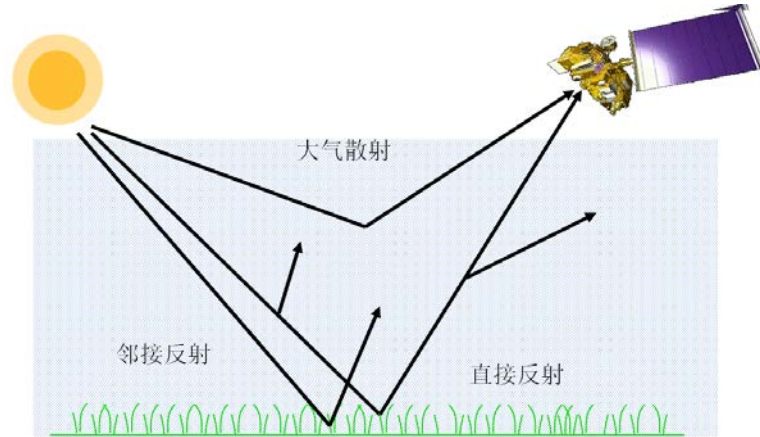


Figure 5: Schematic Drawing of Atmospheric Correction

3.3.1 Production spectral response curve

Environmental small satellites provide a spectral response function provided in text, the first column representing wavelength (nm) and the latter four columns representing the spectral response values of 4 bands corresponding wavelengths. The spectral curve is required to describe the spectral response function for atmospheric correction.

The method of making spectral curve is: open ENVI, search Spectral Library Builder, appear dialog box in Toolbox select ASCII File, select the corresponding spectral function file, select input-from ASCII File, select the corresponding spectral function file, click Select All Items, single OK, new dialog box click Plot, to generate the corresponding spectral response curve.

Spectrum response curve results:

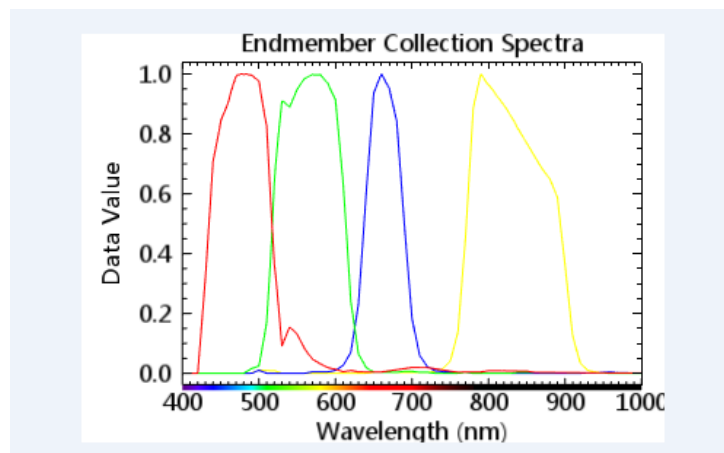


Figure 6: Results of the spectral response curve

3.3.2 FLAASH atmospheric correction

FLAASH has the following requirements for the image files:

(1) The data is radiometric data in: $(\mu\text{W}) / (\text{cm}^2 * \text{nm} * \text{sr})$.

(2) The data has a central wavelength (wavelength) value, if the high spectrum must also have a band width (FWHM), both parameters can be used by editing the header file information input (Edit Header).

(3) Data Type

Four data types are supported: floating, floating, long integer, integer, and unsigned integer (unsigned int). Data store type: ENVI standard grid format file, is BIP or BIL.

(4) Wave spectrum range: 400-2,500 nm

3.3.3 FLAASH basic parameter settings

Method of FLAASH basic parameter setting: open ENVI, search FLAASH Atmospheric Correction, in Tool Box Open the parameter setting dialog box, select Input Radiance Image to select Taihu image in the dialog box, Output Reflectance File chooses to save the file, then set the parameters, and click Apply, to complete the basic parameter setting.

The basic parameters are shown as below:

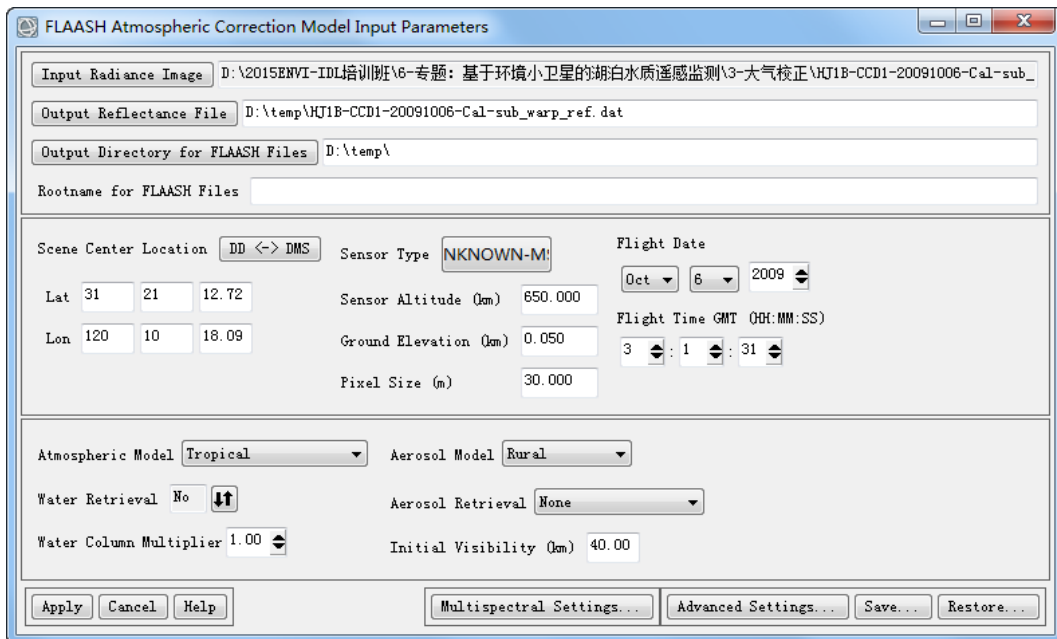


Figure 7: FLAASH basic parameter setting result

3.3.4 FLAASH Multispectral parameter settings

FLAASH Multispectral parameter setting method: in the dialog box of setting the basic parameters, click Multispectral Settings, to open the multispectral parameter setting dialog box. After setting the parameters, click Filter Function File, to select the corresponding file and click OK.

Multispectral parameter setting result:

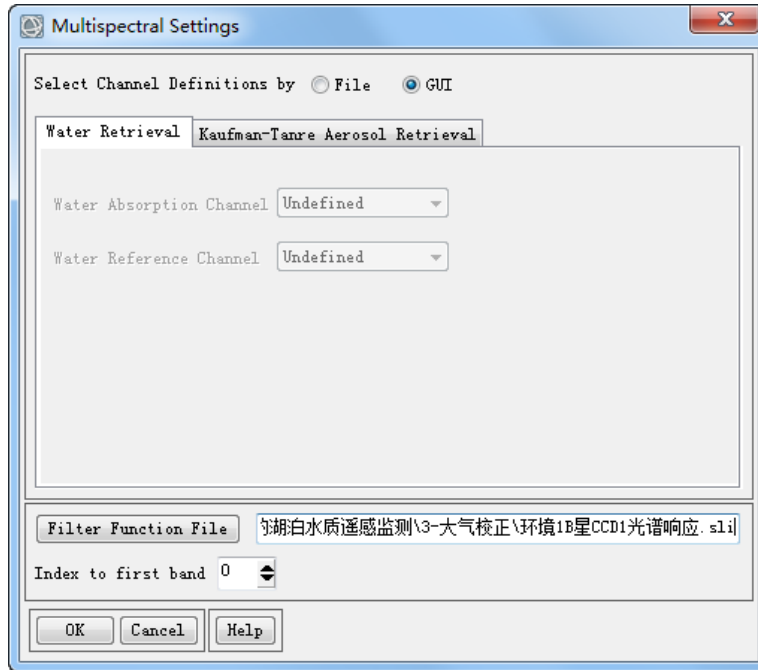


Figure 8: Results of multispectral parameter setting

3.3.5 FLAASH Advanced Parameter Settings

FLAASH Advanced parameter setting method: Open the FLAASH Advanced Settings dialog box, set the parameters, and click OK.

Advanced Parameter Setting Results:

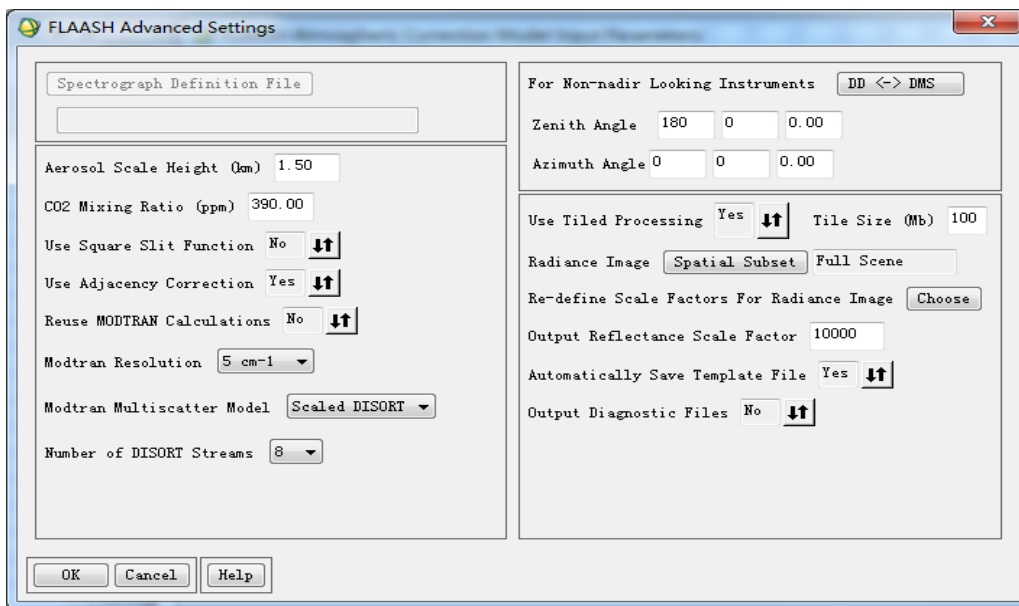


Figure 9: Advanced parameter setting results

3.3.6 Results test

Make the spectral curve of typical land (vegetation) before and after atmospheric correction respectively, and draw the spectral comparison curve of typical ground (vegetation) before and after atmospheric correction:

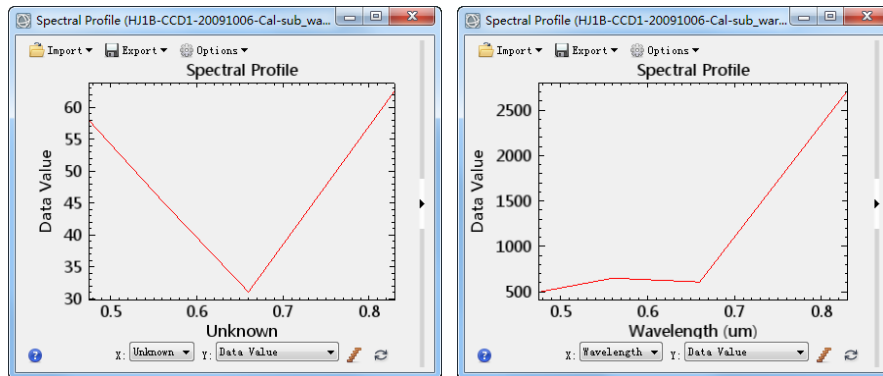


Figure 10: Comparison of the spectral curve of the typical ground (vegetation) before and after atmospheric correction

3.4 Cutting out of Taihu Lake area

The purpose of image cropping is to remove areas outside of the study. The common method is to cut the heads according to the administrative division boundary or natural division boundary; in the basic data production, but also often in the standard segmentation cutting.

ENVI image cropping process, can be divided into regular cropping and irregular cropping. Regular amplitude cutting refers to the boundary range of the cropping image that is a rectangular form, including the column number, two-point coordinates in the upper left and lower right corner, the image file, and the ROI/ vector file. Irregular amplitude cropping, where the boundary range of the cropping image is an arbitrary polygon. Any polygon can be a complete closed polygon region generated in advance, a manually drawn ROI(area of interest) a polygon, or a vector file supported by ENVI.

Cropping method: Using the object-oriented image segmentation tool provided by ENVI FX, first obtain the Shapefile, and then use the vector editing function to obtain the Taihu vector file of ENVI. Cropping result diagram:



Figure 11: Cropping Results

4. Chlorophyll concentration inversion

4.1 Band value model

The most important part in this link is the inversion model of ground measurement points and star points, involving the knowledge of quantitative remote sensing. Based on a large number of algorithms and models, this topic selects the band value model (BNIR/BRED), one of the empirical models, to perform the inversion of chlorophyll as an example.

Band ratio model:

$$\text{Chla} = a * (\text{BNIR} / \text{BRED}) + b \quad (1)$$

4.2 Measured data arrangement of sampling points

This step requires sorting field investigation data and corresponding the spatial position of the surface survey point and the measured chla value one by one. The measured points are classified as — inversion points and verification points. According to the standard format: point number, latitude and longitude of the water surface survey points, chlorophyll content, saved in the form of four columns. The txt and Excel files.

序号	纬度	经度	chla 实测含量 (mg/L) ↵
1	31.516334	120.182215	0.0531↵
2	31.457170	120.041978	0.0535↵
3	31.459692	120.177602	0.0496↵
.....↵			

Figure 12: Field Survey Data

4.3 Data acquisition on the sampling point star

Method of generate band ratio image: open ENVI, to select Basic Tool->Bandmath, input expression: float (b4) / b3, click Add to list, click expression. In the new dialog box, select B3 Band3, B4 and Band 4, and click OK, to generate band ratio image. Figure 13:

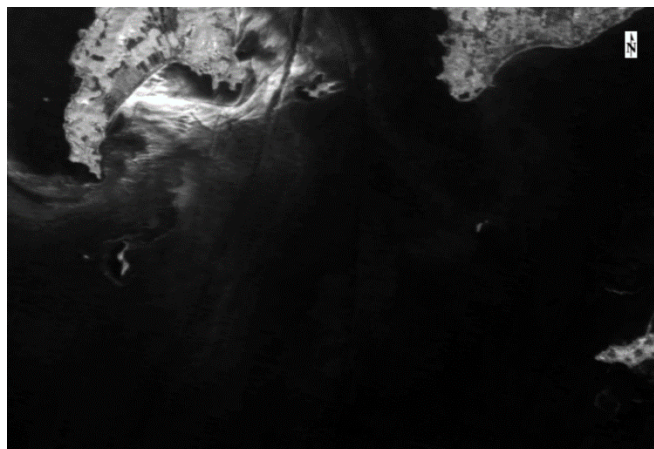


Figure 13: Band-band ratio image

Import the sample point data on the band ratio image, and export the pixel values of the corresponding position on the image:

	A	B	C	D	E	F	G	H	I	J	K	L
1	; Number of ROIs: 1											
2	; File Dimension: 2194 x 2299											
3	;											
4	; ROI name: 反演点											
5	; ROI rgt 0 0}											
6	; ROI npts: 38											
7	;											
8	File X	File Y	Map X	Map Y	Lat	Lon	E1					
9	;											
10	1439	1360	218883.5	3484060	31.45718	120.0417	0.910354					
11	1869	1362	231783.5	3484000	31.45971	120.1773	0.864955					
12	2399	1492	247683.5	3480100	31.42813	120.3455	0.694639					
13	2155	1697	240363.5	3473950	31.37109	120.2702	0.627219					
14	1219	1822	212283.5	3470200	31.33068	119.9764	0.877497					
15	2108	1836	238953.5	3469780	31.33319	120.2565	0.631079					
16	1686	1836	226293.5	3469780	31.33028	120.1235	0.808296					
17	1959	1874	234483.5	3468640	31.3219	120.2098	0.614433					
18	2236	2109	242793.5	3461590	31.26023	120.2989	0.615925					
19	1438	2109	218853.5	3461590	31.25471	120.0477	0.567914					
20	1870	2110	231813.5	3461560	31.25749	120.1837	0.605473					
21	1636	2121	224793.5	3461230	31.25288	120.1101	0.607183					
22	2764	2329	258633.5	3454990	31.20413	120.4667	0.996183					
23	1102	2432	208773.5	3451900	31.16492	119.9448	0.74407					
24	1335	2437	215763.5	3451750	31.16529	120.0181	0.516537					
25	1333	2438	215703.5	3451720	31.16501	120.0175	0.542945					

Figure 14: The pixel value of the corresponding position on the image

4.4 Model parameter inversion

Model parameter inversion method: select the BNIR/BRED value and the chlorophyll a measured value in the Excel, draw the scatter map, and get the image 15:

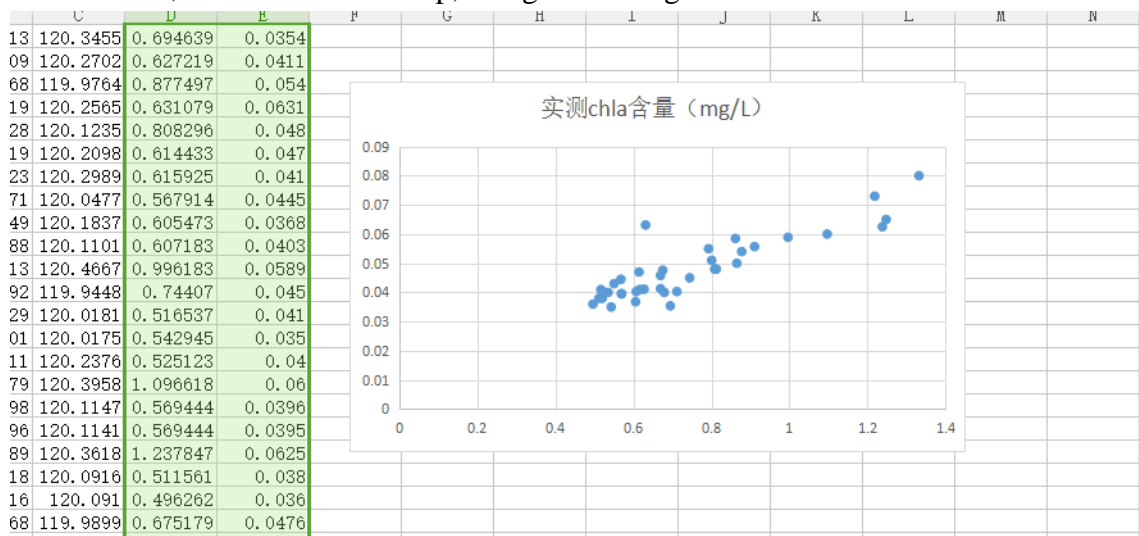


Figure 15: Scatter scatter

4.5 Chlorophyll inversion

(1) According to the scatter diagram obtained above, the parameters of the inversion performance,

a and b, are brought into the inversion model:

$$\text{Chla} = 0.0422 * \text{BNIR/BRED} + 0.0165 \quad (2)$$

(2) Chlorophyll inversion method: Open ENVI, Select Basic Tool - Bandmath, dialog box: $0.0422 * b1 + 0.0165$, Add to list, selects the expression in the list, Click OK, to set b1 as b4/b3 image in the page appearing, OK, gets the chlorophyll inversion diagram.

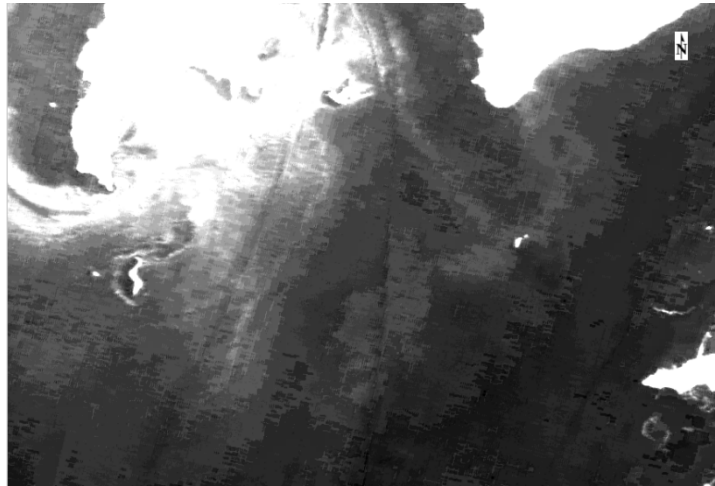


Figure 16: Chlorophyll Reversion Map

5. Post-processing of the results

5.1 Inof result validation

The chlorophyll inversion value corresponding to the verification point is derived, corresponding to the measured value of the verification point in the Excel table.

ID	Lat	Lon	ch1a实测含量 (mg/L)
1	31.45717	120.041978	0.0557
2	31.459692	120.177602	0.05
3	31.42812	120.345765	0.0354
4	31.371076	120.270433	0.0411
5	31.330668	119.976614	0.054
6	31.333178	120.256715	0.0631
7	31.330266	120.1238	0.048
8	31.321892	120.210086	0.047
9	31.254693	120.048001	0.041

Figure 17: The Invert Point

ID	Lan	Lon	chl a实测 (mg/L)
1	31.516334	120.182215	0.05
2	31.421488	120.0431	0.0539
3	31.392147	120.181518	0.0468
4	31.378172	120.041621	0.048
5	31.330676	119.976929	0.0481
6	31.253646	119.934046	0.044
7	31.254686	120.047686	0.0382
8	31.257455	120.183012	0.0406
9	31.251931	119.987315	0.0435

Figure 18: Validation Point

5.2 Drawing and output of the inversion results

(1) Color display method: In Layer Manager, right-select Raster Color Slices, to set the color table in the popup dialog box, and click OK, to display the results in color.

(2) Drawing output method: Start the 32-bit envi, selection menu File → Print, calls ArcGIS's drawing tool. Use QuickMap for ENVI Classic if ArcGIS is not installed.

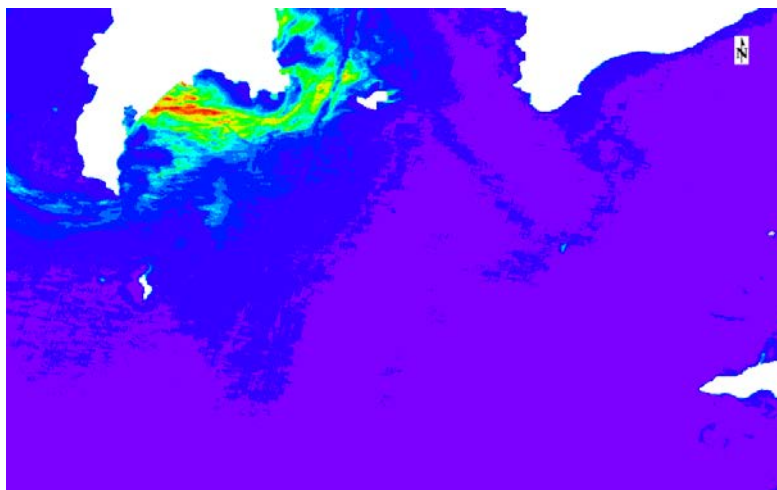


Figure 19: Color Display

6. Conclusion

(1) This paper, on the basis of the summary and analysis of the existing theories, techniques and methods of remote sensing monitoring at home and abroad, takes Taihu Lake as the experimental area and chlorophyll a and suspended objects, systematically studies the methods and techniques of using measured spectral data and satellite images, and constructs the corresponding remote sensing quantitative model. Based on this basis, the eutrophication remote sensing evaluation method of Taihu

Lake was studied and monitored by long phase data.

(2) On the basis of summarizing the remote sensing research results at home and abroad, the remote sensing monitoring indexes of lake water quality are summarized and summarized. The index system includes chlorophyll, suspended objects, yellow substances, water temperature and water depth, where chlorophyll and suspended objects are the main substances affecting the spectral characteristics of water bodies, and they are also the relatively mature water quality parameters in research and application.

(3) Taking Taihu Lake as the experimental area, the analysis of Taihu Lake water spectral measurement spectrum reveals the optical reflection characteristics of Taihu Lake water, which is the premise and basis for remote sensing and quantitative monitoring of the water quality of Taihu Lake. The results showed that 550nm, 660nm and 590 nm and nearby bands showed a better correlation with chlorophyll concentration, while 570nm near 700nm site were highly correlated with suspended matter. Compared with the single band, the band ratio, difference value, and difference combination have significantly improved the correlation with the water quality parameters.

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