USE REMOTE SENSIN DATA TO INVENTORY ECOLOGIC ENVIRONMENT IN HULUN LAKE

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ABSTRACT

In this paper the four ecologic factors are inventoried by using remote sensing data. They are the concentration of algae, water depth, bottom sediment and current character in Hulun lake. In the past, it was difficult to resolve these subjects by ordinary method.Some new theoretical analyses and interpreting methods are introduced in this work, such as using TM 5 band of remote sensing data in summer to interprete the concentration of algae,using TM 6 band data in autumn to determine the water depth etc.. The convection and stratified flow models are set up for interpreting water depth and current character respectively. The results and conclustions obtained from this work have great signification for environmental protection and regional development.

KEY WORDS: Water application, Ecologic environment, Concentration of algae, Water depth, Bottom sediment, Current character.

1. INTRODUCTION

Hulun lake lies in the Hulunbeir League of Inner Mongolia. Geographic coordinates are from N48°30'40" to 49°20'40" and E117°00'10" to 117°41'40". Its geomorphic background is the Hulunbeir prairie, a wide and beautiful grassland, today keeps the notural landscope in the world. Hulun and Beir lakes look like a pair of glossy pearl inliad on the prairie. The shape of Hulun lake offers as an inclined rectagle with length 90 Km in NE direction and width 41 Km in NW direction. When the water level up to 545.33m of elevation, the average of water depth cuold be 5.7 m, the maximum depth could overtake 8m; the area of water surface could be about 2,339(Km)^2; and the capacity could be $1.385\times10^{10}m^3$ There are rich hydrogrophytes in the regions of Hulun lake and in marsh and swamp surrounding it, where are a good stations for waterfowls(see Fig.1.).

In history, Hulun lake have had the powerful actions for the rise and the fall of notions in the north of China, such as Mongol and Jurchen etc.. Today, Hulun lake and its circumference get development and are growing into a bases of agriculture, pasturage, fishery, coal and colored metal mines in Inner Mongolia.In these years, an environmental protected location with 7,000 Km have been confined, and would be continualy expanded from now on. We still plan to develop this region as a tourist area.

Therefore it is important for us to inventory the ecologic environment and resource in this region. In the past, the knowledge about Hulun lake is very simple, though the records on it can be read in the literatures written since 200 B.C, and in the country official files through out ages. Since 20th century Russian and Japanese scientists have taken some investigation for geography of this lake, but those works were superficial.

The systematic and scientific investigation for this lake started on 50th years of current century. In 1958 seven hydrologic substations have been built at Hulun lake and at the three main rivers directly jointing with Hulun lake, by the Hydrologic Station of Hulunbeir League. Then the chinese scientists have friquently investigated for fishery and other animal and plant resources of this lake. Since 1987 a series of investigation of Hulun lake have been taken by the Institute of Environmental Science of Inner Mongolia Autonomous, in order to prevent from contamination,to protect ecologic environment and to develop as well as finely untilze aquatic animal and plant resource of Hulun Lake.This work mianly contains analysing water quality and measuring concentration of algae. The bottom sediments and current character are simultaneously considered. One of methods for these subjects is the analysing and synthesizing remote sensing data by computer system.

Simultaneity, reliability and lower price are seen as the superiority of using remote sensing data to inventory ecologic environment in water bodies, but the accuracy would be not too better, because of less gray levels and of the intermixture caused by mulit-signals in the remote sensing imagery of water bodies.

Formerly, visible and near infrared (TM 1--4) bands of remote sensing data were generally attached much importance in extracting geophysical information in water regions.In addtion the transparence of the mid-infrared (TM 5,7) and therm-infrared (TM 6) light is considered too low than that of visible and near infrared light in water bodies, so they could not reflected the features of water under-surface. However, these conventional views have encountered some difficulties in the subjects about Hulun lake, because the transparence of the visible and near infrared light is diappointed, because of turbid water quality and superabundance of algae. Hence the middel and thermal infrared bands of remote sensing data have to be used into the interpreting many kinds of environmental information in this study. So it is necessary to present new theories and to build models.

This paper is divided into five sections, apart from first section, from second to fourth sections consider with concentration of algae, water depth, bottom sendiment and current character. Finally the conclusion and the discussion are presented.

2. CONCENTRATION OF ALGAE

2.1 Theoretical Analysis

In the past, the visible and near infrared, such as MSS 4--6 or TM 1--4 bands of remote sensing data have frequetly been used to interpret concentration of algae in water bodies (Jahanson R. V. 1987). Based on experiments, the relationship of amount of chlorophyll with value of gray level was considered linear or logarithmic linear (Nykjaer L. et al, 1982 and Shiroh Und, et al 1980.). Several works have shown that,the increase in reflectance in TM 2 (λ= 0.52--0.57μm) and TM 4(λ=0.76--0.81μm) bands as will as the decrease in reflectance in TM 1(λ=0.45--0.52μm) and TM 3(λ=0.63--0.69μm) could be caused by increase in amount of chlorophyll(algae) in water bodies(Davis P.A. et al,1982.).

However, the relationship, as mentioned above, is unreasanable for using remote sensing data to calculate concentration of algae in Hulun lake. Digital analysis showed that,TM 1--3 bands of remote sensing data in Hulun lake are uncorrelative with the concentration of algae (see.Table 1.).

Table 1.Means, Stand deviations, Covariance and Correlation Matrices of Lanndsat 5 Remote Sensing Data of Hulun Lake (received on Jul. 20 1987).

TM 1	TM 2	TM 3	TM 4	TM 5	TM 7	TM 6
84.34	35.88	50.06	10.99	5.57	2.49	121.30
4.14	2.90	4.24	7.91	10.50	4.91	5.10
18.9						
10.53	8.31					
11.76	10.64	18.00				
1.13	5.65	19.89	62.52			
-3.36	1.01	18.37	70.56	100.97		
-1.13	0.65	8.96	30.13	45.38	26.06	
-1.16	1.45	9.09	25.80	34.47	17.35	36.34
1.00						
0.84	1.00					
0.64	0.86	1.00				
0.03	0.24	0.58	1.00			
-0.08	0.01	0.29	0.89	1.00		
-0.05	0.04	0.41	0.76	0.88	1.00	
-0.05	-0.10	0.41	0.64	0.67	0.66	1.00

This table show that, except algae, there exist some other substances suspending in water of Hulun lake. Their influece on spectral reflence of water in visible bands is much stronger than algae. Mainly, remote sensing data in visible (TM 1--3) bands don't reflect distribution of algae concentration, but if suspending substances, such as clay, sand and vrious organic substainces. Therefore, the near and mid infrared (TM 4,5,7) bands of remote sensing data are considered as the primal bands to interpret the concentration of planktonic algae.

From table 1. we can see the variances of TM 4,5 and 7 bands of remote sensing are larger than that of TM 1--3 and 6 bands.In addtion, their correlation is better.

Practical invenstigation have shown phytoplankton, mainly consisted of blue and green algae, have the extradinery phototropism and thermataxis, i.e under suitable weather they would float on water surface as duckweeds as done.

So it could be decieded that, variation in spectral reflectece of water bodies in TM 4, 5 and 7 bands is caused by algae.The data of these bands received at this time may principally reflecte concentration of planktonic algae floating on water surface.so far influence caused by other sebstances can be neglected, because those material particles generally suspanding below surface, while the transparence of near and mid infrared light in water is only oseveral millimetres (see Fig. 2).

Therefore it is possible to use the near and/or mid infrared (TM 4,5 and 7) bands of remote sensing data to interpret distrabution of concentration of algae in Hulun lake.

2.2 Data Processing

The data processing simply is a density spliting for interpreting distrabution of algae in Hulun lake. In other words, it is edcoding the numbers of gray level of TM 5 band into different colors,in order to enhance the personal recognition effect(see Fig.3.a and Fig.3.b). Here the numbers of gray level of TM 5 band of remote sensing data is from 0 to 9. The encoded color imagery have nine colors, correspoding with the nine gray levels.

Apart from physical signifecation metioned earlier for us subject the reason of selecting TM 5 band to encode and to interpret concentration of algae is that, the data of this band have the maximum variance, so it is passible to sort them into more classes of concentration of algae. If selecting one of the other two (TM 4 or 7) bands to be encoded the analogical results would be obtained, but the recognizable classes were less.

In order to explicate the correctness of this method for interpreting concentration of algae in Hulun lake, a statistical analysis of TM 1--7 bands in traning areas is made for every concentration classes arranging by gray levels of TM 5 band. The result shows the variation regulority in averages of gray levels of TM 4 and TM 7 bands accord with TM 5 band in each traning areas. But this rules are improbable to TM 1-3 and 6(see Table 2.).

Table 2. Variation of TM1--7 bands data in each traning areas of algae concentration classes.

TM 1	TM 2	TM 3	TM 4	TM 5	TM 7	TM6
85.18	35.08	28.23	7.52	0.96	0.02	121.34
85.72	34.08	27.03	7.85	1.96	0.64	121.34
85.79	35.99	29.73	8.55	3.06	1.04	117.92
85.85	35.86	30.12	9.19	3.92	1.42	120.13
85.01	35.52	29.30	9.93	5.01	2.04	117.16
85.75	36.25	30.51	10.15	6.01	2.99	119.98
84.12	35.26	28.57	10.67	7.10	3.52	119.17
84.14	38.78	29.05	11.00	8.14	4.12	120.07
85.15	37.00	31.91	12.64	9.00	4.45	119.00

2.3 Calibration

In relative quantity, it is completely passable to express the concentration classes of algae with TM 5 band of remote sensing data in water bodies, but in absolutel quality, only using remote sensing data one cann't calculate the value of concentration of algae in water bodies. It is necessary for us to calibrate each of concentration classes by practical measurmebts. So that in Jul. 1987 we have taken 20 samples of water with planktonic algae in Hulun lake, and have examined them in laboratary. Table 3 shows the measured data for sample points accoding with each class of concentration.

Table 3. Measurmations of planktonic algae concentration at each of sample points.

P.	co.	P.	co.	P.	co.	P.	co.
1	3.56	6	35.44	11	5.69	16	9.30
2	7.76	7	32.52	12	7.04	17	8.90
3	5.54	8	10.79	13	13.15	18	13.02
4	6.71	9	32.33	14	5.31	19	19.56
5	50.20	10	36.39	15	12.65	20	16.83

correspodent points listed in Table 3., as P1, P2,.. ....P20 have be pointed in Fig 3. b).

From table 2 and table 3 we can see the relationship of grey level of TM 5 band with concentrations of algae in Hulun lake: the concentration of algae is from 3.50mg/l to 50.20mg/l, the grey levels is from 1 to 9. So the conclusion obtianed is that, the numebor of gray level of TM 5 band of remote sensing is approximated to 3.5mg/l of concentration of algae.

This result is very suitable for us to study ecologic environment of water bodies in macroscopic fields, though its precision and ground resolution are lower.

3. WATER DEPTH AND BOTTOM SENDIMENTS

3.1 Background

Water depth and bottom sediments are two important environment factors in the limnology and have significant neamings to inventory the degree of eutrophication and environment reduce situation, rationally develop and to utilize aquatic resources from now on.

Before this century all literatures about Hulun lake have not metioned water depth and bottom sediments. In the middle decaces of this century Russian scientist Mochiakof have had imprecisely indicated the avarage of water depth of Hulun lake was 2--3m, maximally to 8--9m. After biulding of hydrometetric substations the depth of water could be deduced by using the observations, as metioned in the past section. In 1967, some imperfect measurements were done by the state surveying and mapping office using ropes. The results have been reflected at the topographic maps printed in 1967. But those measurements were unrefined, specially, at the center-south patrs of Hulun lake. As regards investigation on bottom sediments of Hulun lake, it is constantly not attached much importance .

In our state, the significance of bottom sediments to limnology has not sufficiently be cognized until eighty of this certury. Since 1987, many times of measurement of water depth and bottom sediments have been wanted to do, in order to improve the contents of eutrophicate inventory, but it is a difficult task to be finished in sort poriod. So the depth measuremention and bottom sendiments sampling were only taken at several points, where the water samples with algae have been done. The macroscopic investigating of water depth and bottom sediments have to be helped by the remote sensing technology.

3.2 Theorcal Analysis

Formely, Visble and near infrared bands, such as MSS 4--6 or TM 1--4, have been used to investigate water depth and bottom sediments (Abdel Hady M.A. et al 1982.). The essential idea is regarded light in these bands have certain ability to be transmited by water, and could reflect some underwater features. (Lyzenga D.R., 1987 and 1981. and Gorden H.R. et al, 1978). However, this idea is invalid in subjects of Hulun lake, because of the distance of transmitting light in this lake is no more than 0.5m in normal condition. Therefore we should present a new method to interprete the water depth and bottem sediments of Hulun lake.

Principle of this method is regard as that, the surface temperature of Hulun lake is quasi-direct propartional to water depth in convection period. Thus TM 6 band of remote sensing data could reflect water depth, but only the correspondent relationship of gray levels with water depth must be scaled by field measurement. If that was done, then the bottom sediments and their buondary line would easely be defined based on relationship of the buandary line with water depth, built in observation.

The vertical convection between the upper and the lower loyers of lake water can occurs in two period one of them is the spring, when the ice is thawing and water temperature is raising, another is the autumn, when water temperature is descending and ice is forming. Usual TM 6 band of remote sensing data in the second peroid is selected to interprete depth of water bodies, because this peroid is longer than the first peroid. one can found the relation contents in any physical textbook for explanation of this phenomenon (Xia-Hai Yan et al, 1990.).
The Water depth interpreted by using TM 6 band of remote sensing date may satisfy to macroscopic ecology, though its spatial resolution is lower.

3.3 Imagery Features

Based on the principle mentioned before, as the primitive data, the TM 6 band of remote sensing data received on oct. 21, 1988 are selected to interpret water depth of Hulun lake. Its gray level are from 84 to 96. the carresponding temperature is from 279.7K to 282.5K. The meteorological data on this day showed that, atmospheric temprature at the south end and the north end of Hulun lake is 3.2c and 1.1c respectively, at that time, when the remote sensing satellite is passing through. Therefore this imagery is completely suitable to interpret water depth of Hulun lake. Each of the thrteen gray levels of TM 6 band would accord with a centain water depth. The higher gray level is the depper the water depth.

3.4 Image Processing and Calibration

In the past section analysis have shown that, distribution of water depth can be determined by using TM 6 band of remote sensing data in the period of convection between upper and lower strata. Thus these data could be decoded false color imagery, each color at which represent one of centain depth stage, while the border line between two color regions would be the isobathyc line. Corrspodent depth cuold be calibrited by field measurements.

Table 3. listed gray levels of TM 6 band data data, encoded colors and corrspodent depth inside Hulun lake. Here the remote sensing data had been recieved on oct. 21, 1988.

Table 3. relationship of water depth, encoded color and gray levle of TM 6 band data

gray level	82	84	86	88	90	92	94	96
coler encoded	red			green			blue	
depth	0.0m		2.0m			5.0m		7.5m

This table show that the gray levels changes from 84 to 96, while the water depth changes from 0 to 7.5m. Thus fonctional relationship between water Depth (D) and Gray level (G) of Hulun lake could be writed into the expermental formula: $D=0.5\times(G-84)$. The depth levels of water in Hulu lake definited by this expression is accordance with the data drawn in the topographic maps published in 1967 by state surveying and mapping office, fondamentally.

Finaly we obtain the sytheicaly interpreted map of water depth distribution in Hulun lake (see Fig. 4).

4. CURRENT CHARACTER

4.1 Difficulty of convetional methods

In this section the problems to resolve are looking for the suppling sources of ground water(spring), expect the known three rivers, and to judge the current character in Hulun lake. these subjects were neglected for long time . In these years , by remote sensing data interpreting current character and suppling sources in lake and in osean generally using Sythetic Aperrture adar (SAR)(Lyzenga D. Y.,

1982) or Thermal Infrared(TI)(Lechi G.M.et al,1974. Kernan Lee, 1969. and Tonelli A.M., 1978.) imagery. Primary conditions of this work is that, there are obvious speed of current (as 1m/sec.) and larger water injection in operating water region. But these conditions were not satisfied in Hulun lake. Observations showed that, in the ordninary annual input of Hulun lake is $22 \times 10^8 m^3$, which is only 1/5 storage capacity of this lake, or only equilibrates with evaporation. Thus the current is unmeasurable on SAR and TI remote sensing imagery.

Therefore, it is concerded that, the visible and near infrared (TM 1--4) bands of remore sensing data have to be used to interpret current character and ground water suppling in Hulun lake.

4.2 Stratified Flow Model

In order to interpret current character and ground water suppling of Hulun lake, the stratified flow model presented in this senction.

The stratified model cuold be understanded that, the water injected into lake from rivers and from springs flows along individual strata,temperature of which would be equal to that of injected water. For examples, in summer temperature of water injected from rivers is higher than that of lake water,so the river water would flows along the lake surface, while temprature of water injected from spring could lower than that of lake water, so the spring water would flows along bottem; as opposed to it,in autumn the process would be contrary to that in summer. Thus remote sensing data received in summer or in autumn could only reflect current character of lake water injected from rivers or springs respectively.

So we could obtain the conclusion: the current characters of Hulun lake are different in various seasons, for example,in summer the river water would flow from stream outlets to spring points along water surface, as well as the spring water would flow from spring points to stream outlets along lake bottom. Therefore the convective circulation would forms in vertical section (Lai D.Y., 1977.) (see Fig. 5.a). On other hand, in autumn the circulation cell of lake water would be cotrary to that in summer(see Fig.5.b).

4.3 Image Processing and Interpreting

For interpreting current character in Hulun lake, the image processing method is simply to compose a pseud color imagery with three bands of remote sensing date selected from TM 1-4 bands. If TM 1, TM 2, and TM 4 bands composed a color imagery with blue green and red, then every colors zones on the composed imagery would represent one kind of the current orginated from one of water source.

These results processed by mentioned method have been showed in Fig. 6.a and Fig. 7.a. From the two Figures we can see the current characters of lake water in summer and in autumn respectevely.In summer imagery the dack zones are the actinve regions of rivers water; In autunm imagery the dack zones are the active regions of spring water. The carrespoding interpreted show as Fig 6.b and Fig 7.b respectively. Here the arrows indicate the flowing directions of surface current of lake water. the sources of arrows are the stream outlets, e.i. the river sources or spring pionts. Thus we could find That The noknown spring points would have more than 30. These springs mianly distribute in coastal zones surrounding Hulun lake, specially, in the north-western coast. The carrectness of these results heve been examined by goelogic interpretation and field investigation.

5. CONCLUSION

We have discussed some problems about using remote sensing date to inventary ecologic environmemt in Hulun lake. These subjects are the important factors for regional developing and environmental protection.

In the past, these subjects were difficult to solve by ordinary methods, now it is very simple, because of using remote sensing data interpretation. The results could satisfy requirement of macroscopic water region research, though theim precision and ground resolution were lower.

From interpreted results we can see following features of ecologic environment of Hulun lake:

(1). The concentration of algae in Hulun lake have overtaken 8mg/l, which is extremelly higher than allowable, and seriously endangers natural ecologic environment. It is a problem to have to resolve.

(2). The distribution of algae in Hulun lake displays with centain regulurity: Usual the probability is that, in the south part of this lake, static water regions and shallow zones the concentration of algae usual is higher than that in north part, mobile water and aphytal zones respectively. But the relationship of algae concentration with the water temperature is none obvious.

(3). The depth distribution of water in Hulun lake have some features: The topographic form in Hulun lake is gentle fuondamentally; the average of depth is 5.67m in 1988, when the water level up to 544.9m. But in the western coastal region the water depth is deeper than that in the east coastal region. A south-westerly trending rise crest has been found in the south-western of this lake, that is unknowmn in the past.

(4). The supplement of ground water (the spring) in Hulun lake possessed of a great scale, it is the important factor to stabilize water surface. All positions of springs interpreted coincide with water bearing strctures surrounding this lake.

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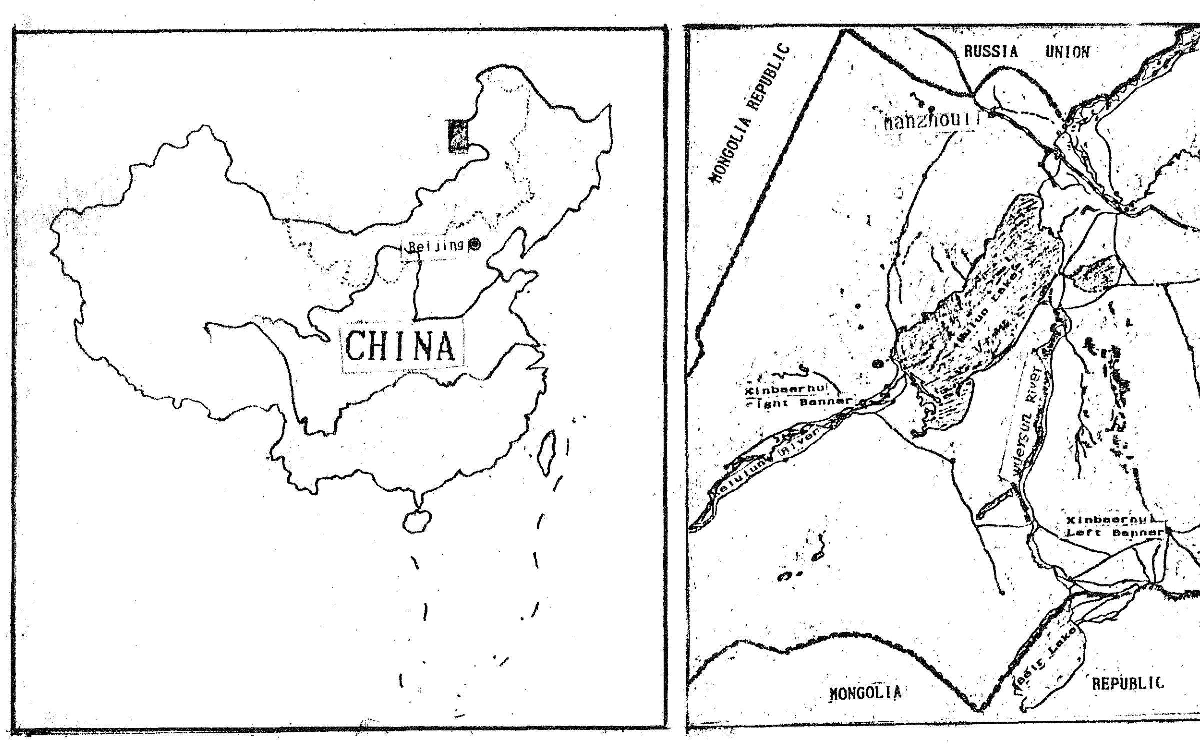


Figure 1. Location of Hulun lake in chinese dominion.

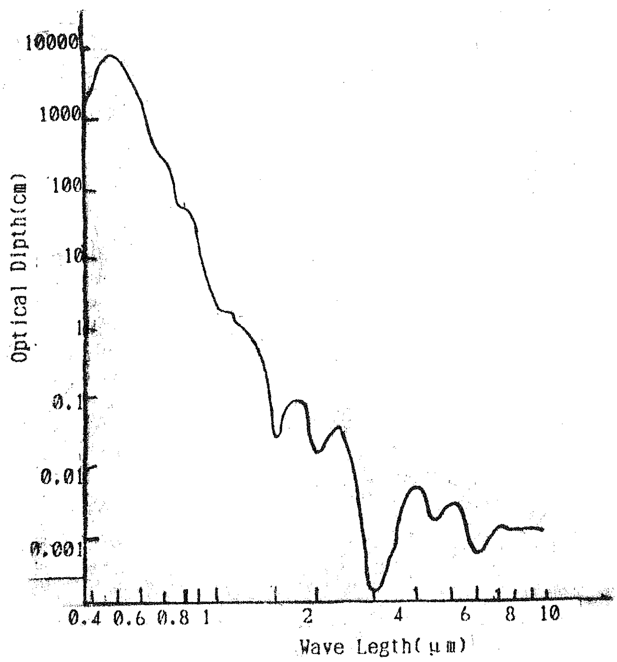


Figure 2. Spectral transparence of clear water.

Figure 3. Distribution map of algae concentration in Hulun lake— false color edcoded imagery of TM 5 band of remote sensing data (Jul., 20, 1987.).

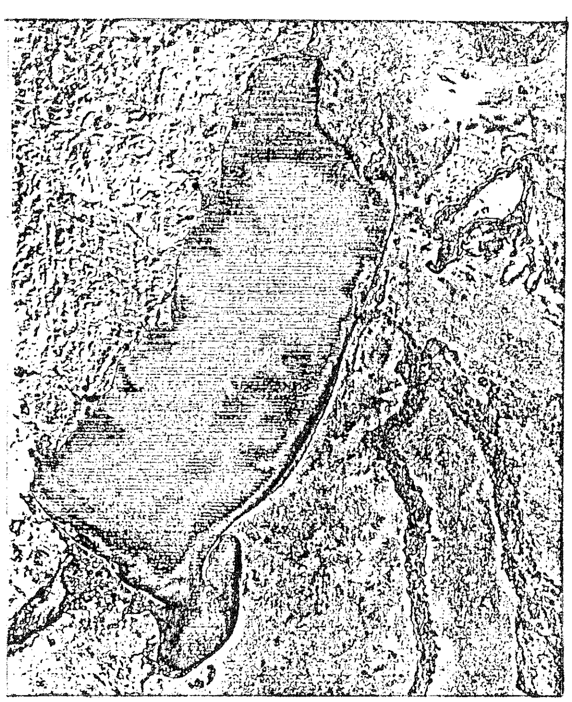
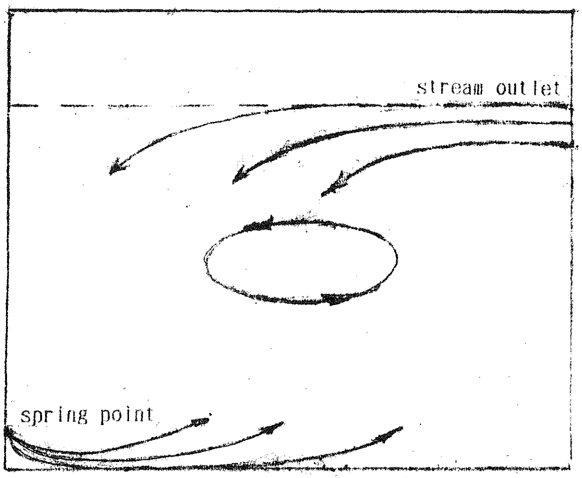
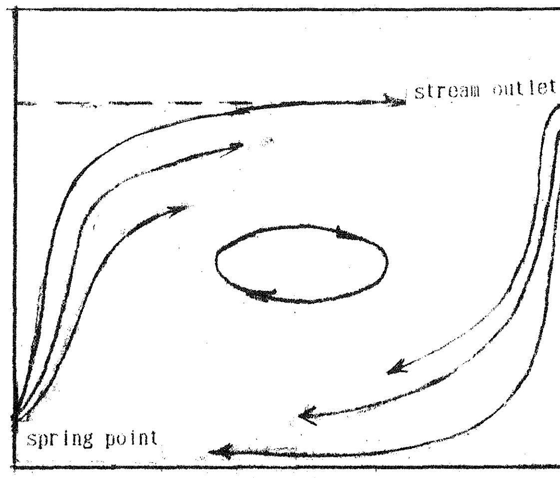


Figure 4. a. Interpreted from TM6 Band of remote Sensing data (oct., 21, 1988).

Figure 4. b. Bathymetric chart of Hulun lake.



(a). In the semmer.



(b). In the autumn.

Figure 5. Convective circulation formed in vertical section of lake water.

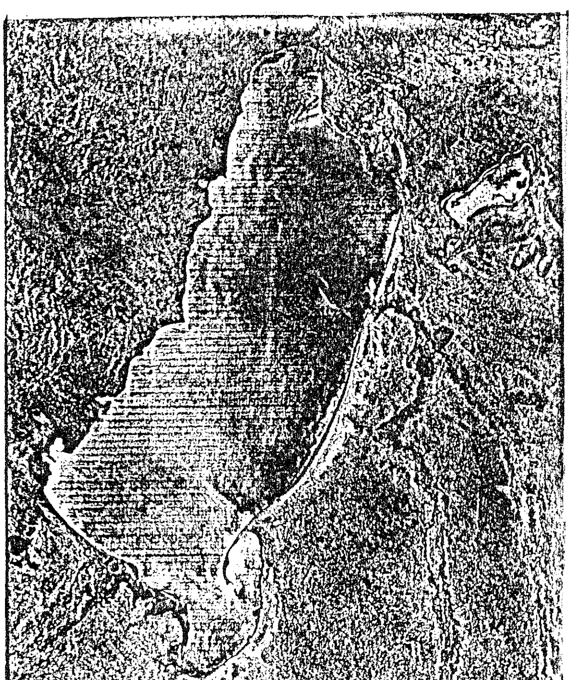


Figure 6. a. Additive color combined image with TM 1, 2, and 4 bands(Jul., 20, 1987).

Figure 6. b. Current character of Hulun lake in summer.

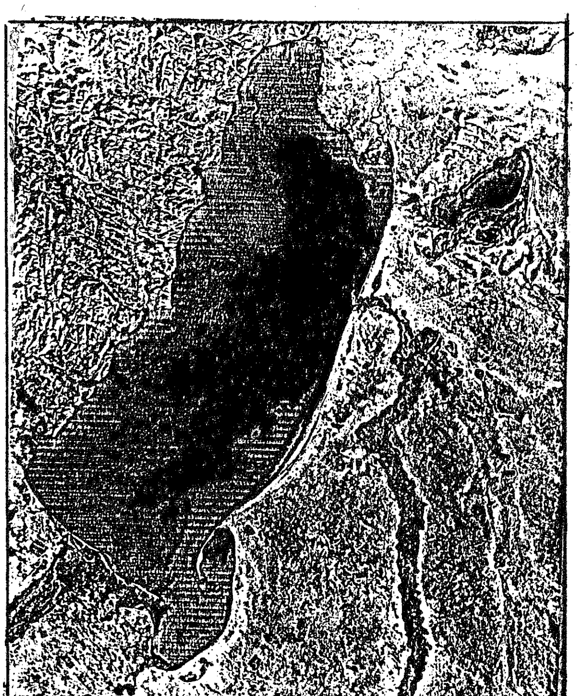


Figure 7. a. Additive color combined image with TM 1, 2, and 4 bands(oct., 20, 1988)

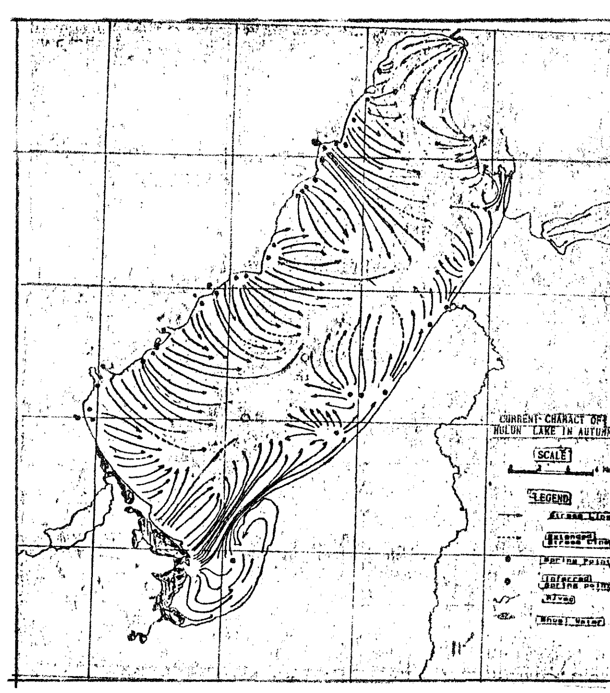


Figure 7. b. Current character of Hulun lake in autumn.