Understanding the Effects of Thermal Power Plants on Regional Water Quality Based on Satellite-derived Data in Yunnan

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I Background

With the rapid growth of economy, the demand of electricity consumption for daily production and people's daily life is exponentially increasing. Thermal power generation is still the main mode in China. In 2017, The total power generation reaches 6.5 trillion kwh. Among them, thermal power plants account for more than 71% of power generation. In addition to air, water is usually chosen as the cooling medium.

In 2015, the Standing Committee of the Political Bureau of the Central Committee deliberates and approves the Action Plan for the Prevention and Control of Water Pollution (Water 10), aiming to strengthen efforts to prevent and control water pollution and ensure national water security. The plan calls for more than 70 percent of seven river basins, including the Yangtze River and Zhuhai, to have water that reaches or exceeds quality category III by 2020.

Yunnan province is located at the confluence of the Yangtze River basin and the Pearl River Basin. Although the basin area of nine plateau lakes represented by Yangzonghai and Dianchi lakes only accounts for 2.1% in the area of Yunnan Province, they play an important role in the economic and social development of Yunnan province and account for more than one-third of the provincial GDP annually.

In recent years, as the industry and tourism develop, Yangzonghai and Dianchi witness a rapid degradation in water quality. Yunnan provincial government and Provincial Environmental Protection Bureau attach great attention to the comprehensive control of water pollution in Yangzonghai and Dianchi and treat it as a major implement of sustainable development. However, due to the influence of environmental factors, water exchange periods of two lakes are long and the ecosystems are fragile. The high-density population brought by the developed economy aggravates the load of pollution in lakes. The multifarious types of pollutants interact with each other, which increases the difficulty of implementing water quality management and leads to long-term accumulation of pollutants. Due to the intense urbanization, the buffer zone is underdeveloped, which leads to fragile plant communities and the decline of self-purification capacity of lakes. Therefore, discharge control is critical in improving the water quality of Yangzonghai and Dianchi and passing the window period of ecological restoration.

To identify illegal discharges from enterprises and individuals, monitor the discharge of major pollution source and provide theoretical and data support for further development of pollution control policies, a detailed evaluation of the temporal and spatial changes in water temperature, chlorophyll concentration and water transparency is required. However, due to the cost and difficulty of implementing field trips, the data obtained have limited coverage in time and space, which will lead to a failure in carrying out long-term spatial and temporal analysis of Yangzonghai and Dianchi.

With the development of remote sensing technology, methods of using empirical formula to evaluate water quality has been optimized and popularized by researchers. Compared to the traditional sampling methods, environmental remote sensing technology has higher spatial and temporal resolution. To investigate the relationship among water temperature, transparency, and chlorophyll concentration, and their temporal ad spatial variations, we develop three models to respectively represent historical situations. Taking advantage of the satellite-based models, we analyze the long-term trend and whole scale variations.

Hypotheses are proposed that discharged warm water could deteriorate aquatic ecosystem by providing a warm and nutrient-rich environment for plankton and plants. Previous studies have pointed out that the discharged warm water from thermal power plants may cause multiple kinds of damage to water quality, including increasing the water temperature (thermal pollution), increasing the concentration of suspended particulate matter, and changing chemical composition of water body.

However, the remote sensing technology mainly works for revealing correlations, rather than casual relationships, the intermediate processes are not discussed in this report. Analyses are merely based on satellite-derived observations. We ignore the principles of the intermediate reactions among pollutants and aquatic organisms. For instance, the way that discharged warm water impacts the vigor of plankton and plant

II Method

1. Study Area

1) Yangzonghai

Yangzonghai, located in the southeast of Kunming, covers an area of 31.9 square kilometers, with an average water depth of 20 meters. It stores 604 million cubic meters of water, which is about half of the water volume of Dianchi Lake. According to the 2015 Environmental status Bulletin of Yunnan Province, the water quality of Yangzonghai in 2015 is classified as Class IV. Arsenic concentration is classified as Class IV, which is 0.05 times above the standard. Phosphorus and chemical oxygen are 0.36 times and 0.17 times above the standard respectively. The average nutritional status index of the whole lake is 41.2, which is classified as mesoeutrophic.

2) Dianchi

Dianchi is the largest lake in southwest China, belonging to the Yangtze River Basin. It is in the south-central part of Kunming Basin. The lake covers an area of 300 square kilometers and the shoreline is about 150 kilometers long. In the north of the lake, there is an embankment stretching from east to west, which is 3.5 kilometers long and 300 meters wide. It divides Dianchi into two parts. South of the embankment, known as the outer sea, is the main part of the Dianchi, covering an area of 289.065 square kilometers, accounting for 97.2% of the total area. North of the embankment is called inner sea, which is also known as grass sea, occupying an area of about 10 square kilometers. The average depth of Dianchi is about 5 meters.

2. Data acquirement and pre-processing

In order to obtain sufficient data for time series analysis, we expand the time period to 2006 to 2018. For the data pre-processing, we firstly conduct radiometric calibration for Landsat5TM and Landsat8OLI images, and the calibration type is radiometric brightness. Secondly, we calibrate the images based on sensor types, the parameters acquired by each image (season, aerosol model, atmospheric model, visibility, etc.), the altitude and regional type of the study area. Thirdly we use the object-oriented image segmentation technology to extract the vector boundary of Yangzonghai and Dianchi Lake. Then, we utilize the vector boundary as a mask to extract areas of Yangzonghai and Dianchi Lake. Finally, for areas covered by clouds, we remove the noise based on spectrum signature.

3. Modeling

1) Water surface temperature model

The inversion of water surface temperature is based on atmospheric correction method. The expression for the infrared thermal luminance value $\boldsymbol{L_\lambda}$ received by the satellite sensor:

$$L\lambda=[\varepsilon B(Ts)+(1-\varepsilon)Ld]\tau+Lu \quad (1)$$

Where, ε is the surface emissivity, Ts is the true temperature (K), $B(Ts)$为 is the luminance of the blackbody at temperature T, τ is the atmospheric transmittance in thermal infrared band, Lu is upward atmospheric luminance, and Ld is downward atmospheric luminance. The luminance of the blackbody at temperature T $B(Ts)$ is expressed as following:

$$B(Ts)=[L_\lambda-L_u-\tau(1-\varepsilon)L_d]/\tau\varepsilon \quad (2)$$

Ts is calculated by Planck formula:

$$Ts=K_2/\ln(K_1/B(Ts)+1) \quad (3)$$

2) Water transparency model

The change of water transparency (SD) is mainly affected by the optical components (algae, non-algal particles, yellow substances). Transparency is also an important index to evaluate eutrophication, which directly reflects the clarity and turbidity degree of the lake. The reflectance of red and near-infrared bands is easily affected by suspended matters. Suspended matters have a strong negative correlation with transparency. However, it is rarely used due to the strong absorption of near-infrared bands in water. Based on the reflectance characteristics of each band, we select the ratio of red and green bands to construct a water transparency model:

$$\mathrm{Ln(SD)} = a * (B_{Green}/B_{Red}) - b \quad (4)$$

3) Chlorophyll concentration model

Based on the empirical models for the same water area, the ratio of near-infrared band to visible red band is used as a sub-factor, which can effectively minimize the influence of the atmospheric effect. The model established is the relationship between the natural logarithm of chlorophyll A (chla) and B_{NIR}/B_{red}:

$$Ln(chla) = a - b/(B_{NIR}/B_{red}) \quad (5)$$

4) Evaluating model

According to the requirements from China's environmental monitoring station 'surface water environmental quality assessment method', the evaluation of surface water quality is referenced by standard GB3838-2002. Lakes and reservoirs nutritional status evaluation indexes include the chlorophyll a (chla), total phosphorus (TP), total nitrogen (TN), transparency (SD) and potassium permanganate index (CODMn). The nutrition level rangers from 1 to 5 which is from poor to severe eutrophication.

$$TLI(chla) = 25 + 10.86 \ln chla \quad (6)$$

$$TLI(TP) = 94.36 + 16.24 \ln TP \quad (7)$$

$$TLI(TN) = 54.53 + 16.94 \ln TN \quad (8)$$

$$TLI(SD) = 51.18 - 19.4 \ln SD \quad (9)$$

$$TLI(CODMn) = 1.09 + 26.61 \ln CODMn \quad (10)$$

Where the unit of chla is mg/m^3, and the unit of SD is m. Units of other indicators are mg/L. In this study, instead of chlorophyll concentration and water transparency, TLI(chla) and TLI(SD) are used as water quality evaluation indexes.

III Result

1. Yangzonghai

1）Water temperature

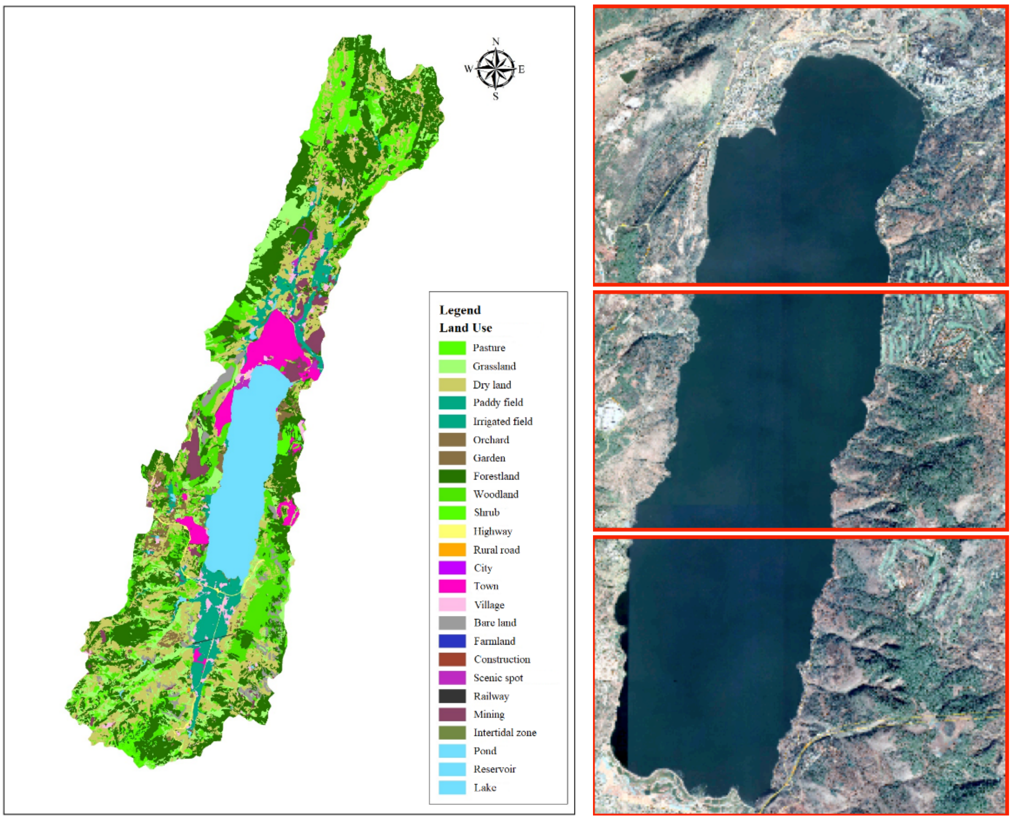

Figure 1. Yangzonghai land uses (left) and research area division (right)

The land uses along the Yangzonghai coast are diverse (Figure 1), mainly including towns, woodland, and paddy fields. The south bank is majorly occupied by agricultural land. The land uses in the west bank include towns, cities, woodland orchards, and mining. According to the Manual of Discharge Coefficient of Livestock and Poultry Industry, the pollution along the southwest shoreline of Yangzonghai mainly comes from livestock breeding. The northern part is a cluster of towns and industries. Based on the statistics from the second national pollution census, industrial pollution in the Yangzonghai Basin mainly comes from the northern part, accounting for 63.1% of the total discharges in 2018. Nine companies, including the Yangzonghai Power Plant, discharge 362,100 tons of wastewater. According to the above information, we divide the waters of Yangzonghai into southern, central, and northern regions to distinguish the effects of various land uses.

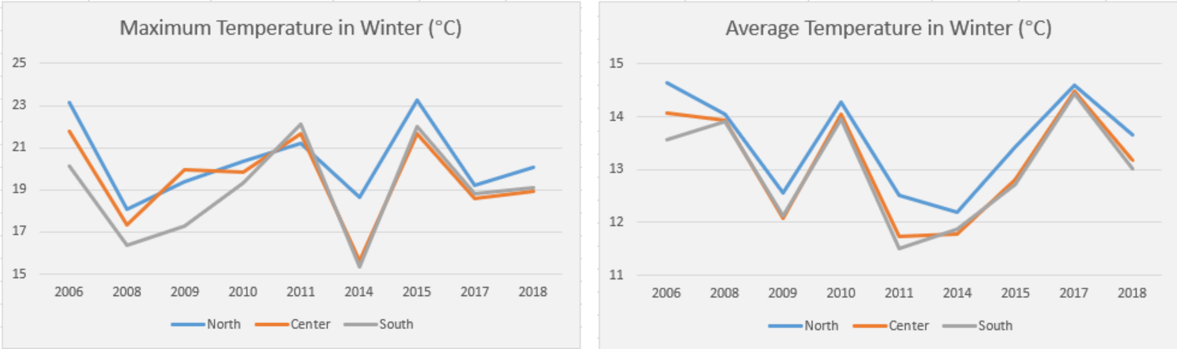

Figure 2. Yangzonghai maximum (left) and average (right) water temperature in winter

Due to the limitations of Landsat temporal resolution and climatic conditions, as well as the consideration of amplifying the impact of agricultural water, residential water and discharged warm water, data from winter (December, January, and February) data are mainly selected for analysis. In terms of spatial distribution, the highest water temperature is found in the river channels and coastal areas dominated by urban. We assume that the highest temperature represents the temperature of pollutants (including water itself), and the location where they appear is the source of pollution. Variations in average temperatures in different regions indicate that there is a significant feature in the spatial distribution of the temperature in Yangzonghai. From 2006 to 2018, the highest water temperature in the northern Yangzonghai is always higher than that in the central and southern part, as well as the average water temperature. The average temperature in the north, central and south of the 12 years is 13.6□, 13.1□ and 13.0□, respectively. Therefore, out preliminary analysis suggests that the main source of the overall temperature rise of Yangzonghai is industrial cluster represented by the Yangzonghai Power Plant in the northern part.

In order to investigate the influence on the water temperature from outside, we visualize the water temperature by taking the temperature of unaffected water as the reference temperature. There are two main methods to calculate the reference temperature. The first is the average temperature obtained from the core area that is not affected by the outside. The second is to take the average water temperature of the whole research area as a reference, and then calculate the average temperature after excluding the areas that have higher temperature than the average. Regions above the base temperature is known as the warming zones. We determine the reference temperature by referring the second method.

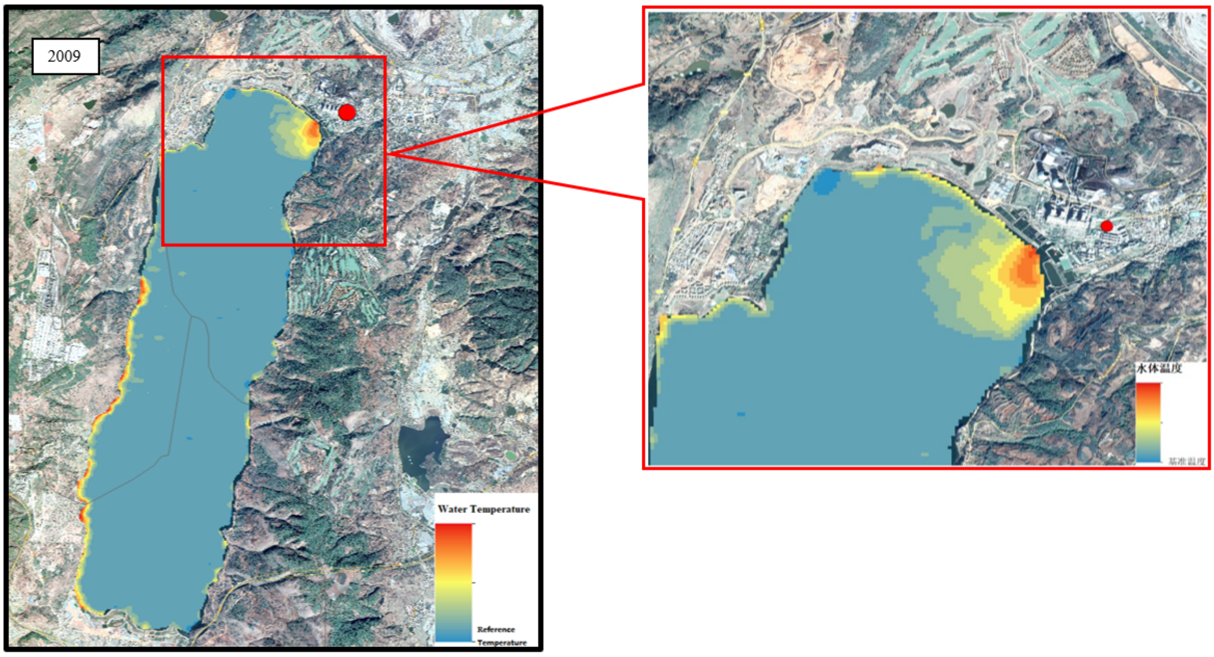

Figure 3. Distribution of Yangzonghai warming zones in 2009 (left) and distribution of Yangzonghai North Coast warming zones (right)

After calculating the reference temperature and visualizing warming zones, the results (Figure 3) are consistent with the hypothesis. The southwest coast is affected by the pollution from large-scale livestock breeding. The water temperature is much higher than the reference temperature. However, due to the average depth of Yangzonghai, the discharged water cannot threaten the core area, and the warming area is zonally distributed along the southwest coast. Different from the southwest coast, the discharged warm water from the north coast enters the Yangzonghai through channels near the Yangzonghai power plant, and the warming zone extends forward the core area in a radiative pattern.

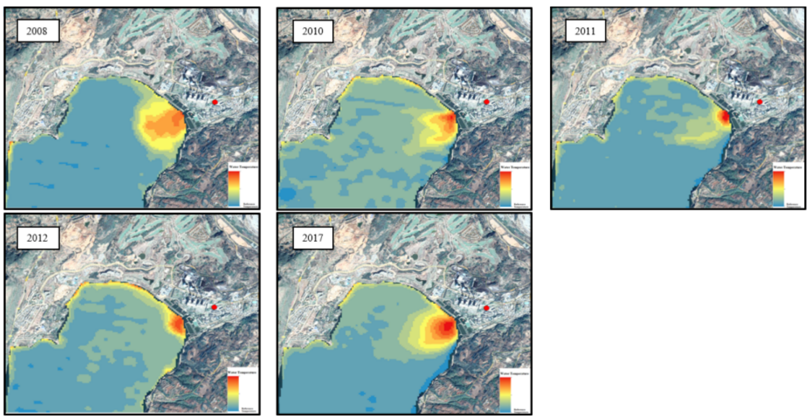

Figure 4. Distribution of warming zones

Since the water temperature in winter is the lowest all year round, and the temperature difference between discharged warm water and the natural water body is the largest, the distribution of warming zones can be more clearly observed. Although other land uses in the northern part, such as parks, agriculture, and tourism, also impact water temperature, data and images over the years show that discharged warm water from channels near the Yangzonghai Power Plant contributes significantly on water temperature in the northern Yangzonghai.

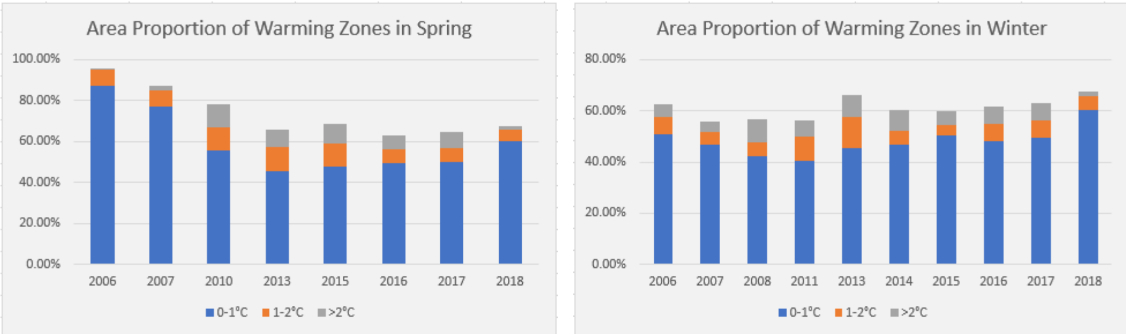

Figure 5. Area proportion of Yangzonghai warming zones in spring (left) and winter (right)

km²	Spring			Winter		
Year	>0°C	>1°C	>2°C	>0°C	>1°C	>2°C
2006	29.98	2.58	0.11	19.78	3.76	1.57
2007	27.58	3.32	0.73	17.61	2.84	1.28
2013	20.79	6.47	2.68	20.76	6.48	2.65
2015	21.60	6.63	3.01	18.85	2.92	1.66
2016	19.91	4.27	2.15	19.39	4.25	2.16
2017	20.45	4.73	2.53	19.91	4.27	2.15
2018	21.31	2.63	0.67	21.34	2.36	0.67

Figure 6. Area of Yangzonghai warming zones in spring and winter

Figure 5 shows the proportion of Yangzonghai warming zones in spring and winter, as well as the trend. Each bar represents the percentage of the area above the reference temperature. The orange and gray parts in the column respectively represents the proportion of the areas that are 1□ and 2□ higher than the reference temperature. From figure 6, we find that during 2006-2007, the area of spring warming zone is significantly larger than that of winter, with a difference of nearly 10km^2.

2）TLI（chla） and TLI（SD）

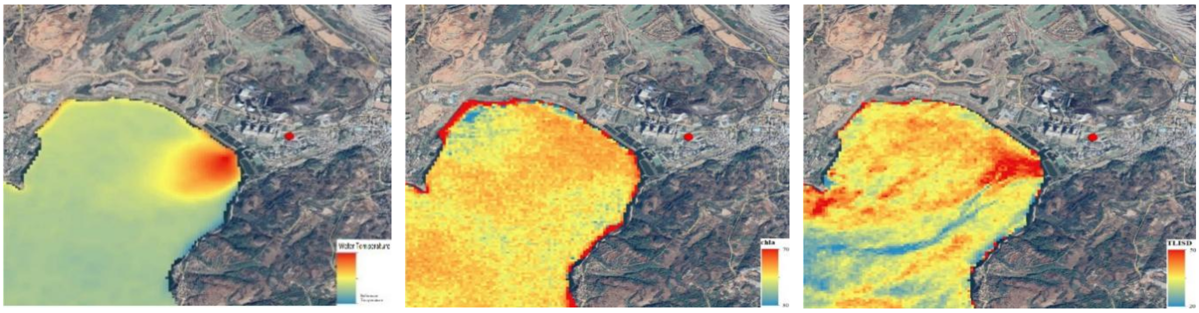

Figure 7. Spatial distribution of water surface temperature (left), TLI(chla) (middle) and TLI(SD) (right) in northern Yangzonghai in 2017

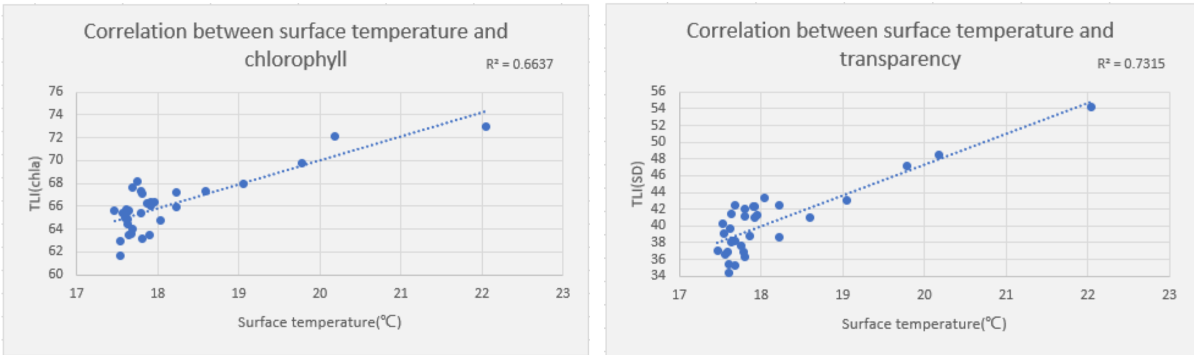

Figure 8. Correlations of water surface temperature with TLI(chla) (left) and TLI(SD) (right)

Figure 7 shows the spatial distribution of water temperature, TLI(chla), and TLI(SD) in 2017 winter. In general, the concentration along the shoreline is higher than in the central, and the concentration in the north is higher than in the south. The average TLI (chla) value is maintained above 60. Besides, the high values are clustered near the industrial area in the north. There is a downward trend from 2015 to 2017 in TLI(chla). In 2017, TLI(chla) in southern and central Yangzonghai decreased to 30-40, indicating a state of medium nutrition. In terms of TLI(SD), the distribution pattern of high values is similar with that of TLI(chla). One conjecture is that discharged warm water with a certain velocity promoted the upper and lower circulation of the lake when it enters the Yangzonghai, causing upward movement of suspended or deposited particles, which brings nutrients for plankton, reducing the transparency of the water. According to the statistics shown in figure 8, we found that the correlation coefficient between water surface temperature and chlorophyll concentration TLI(chla) was up to 0.66, and the correlation coefficient with water transparency was up to 0.73.

2. Dianchi

1） Water temperature

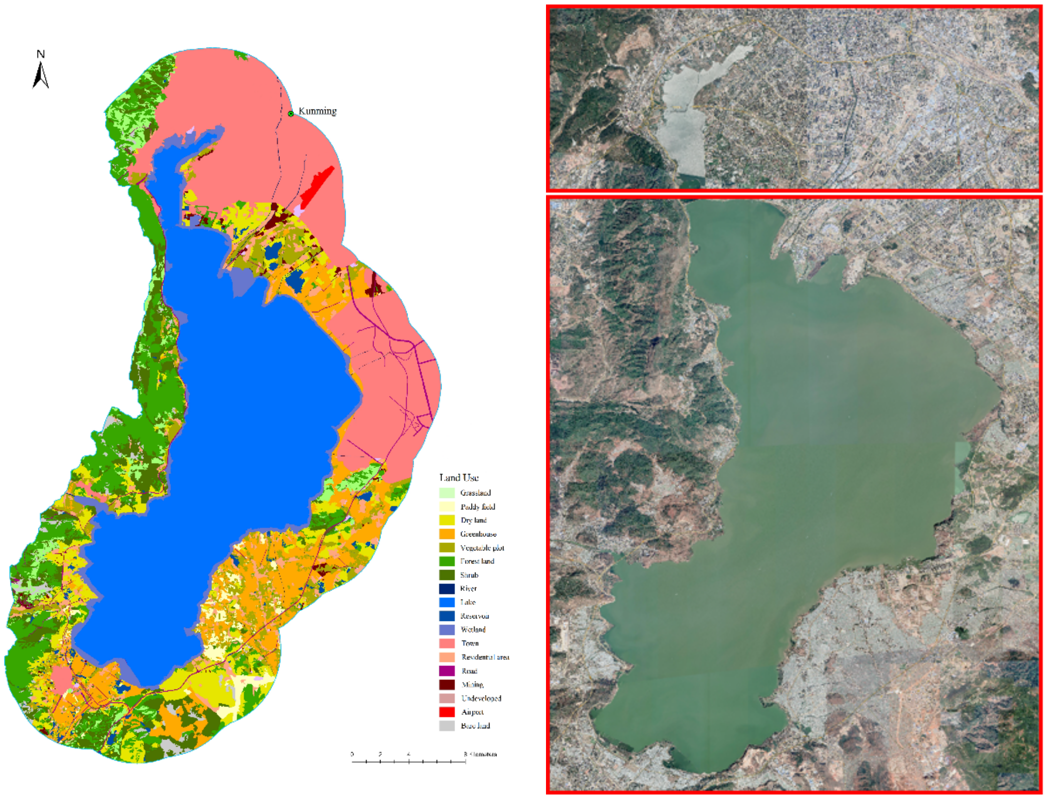

Figure 9. Dianchi land uses (left) and research area division (right)

In 2010, the land uses along the Dianchi are dominated by towns, greenhouses, woodland, and grassland. Due to the geographical environment, the urban development begins to shift to the south and west shoreline of Dianchi. In order to explore the influence of Kunming Thermal Power Plant to water quality, we divided the water body into inner sea, where Kunming Thermal Power Plant is located, and outer sea.

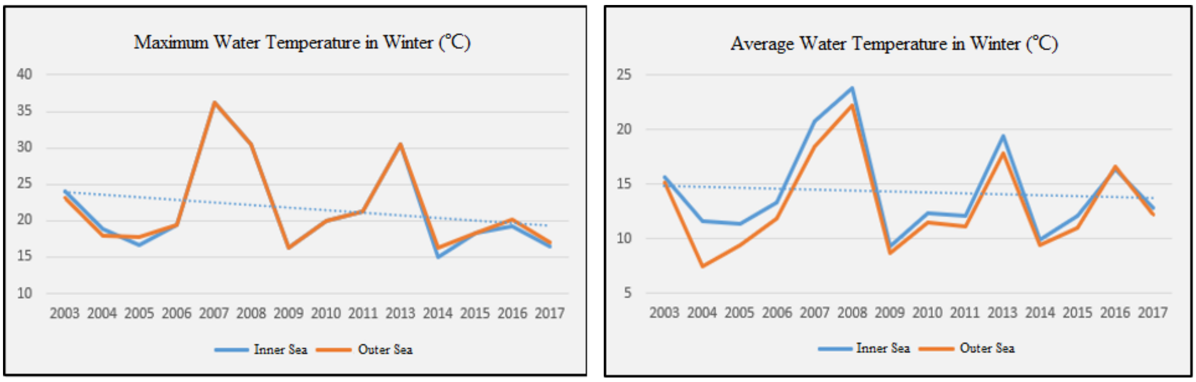

Figure 10. Maximum (left) and average (right) water temperature in winter

In terms of the highest water temperature, inner sea shares a similarity with outer sea. In 2007, 2008, and 2013, extreme events occur, with the highest water temperature exceeding 30℃. From 2003 to 2017, the overall trend showed a downward tendency. During this period, the average water temperature fluctuates around 15℃, and the floating range gradually converges. According to the statistics, the average temperature of inner sea in water from 2003 to 2009 is 14.7℃, and the average temperature from 2010 to 2017 is 13.5℃. After the shutdown of Kunming power plant, the average temperature of inner sea in winter drops by more than 1℃. Overall, the average water temperature of inner sea is still higher than that of outer sea, even after the Kunming power plant ceases. The main reason may be that the inner sea is surrounded by urban land, the load of industrial discharge and residential water discharge is large. Besides, inner sea has a weaker capacity in purification and cooling because of the poor water storage capacity, resulting in the average water temperature is higher than the outer sea all the year round.

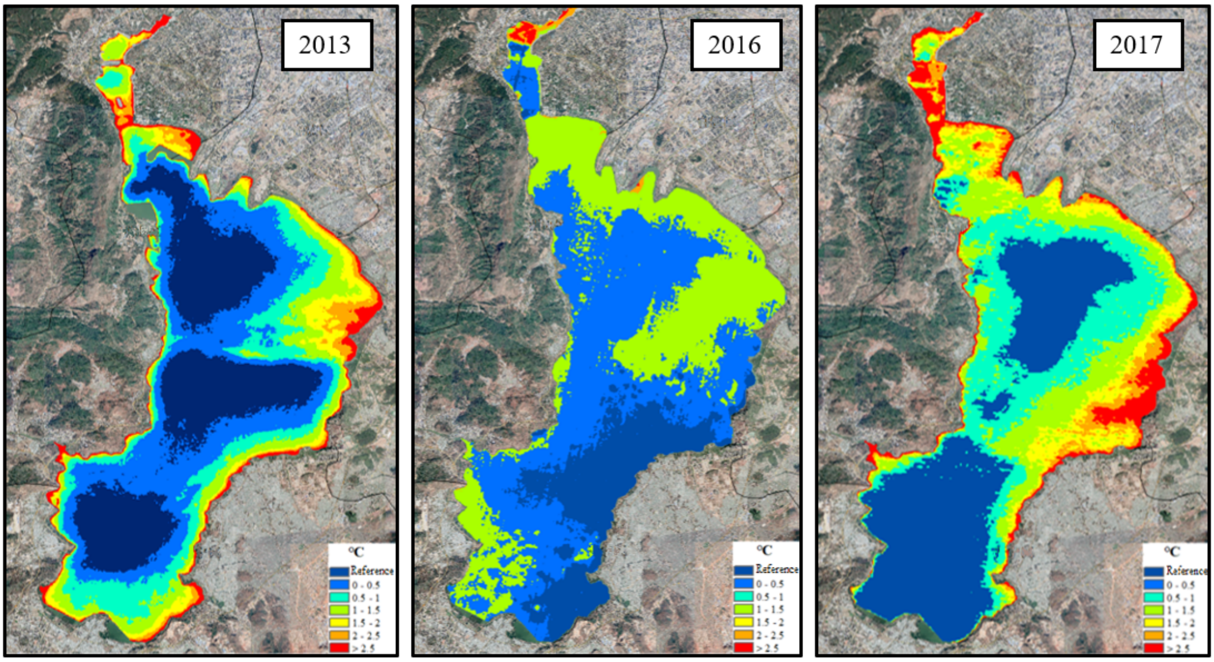

Figure 11. Distribution of warming zones in Winter, 2013 (left), 2016 (middle) and 2017 (right)

Figure 11 shows the distribution of warming zones in Dianchi in the winter of 2013, 2016 and 2017. Due to the rapid urbanization, the distribution of warming zones is various. In general, the central and northern Dianchi are regions with little influence, which is within 0.5℃ higher than the reference temperature. Chenggong district poses a great threat to the core area of Dianchi. Although the water storage volume of Dianchi is twice that of Yangzonghai, the average depth is 5 meters which makes discharged warm water more likely to spread outwardly.

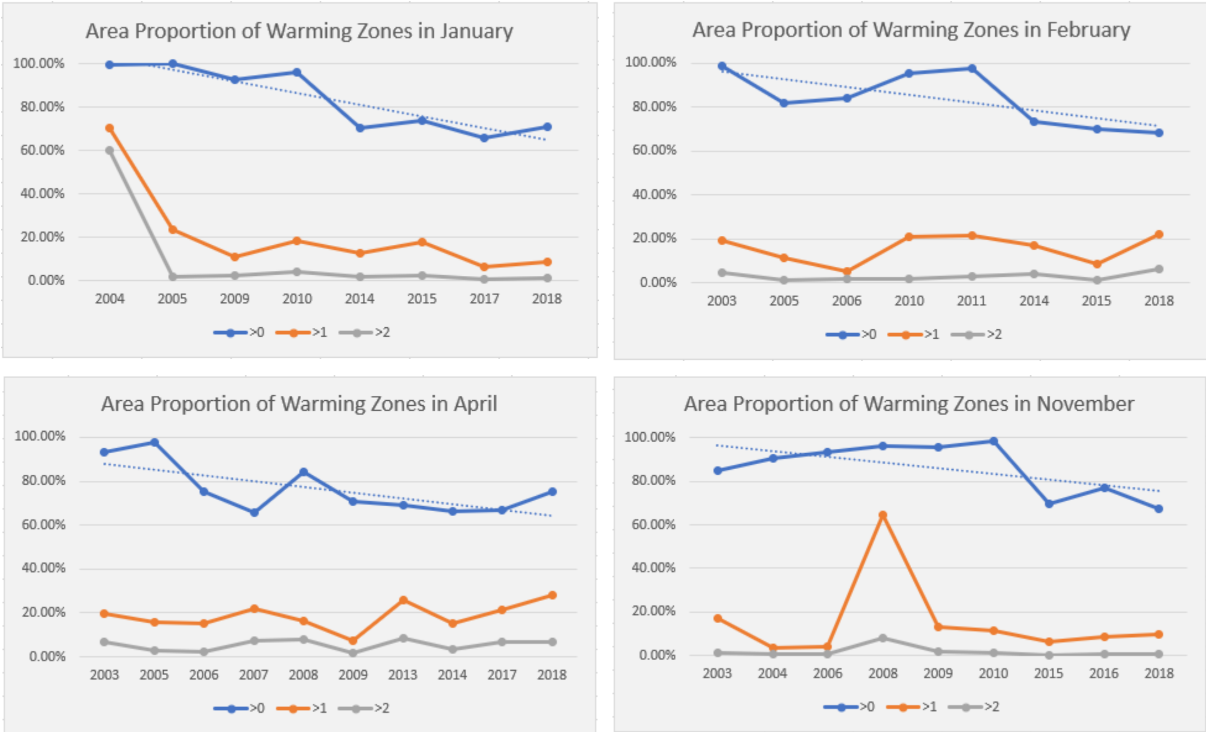

Figure 12 Proportion of warming zones in January, February, April, and November

By 2018, warming zones of the whole lake decreases to 80% (210km^2), and the warming zones above 1℃ accounts for less than 20%. Extreme events occur in January 2004 and November 2008, with more than 60% of the area exceeding 1℃ above the reference temperature.

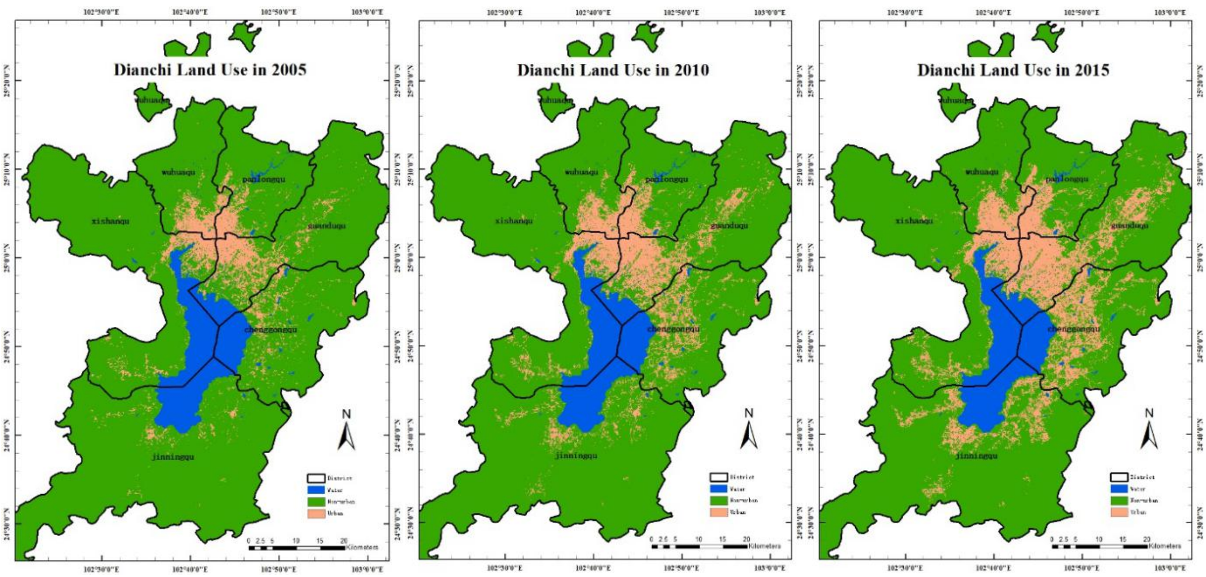

Figure 13. Land uses along Dianchi in 2005 (left), 2010 (middle) and 2015 (right)

In 2010, the urban area along Dianchi exceeds 330km^2, accounting for more than 30% of land uses. The forestland area is 84.06km^2, accounting for 7.81% of the total area. Greenhouses, with an area of 82.03km^2, are mainly distributed around Chenggong district and Jinning district. With the planning and development of Jinning district after 2010, the urban coverage rate of this district is 8 times that of 2003 by 2017. The growth rate of Chenggong district comes the second, and the urban coverage rate of 2017 is 3 times that of 2003. By comparing the layouts of urbanization, we find that there is a correlation between the urbanization and the rise in coastal water temperature. One guess we make is that during the transformation from agricultural land to urban land, nutrients, and particulate matters flow into the nearby waters, affecting water temperature, chlorophyll concentration, and water transparency. To distinguish the impact of urbanization development in different regions, we redivide the study area into Guandu district, Xishan district, Chenggong district and Jinning district.

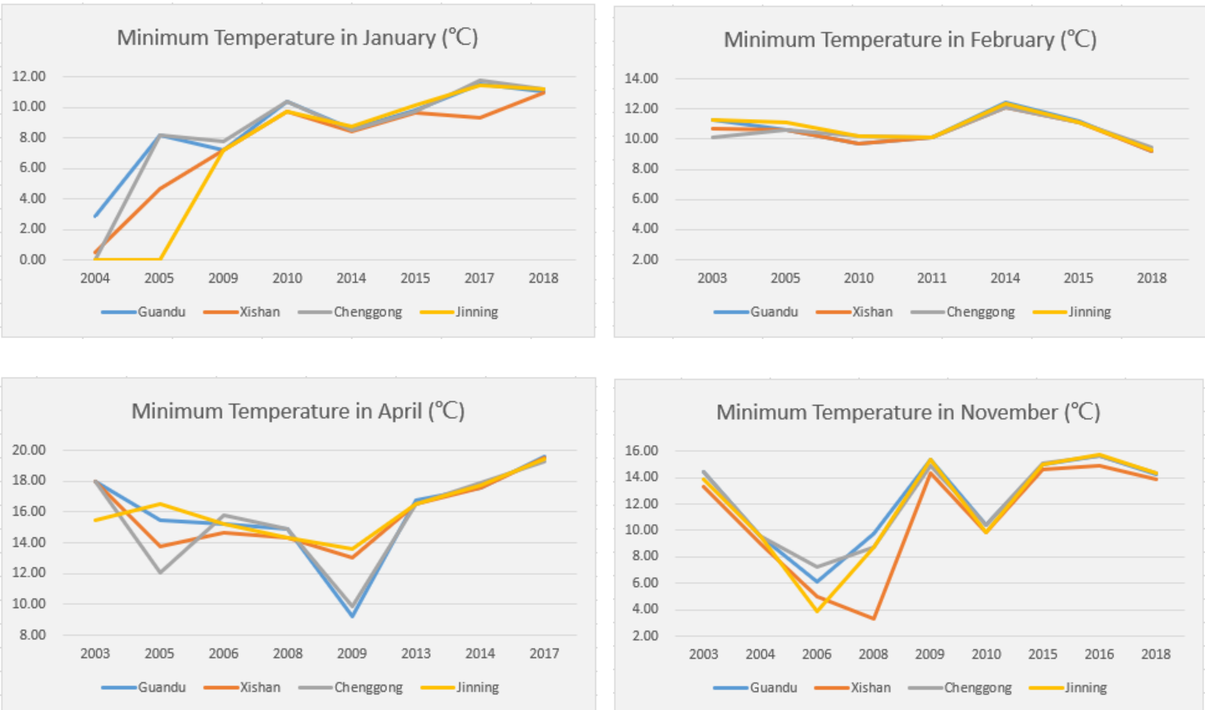

Figure 14. Minimum water temperature in January, February, April, and November

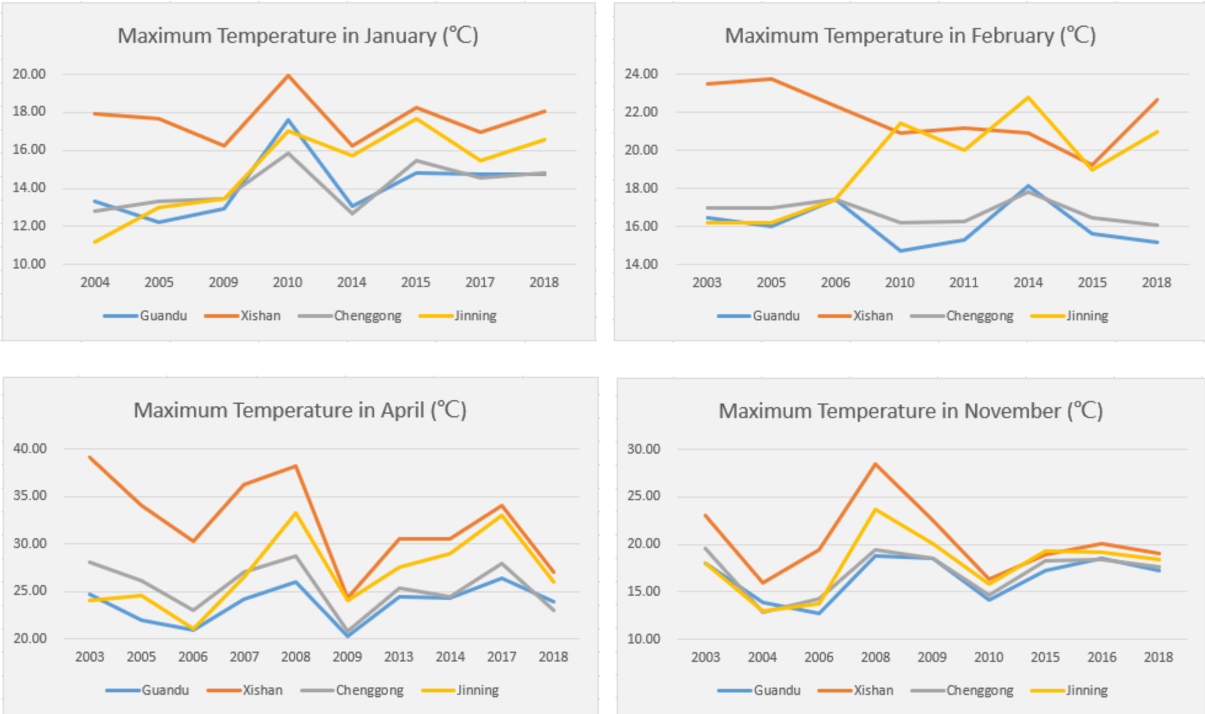

Figure 15. Maximum water temperature in January, February, April, and November

As shown in figure 14, the lowest temperatures in each district are close to each other. This may be ascribed to the existence of undeveloped natural land along the shoreline of each district, so the statistical results show similar values. In April 2009, the lowest temperature in Jinning district and Xishan district is 4□ higher than the other two districts. Figure 15 shows that whether Kunming power plant is shut down or not, the highest temperature in Xishan district is always higher than the other three districts. In April and November 2008, the highest temperature in Xishan district and Jinning district are significantly higher than the other two districts. After 2010, the urban coverage rate of Jinning district doubles. The highest temperature in Jinning district significantly increases after this time node and becomes close to the Xishan district.

2）TLI（chla） and TLI(SD)

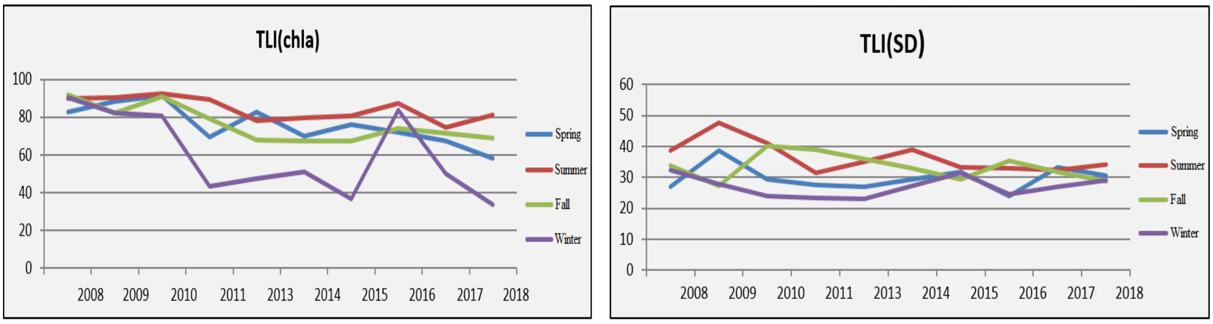

Figure 16. Seasonal TLI (chla) and TlI(SD) in Dianchi

As figure 16 shows, from 2008 to 2018, the chlorophyll concentration in Dianchi Lake shows a trend of slight decline. Chlorophyll concentration throughout the year in 2008-2010 TLI(chla) values remain above 80 for the whole year, the water quality is □ class. From 2011 to 2013, it decreases year by year, and maintains mesoeutrophic in winter. In terms of seasonal characteristics, chlorophyll concentration is positively correlated with temperature, and summer is the season when chlorophyll reaches its peak all year round. The transparency evaluation index TLI(SD) shows a decreasing trend.

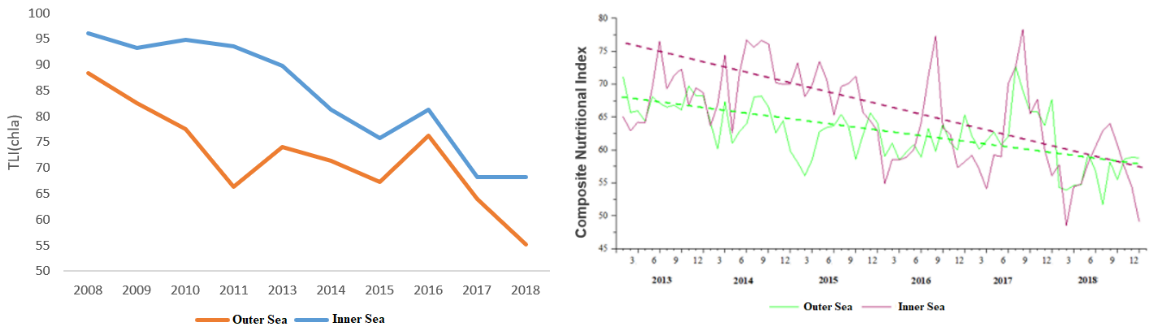

Figure 17. Dianchi TLI(chla) (left) and composite trophic index (right) variation tendency

Figure 17 shows that the variation tendency of TLI(chla), as one of the parameters, is consistent with that of composite trophic index, which is evaluated by a confidential organization. Within a time period from 2008 to 2018, the trophic state drops from hypereutrophic to mesoeutrophic.

Water transparency shares a similar decreasing tendency, but there is little variation in seasonality. Besides Kunming Thermal Power Plant, land uses consist of livestock farming, agriculture and residual land are major factors threating the water quality.

IV Discussion and conclusion

1) Kunming power Plant and Yangzonghai power Plant can be suspects who worse water quality by influencing water temperature, chlorophyll concentration and water transparency

In Yangzonghai basin, the average temperature in the northern part is constantly higher than the rest of water body. Based on our observations, we find that the channel near Yangzonghai Thermal Power Plant is the major heat source and strong correlations exist. The conclusion can be drawn that as warm water is discharged from the channel near Yangzonghai Thermal Power Plant, areas with higher temperature maintain higher chlorophyll concentration and worse status in water transparency. Through the inversion based on satellite data, we find that nearly 60% (about 20km^2) areas of Yangzonghai are above the reference temperature, and the river channel of Yangzonghai power plant is the main heat source. The correlations between water temperature and chlorophyll concentration and transparency are more than 0.66.

Due to the numerous types of land uses around Dianchi, the process of identifying and distinguishing sources of pollutants is complicated and hard to be fulfilled. The shutdown of Kunming Thermal Power Plant, which is located to the west of inner sea, becomes a time node that the gap between the average water temperature of inner sea and outer sea narrows. In terms of chlorophyll concentration, a slight decline is observed from 2008 to 2018. It is highly correlated with seasons, as the maximum mostly appears in summer.

2) Advantages and limitations of using satellite remote sensing data for monitoring

Remote sensing has become more and more popular among water researchers in recent years. Compared with ground stations, satellite data has the advantages of wide coverage, good continuity of historical data and low cost. All data used in this project is publicly available and applicable to all waters.

There are some limitations in retrieving chlorophyll concentration and water transparency from satellite data. The accuracy of the two parameters obtained from satellite is lower than the ground measurement. Due to the influence of climatic conditions and other factors, some satellite images are disturbed by clouds, resulting in the reduction of historical data continuity. Our research hopes to integrate satellite data and ground observation data, and make up the gap of time period disturbed by clouds by machine learning, to obtain more continuous data and conduct year-round time series analysis.

3) Policy recommendation

The demand of electricity consumption for daily production and people's daily life is exponentially increasing. Shutting down power plants without alternatives will cause dissatisfaction among the public. Stakeholders have conflicts as well as common interests which make them unable to decouple from each other. This project can be a reference for water pollution control or site selection of thermal power plants. Although the mechanism of aquatic ecosystem is ignored in this research, the similarities in distribution pattern of temperature, transparency and chlorophyll concentration reveal their correlations. One recommendation can be proposed that local government and officers should weigh more on thermal plants when they implement water managements. Filters and cooling systems are critical as they are the final step that can restrict pollutants from entering the water body. Land uses, including livestock breeding, agriculture, and residential land, related with chemical nutrients are the secondary source of pollutants. Discharges should also be regulated and restricted.

4) Limitations of this project

The discussion and conclusion are merely based on the satellite-derived observations and inversions. The knowledge of aquatic ecology is required, but absent, for analysis in this project. Therefore, the weights of direct and indirect impacts of thermal power plants on water quality cannot be distinguished. For instance, aquatic organisms may be affected by changes in temperature, which results in changes in water quality. To quantify the weights of direct and indirect impacts, further collaboration with aquatic ecologists is necessary.

Appendix

Description of data sources

All satellite imageries are acquired from Landsat5TM and Landsat8OLI. Due to the half-a-month temporal resolution and restrictions from weather conditions, scenes are precious but sometimes absent in the corresponding period. To compromise data quality and comparability, we set a flexibility of one month in selecting target scenes for time-series analysis purpose. Below is a table showing all the imageries we acquire. Parameters with ticks (√) indicate which we have employed in this project. The dates of scenes are expressed as YYYYMMDD.

Region	Yangzonghai			Dianchi		
Parameter	Temperature	Chla	SD	Temperature	Chla	SD
20060212	√			√		
20060401	√			√		
20060519	√			√		
20061127	√			√		
20070420	√			√		
20070506	√			√		
20070623	√			√		
20080406	√	√	√	√	√	√
20080524	√	√	√	√	√	√
20080913	√	√	√	√	√	√
20081116				√	√	√
20081202	√	√	√	√	√	√
20090119	√	√	√	√	√	√
20090324				√	√	√
20090409	√	√	√	√	√	√
20090511	√	√	√	√	√	√

20091103	√	√	√	√	√	√
20100122			√	√	√	√
20100207				√	√	√
20100514	√	√	√	√	√	√
20101021				√	√	√
20101106	√	√	√	√	√	√
20101224	√	√	√	√	√	√
20110210	√	√	√	√	√	√
20110720	√	√	√	√	√	√
20130420	√	√	√	√	√	√
20130522				√	√	
20130911	√	√	√	√	√	√
20140101	√	√	√	√		√
20140202	√	√	√	√		√
20140423	√	√	√	√	√	√
20150104	√	√	√	√		√
20150221	√		√	√		√
20150309				√		√
20150528	√	√	√	√		√
20151120	√	√	√	√	√	√
20160818	√	√	√	√		√
20161005	√	√	√	√	√	√
20161122	√	√	√	√	√	√
20161208	√	√	√	√	√	√
20170109	√	√	√	√	√	√
20170314	√	√	√	√	√	√
20170501	√	√	√	√	√	√
20180128	√	√	√	√	√	√

20180213	√		√	√		√
20180301	√		√	√		√
20180402	√	√	√	√	√	√
20181128	√	√	√	√	√	√