

# Area changes of Nam Co during 2000-2011 based on remote sensing study

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**Abstract**—Using MODIS satellite data of different periods, the change in water area of Nam Co during 2000-2011 is analyzed based on geographical information system (GIS) and remote sensing (RS) techniques. The results show that the Nam Co expanded continuously in recent 11 years with an average increase rate of  $4.90 \text{ km}^2 \text{ a}^{-1}$ . To find out the climate elements which affect the area expansion, the precipitation and temperature are analyzed according to meteorological data in the Nam Co basin. It shows that higher temperature is the direct cause of the extension, and the decreasing in lake evaporation also affects the area of Nam Co.

**Key Words**—Nam Co, area expansion, MODIS, precipitation, temperature

## I. INTRODUCTION

The Tibetan Plateau is the largest plateau lakes area on earth, with the highest elevation and largest number of lakes. The total area of lakes in Tibetan Plateau is about 49.5% of the total area of lakes in China<sup>[1]</sup>. Lake evolution is closely related to environmental changes, on the one hand, the lake volatility indicates climate change sensitively through water changes and changing the depositional environment, on the other hand, lake area changes have an impact on climate change by changing surface conditions<sup>[2-4]</sup>. Therefore, the lake is the key factor that affects the Tibetan Plateau water cycle and a sensitive indicator of regional climate change<sup>[5-6]</sup>.

Satellite remote sensing has wide coverage, large amount of information, and high frequency advantages, thus it has become an important information source that can not be replaced by conventional observations in the study of global change. There are already some researches on lake variation in Tibetan Plateau based on remote sensing and GIS technology<sup>[7-14]</sup>.

Nam Co was once the largest lake in the Tibet Autonomous Region. For Nam Co lake fluctuations and genetic analysis, there are many researches for reference. Existing study shows that Nam Co expanded rapidly from 2001 to 2009<sup>[15]</sup>. However, further research on lake expansion process over the past decade is needed. For example, the lake expansion is continuing or with fluctuations.

In this paper, the long time sequence of lake area data of Nam Co during 2000-2011 was established with MODIS data, and the variation of the lake area was analyzed. On this basis,

the climate elements, precipitation and temperature were analyzed in order to discuss the possible reasons on lake area variation.

## II. STUDY AREA AND DATA

### A. Study area

Nam Co is a close lake located in the northern Gangdise-Nyainqentanglha Mountain (Fig.1). The geographic range of lake water surface is  $90^\circ 16' \sim 91^\circ 03' \text{ E}$ ,  $30^\circ 30' \sim 30^\circ 55' \text{ N}$ . Lake area was  $1920 \text{ km}^2$  and elevation was 4718 m according to the survey in 1970s<sup>[16]</sup>. The lake depends on surface runoff and lake precipitation<sup>[17]</sup>. There are many modern glaciers on the Nyainqentanglha Mountain, and the glacier melt water is injected directly into the lake after the piedmont<sup>[10]</sup>. The north and northwest of this basin are gentle hilly area within the plateau, with the average elevation of 5000 m. The solar radiation in Nam Co basin is strong, and the sunshine time is long, about 2900~3200 h a year. This area belongs to plateau sub-frigid monsoon semi-arid climate zone, with cold weather, not clear season. And the annual temperature difference is greater than the diurnal temperature range<sup>[18]</sup>.

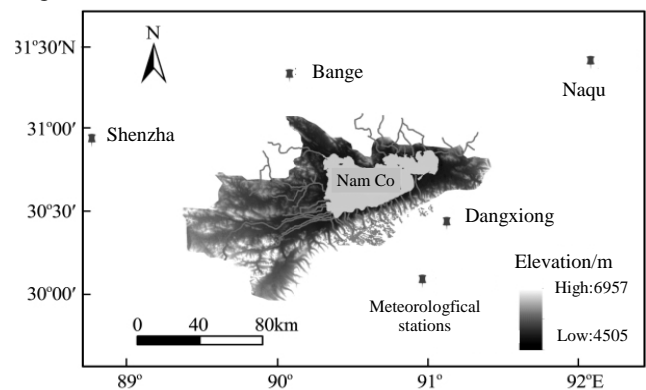


Fig. 1. The locations of Nam Co basin and meteorological stations

### B. Data collection and preprocessing

MODIS (Moderate Resolution Imaging Spectroradiometer) is a key instrument aboard on the Terra (EOS AM) and Aqua (EOS PM) satellites. Terra MODIS and Aqua MODIS are

viewing the entire Earth's surface every 1 to 2 days, acquiring data in 36 bands with a spectral range of 0.4~14.5  $\mu\text{m}$ . These data will improve our understanding of global dynamics and processes occurring on the land, in the oceans, and in the lower atmosphere. MOD09 (MODIS Surface Reflectance) is a seven-band product computed from the MODIS Level 1B land band1, 2, 3, 4, 5, 6 and 7. The product is an estimate of the surface spectral reflectance for each band as it would have been measured at ground level as if there were no atmospheric scattering or absorption. It correct for the effects of atmospheric gases and aerosols. Since the Nam Co lake area is relatively stable September, the MOD09 data used in this study were acquired in September from 2000 to 2011<sup>[19]</sup>. These data were downloaded from U.S. NASA website, and the meteorological data were downloaded from China Meteorological Data Sharing Service System.

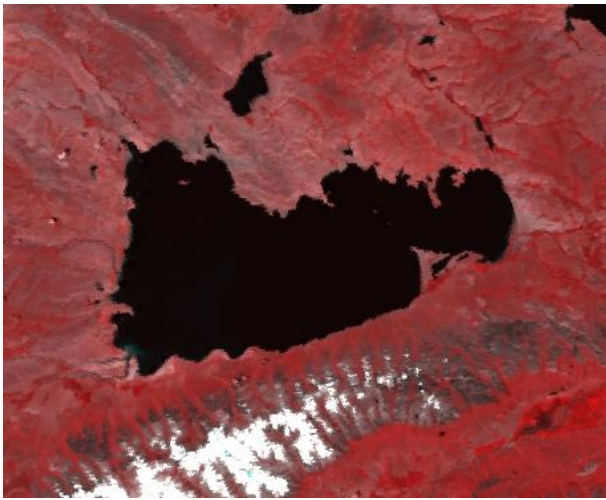


Fig. 2. Synthesis image of MOD09 data

MRT (MODIS Reprojection Tool) software was used to crop MODIS images and transform the projection (Fig.2). In this study, the ALBERS area projection was used.

The meteorological data used in this study are the annual temperature, precipitation of Shenzha, Bange, Naqu, and Dangxiong meteorological stations in Nam Co surrounding areas from 2000 to 2011.

### III. LAKE WATER SURFACE EXTRACTION METHOD

The satellite remote sensing images document the thermal radiation of surface features and their reflection of solar radiation information truthfully. The electromagnetic spectrum characteristics of different objects are different, caused by the differences of the composition, physical and chemical characteristics. Previous studies show that the reflectance of water in the visible, near-infrared band (400~2500 nm) is very low, about 1 % to 4%<sup>[20-21]</sup>. This reflectance is much lower than other features, therefore, it can be used to distinguish water from other features. In addition, the reflectance of water in the near-infrared band is less than that in the red band, while the reflectance of vegetation and soil is on the contrary, that is, the reflectance in the red band is less than that in the near-

infrared band. So water body can be extracted using both red and near-infrared band. After comparing the results from these two methods with that from Landsat TM data by visual interpretation, we found that combining the above two methods could get the most accurate results. Thus, for the MODIS data, this paper used the following rules to extract water:

$$red - nir > th1 \& nir < th2 \quad (1)$$

Where *red* and *nir* are the reflectivity of the red band and near-infrared band, corresponding to band 1 and band 2 on MODIS image, *th1* and *th2* are the thresholds. In order to improve the water extraction, different images used different thresholds. In this paper, the iterative threshold algorithm was used to calculate the threshold of each image. This algorithm calculates the threshold through iterative manner based on the idea of approximation.

According to the above method, Nam Co surface information from 2000 to 2010 was extracted with the software ENVI, and the water areas were calculated.

## IV. RESULTS

### A. Nam Co lake surface area variation from 2000 to 2011

Fig.3 shows the Nam Co water area variation from 2000 to 2011. During this period, Nam Co expanded rapidly. In 2000, the lake area was only 1972.44  $\text{km}^2$ , and in 2011, it increased to 2026.38  $\text{km}^2$ . The lake area was increasing year by year stably, as the lake area curve shows. The average increase rate was 4.90  $\text{km}^2 \text{a}^{-1}$  during 2000 ~ 2011, while the average increase rate was 1.07  $\text{km}^2 \cdot \text{a}^{-1}$  from 1970 to 2000<sup>[15]</sup>, which means that Nam Co expanded rapidly in recent years than before.

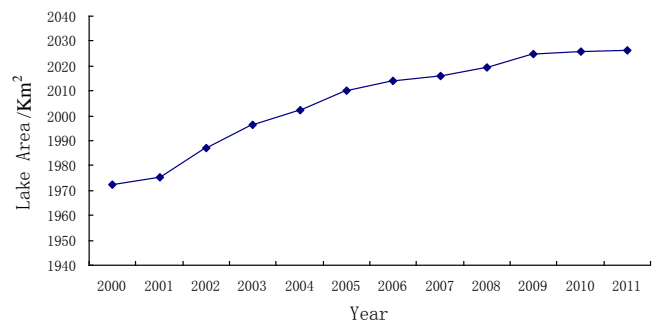


Fig. 3. Changing in area of Nam Co from 2000 to 2011, acquired from MOD09 data

### B. Climate change in Nam Co basin

June to October is the monsoon period of Nam Co basin, and the weather is warm and humid. From November to May of the following year, this basin is affected by westerly circulation, and the weather is cold and dry. The rainy season and dry season is clear, and the average humidity is 52.6%. In the warm season, the precipitation accounts for 91% of the annual total precipitation, and the precipitation is basically ended in early October<sup>[15]</sup>.

There are many reasons for the change of Nam Co water area [2,15]. Fig.4 shows the inter-annual variation of the precipitation of the meteorological stations in Nam Co basin. At the Shenzha station, the cumulative precipitation increased continuously, while the cumulative precipitation showed some fluctuations at other stations. However, the cumulative precipitation anomaly curve indicates that the annual precipitation of the four stations during 2000~2011 is obviously more than the average precipitation of the past years. Dangxiong, Naqu, and Bange had the maximum precipitation in 2008, which means that the precipitation of Nam Co basin in this year was the most.

The average temperature in Nam Co basin was 0.1°C for years. It was basically lower than 0°C before 1983 and higher than 0°C in most years since 1984 [15]. The maximum of temperature was in 2009, with a value of 1.9°C. From 2000 to 2011(Fig.5), the average temperature was positive anomaly, shows that this area is in the warmer period compared with the previous period. Although there are fluctuations in the annual average temperature, it shows increasing trend.

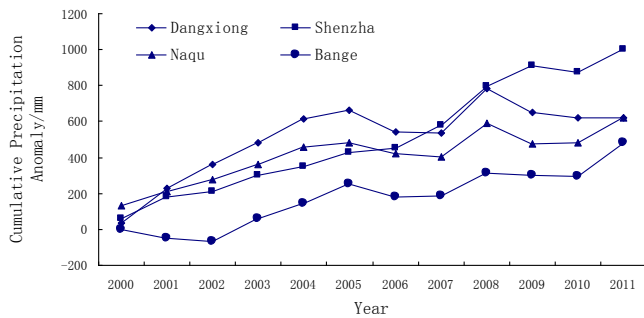


Fig. 4. Variations of the precipitation in Nam Co area from 2000 to 2011

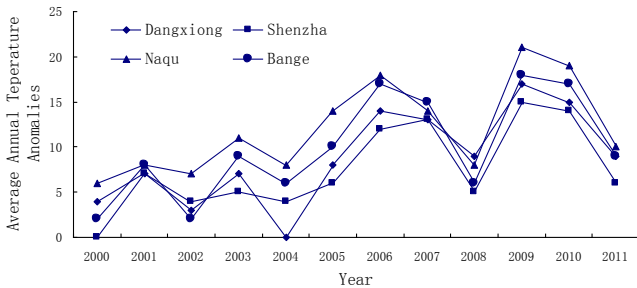


Fig. 5. Variations of the air temperature in Nam Co area from 2000 to 2011

## V. DISCUSSION

### A. Accuracy

Validation of the water surface information extracted from MODIS data using traditional groundtruthing methods is nearly impossible for Nam Co. Therefore, the accuracy of the water distribution map was assessed using two methods: visual examination and comparison with concurrent high resolution satellite imagery Landsat TM.

The water distribution map was linked with the co-registered MODIS RGB images in the software ENVI, then examined visually. Zooming was used to determine how the water map derived from MODIS fit the visually determined water and land objects in the RGB images. It is found that the water extraction method works well for most of the MODIS images. However, for some images with pixels of abnormal values, these pixels were not classified correctly. In those cases, the result would be modified manually to improve it.

One cloud-free Landsat TM collected on 19 December 2000 was visually interpreted and compared with the MODIS observations on the same day. The result shows that water /land boundary from the two measurements are similar with most of the boundary overlapped, and the difference between the estimated lake areas from the two independent measurements is 1.1%. Although the water area derived from 250-m resolution MODIS imagery is not as accurate as that from Landsat TM, it can still be used to study the change trend of lake water area.

### B. The impact of climate change on lake expansion

Fig.2 to Fig.4 show that the Nam Co expanded gradually in the past 11 years, and increased over 50 km<sup>2</sup> during 2000~2011. Higher temperature and increased precipitation are related to Nam Co expansion to some extent. In addition to the direct injection of the lake, the precipitation affects the lake district changes through the runoff formation process. In recent 10 years, the precipitation is obviously more than the average of the past years, which made the runoff into Nam Co from non-glacier area increased. At the same time, higher temperature made the melt water from glacier increased. Moreover, existing researches show that the evaporation in Nam Co area decreased in recent years [15]. All of the above factors led to Nam Co expansion directly.

## VI. CONCLUSIONS

The observation result from satellite remote sensing shows that the Nam Co expanded continuously in recent 11 years. From 2000 to 2011, the lake area increased more than 50 km<sup>2</sup> with an average increase rate of 4.90 km<sup>2</sup> a<sup>-1</sup>. Increasing in precipitation and the decreasing in lake evaporation affects the area of Nam Co.

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