TEMPORAL PATTERN DETECTION OF SNOW COVER, WATER STORAGE AND VEGETATION IN NAM CO LAKE BASIN, CENTRAL TIBETAN PLATEAU

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ABSTRACT:

The long-term and seasonal variation of snow and vegetation phenology in Nam Co Lake Basin were monitored, using Moderate Resolution Imaging Spectroradiometer (MODIS) snow cover, and vegetation index products. And the lake storage was calculated using LANDSAT TM/ETM, HJ-1 images and in-situ measurements data. Our preliminary results show that the average annual snow cover shrank during 2000-2009, and there is an obvious relation with the elevation and a clear decreasing southeast-northwest trend in snow cover persistency. The results also show that the water storage of Nam Co Lake increased obviously during the study period. Vegetation phenology varied with start of season dates comparatively consistent with the snowmelt during 2000 to 2009. SOS (start of season) monitored is usually late April and early May, while EOS (end of season) monitored is commonly late September and early October.

Keywords: Nam Co Lake; Tibetan Plateau; MODIS

1 Introduction

Impacts of global climate change are expected to result in greater spatial and temporal variation in the snow, lake storage and vegetation dynamics in highland regions (Bradley et al., 2006; Yang et al., 2010).

Remote sensing data can potentially capture much of this variation in seasonality provided that the data record is sufficiently long, especially in no data area as Tibetan Plateau (TP). Some studies have analyzed climate and environmental change in TP using in situ observation and remote sensing data (Dankers et al., 2004; Lu et al., 2005; Li et al., 2007; Immerzeel et al., 2009). In view of the previous results of these studies, comprehensive regional studies on this topic are largely lacking, more work is clearly required for monitoring temporal trends of environmental factors and mapping the change of vast regions in TP.

Nam Co Lake is the largest lake on Tibet plateau as well as the highest big lake in the world. The hydrological and ecological environment change of the basin is typical and representative among highland lakes and some researches have been done (Wang et al., 2009; Zhang et al., 2011). In this study we used Moderate Resolution Imaging Spectroradiometer (MODIS) snow cover extent, and vegetation index products for temporal pattern detection for the Nam Co Lake Basin. Simultaneity we chose LANDSAT TM/ETM and HJ-1 images for calculating water storage of the Lake. Finally we conducted the comprehensive analysis of the environmental factors of Nam Co Lake Basin.

2 Study area

Nam Co Lake is the largest lake in Tibet plateau, and located at 90°16′~91°03′E, 30°30′~30°55′N, central Tibetan (Fig. 1). It belongs to Damxung County of Lhasa City and Baingoin County of Nagqu Prefecture of Tibetan Autonomous Region. Its elevation is 4718m and the water area is 1920 km^2 measured in 1979 (Guan et al., 1984), and the maximum depth is over 90m (according to the measured data from 2005 to 2007). It is in the northwest of Nyainqentanglha Mountain with the average altitude about 5500m. Nam Co Lake Basin is located in 89°21′~91°23′E, 29°56′~31°7′N, which reaches 10610km^2.

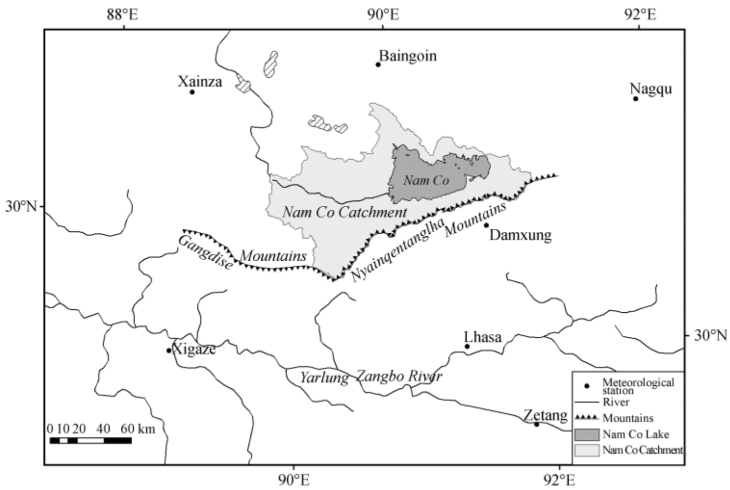


Fig. 1. Study areas overlaid over land cover map

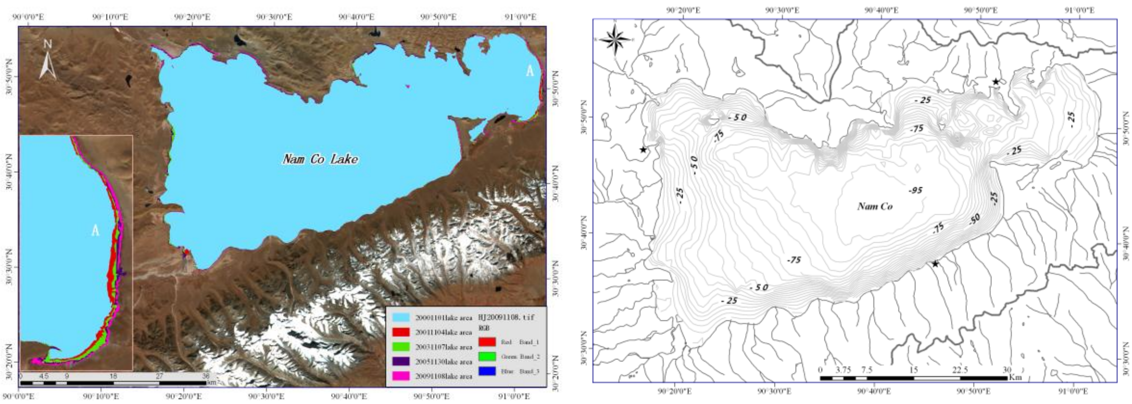
3 Methodology

3.1 Snow extent

In this study we use MOD10A2 products for snow cover analysis for the period March 2000 to December 2009. The MODIS snow cover mapping algorithm uses satellite reflectance data collected in MODIS bands 4 (0.545–0.565 μm) and 6 (1.628–1.652 μm) to calculate the normalized difference snow index (NDSI; Eq. (1)) (Hall et al., 2002; Salomonson and Appel, 2004). NDSI = (band 4− band 6)/(band 4 + band 6)   (1)

3.2 Lake water area and volume

The images and data resources utilized for calculation of lake area and water volume by this research are 32 CCD images from landsat TM/ETM, CBERS and HJ-1A/1B covering the research area (Table 1). Lake water storage were gained by the "Area and Volume" module of 3D analysis in ArcGIS, utilizing the calculation of excavation and filling based on the underwater landform (Fig. 2-b) and the lake surface area data (Fig. 2-a), which were obtained through the actually measure in the field and remote sensing images respectively (Wang et al., 2009; Zhang et al., 2011).



(a) (b)

Fig.2. Map-a showing the surface fluctuation of the Nam Co Lake; Map-b showing the isobathic map of Nam Co Lake.

Table 1

Remote sensing data and Digital Elevation Model (DEM) data used for lake volume calculation in this paper.

SN	Data type	Acquisition time (year/month/day)	Resolution (m)
1	Landsat5 TM	2007/05/15; 2009/10/17; 2009/12/04	30
2	Landsat7	2000/03/06; 2000/04/07; 2000/10/16; 2000/11/01; 2000/12/19; 2001/02/25;	30

	ETM	2001/06/13; 2001/11/04; 2001/12/06; 2002/02/24; 2002/03/28; 2002/05/15; 2002/12/09; 2003/01/10; 2003/04/16	
3	CBERS-CCD	2003/11/07; 2004/09/14; 2004/10/10; 2005/11/30; 2006/01/21	19.5
4	HJ-CCD	2008/12/13; 2009/01/07; 2009/02/06; 2009/03/14; 2009/04/16; 2009/05/19; 2009/06/25; 2009/08/30; 2009/11/08	30

3.3 Vegetation dynamics

Vegetation phenology was derived from 250 m, 16-day NDVI data.

Considering the definition of start of season (SOS), the end of Season (EOS), duration of season (DOS) and the solution of effect of snow melt (Soudani et al., 2008), the dynamic threshold-based approach to extract the phenological metrics from time-series of NDVI data was illustrated as the following formula (2). The EOS is defined in a similar way, whereas DOS could be calculated from the number of days from the DOY of SOS to the DOY of EOS. $NDVI_{\lim} = (NDVI_{\max} - NDVI_{\min}) \bullet C + NDVI_{\min}$ (2)

Where $NDVI_{\lim}$ is the dynamic threshold, $NDVI_{\max}$ is the maximum of NDVI during the DOS, $NDVI_{\min}$ is the minimum during the upward and downward phases, and C is coefficient.

4 **Results and discussion**

4.1 Snow extent

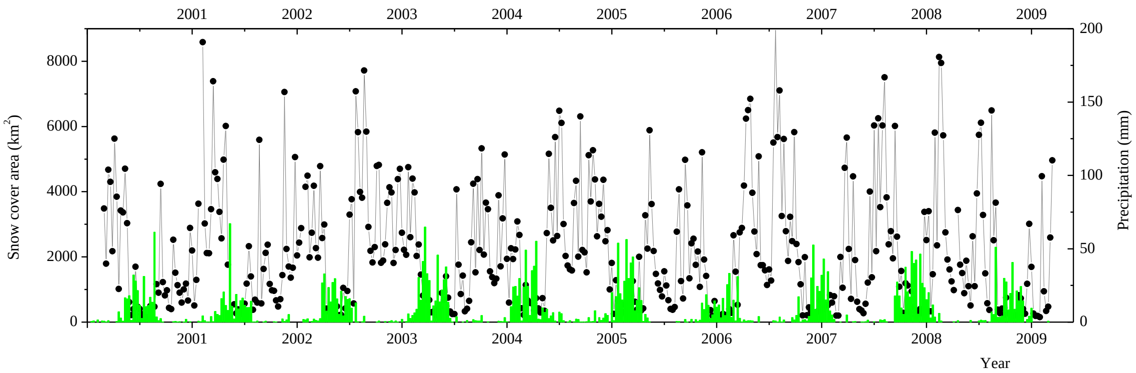
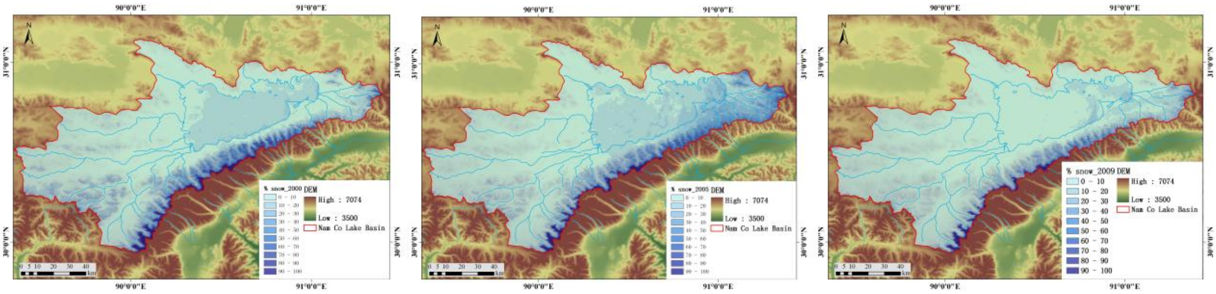


Fig.3. Seasonal snow cover based on MODIS MOD10A2 product and daily precipitation from 2000-2009 for the Nam Co Lake Basin.

The seasonal evolution of snow cover in Nam Co Basin from 2000 to 2009 is shown in Fig.3 and Fig.4. The average annual snow cover is 19.87% of the total basin with shrinking trend during the study period. Snow cover is more obviously persistent in the southeast regions of Nam Co Basin, and the duration mainly concentrate from October to May of next year, with the snow cover peak found in October and May, and with the snow cover vale happened at the late July and early August during the study period.

Across the Nam Co Basin there is a large spatial variation in snow cover due to the large climate and altitudinal differences. Comparison by the three years (2000, 2005 and 2009) in Fig.4, the obvious shrinking trend can be observed in snow cover persistency regions.



(a) 2000 (b) 2005 (c) 2009

Fig.4. Snow cover of 2000, 2005 and 2009. It was based on MOD10A2 snow cover time series from March 2000 to December 2009. The values show the percentage of time that a pixel was snow covered during the specified season within the entire time series.

4.2 Lake level, water storage and surface area

The lake water storage is obviously increasing from 897.44 $\times10^8$m^3 to 936.86 $\times10^8$m^3 over the ten years. And the lake storage increases from March to late September and early October then begins to decrease to December in a year (Fig. 5). The lake surface area also showed the same fluctuation character. Viewing from the spatial variation characters of lake surface enlargement, it appears that the east and west flat bank areas of the lake obviously enlarge, while the south and north abrupt slope areas of the lake enlarge weakly (Fig. 2-a). We selected the data of the same month in different years to make further analysis. Compared with the lake surface area in November of 2000, the ones in November of 2001, 2003, 2005 and 2009 are enlarged by 6.94 km^2, 18.26 km^2, 32.20 km^2 and 39.64 km^2 respectively.

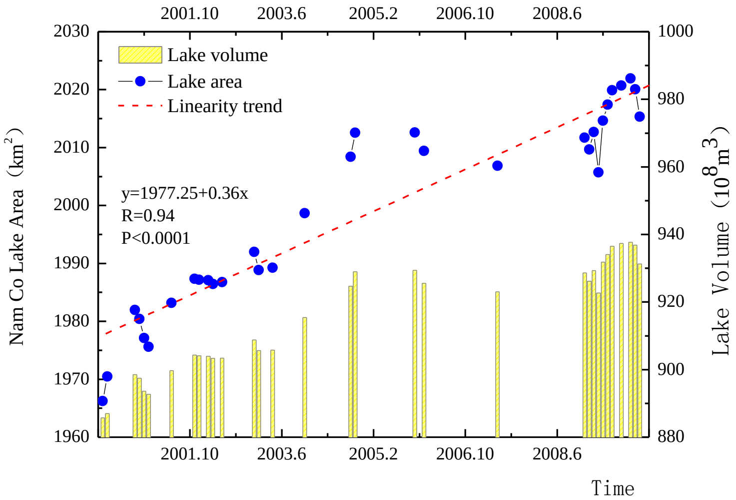


Fig. 5. Inter-annual variation trend of water storage and surface area of Nam Co Lake of 2000~2009.

4.3 Vegetation dynamics

In this study, we designed a dynamic threshold-based approach to extract SOS, POS, EOS and DOS from time-series of NDVI data. And the results show, for the low temperature at the Nam Co Station, DOS of vegetation is about 5 months from late April and early May when vegetation turn green to late September and mid October when vegetation scorch, which is shorter than that in the low altitude area.

The phenology data showed a range of median start of season dates of 21 days in Nam Co Lake Basin (22 April to 13 May). Since the wide ranging end of season dates for Nam Co Lake Basin, the median length of growing season varied by 33 days (140 to 173 days) over the ten years, with the mean value 162 day during 2006 to 2008, which was very close to the research results of Li et al. (2004) and Lv et al. (2009).

5 Conclusions

Remote sensing data have advantages in detection of long-time spatial-temporal patterns of environmental change in inaccessible regions. We used multiple sensor-based dataset to monitor temporal and spatial trends of snow cover, lake water storage and vegetation phynology in Nam Co Lake basin during 2000 to 2009. Results include the following:

The average annual snow cover is 19.87% of the total basin with shrinking trend during the study period, and the snowmelt curve has two peaks both in May and October.

The water storage of Nam Co Lake increasing from $897.44 \times 10^8 m^3$ to $936.86 \times 10^8 m^3$ during 2000 to 2009. And the expanding trend of the lake surface can be obviously monitored.

The vegetation in Nam Co Lake Basin generally turn green in the late April and scorch in the late September and mid October, with the DOS about 5 months.

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