CHANGES OF SNOW COVER AREA IN DIFFERENT ASPECTS IN KAIDU RIVER BASIN BASED ON MODIS DATA

Fei-yun Zhang[1], Lan-hai Li[1]*

[1] Tianshan Station for Snowcover and Avalanche Research, Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi 830011, China

ABSTRACT: Snow cover plays an important role in balancing earth surface heat and generating runoff in alpine basins. Snowpack accumulation depends on snowfall and snowmelt. The blowing snow results in a re-allocation of the snow after snowfall. The re-allocation of the snow depends on the wind and land surface characteristics, especially slope aspects. This study took a typical alpine basin, the Kaidu River basin, as an example to study the variations of snow cover in different aspects using remote sensing data. In order to analyze the variation of snow cover under different aspects during the snow cover seasons, this paper applied the moderate resolution imaging spectroradiometer (MODIS) snow cover products from 2000 to 2010 as well as the aspect data generated by the digital elevation model (DEM) data to calculate the snow cover variations of 8 different aspects. The aspects were set in the clockwise direction, i.e. the north is set as 0°, the east as 90°, and the south as 180° and the west as 270°. The results showed that the change in snow cover exists seasonally in all aspects. With the aspect change from the east along the clockwise direction, the snow cover ratio increased first, and then decreased in spring. The change of the snow cover ratio in summer followed a decreasing – increasing – decreasing trend. The snow cover ratio change in autumn followed a pattern similar to that in spring, while the change in winter showed a contrary pattern to that in summer, i.e. an increasing – decreasing - increasing pattern.

KEYWORDS: MODIS; snow cover; aspects; Kaidu River basin.

1. INTRODUCTION

The snow cover plays an important role in surface heat balance and runoff processes. Snowfall in cold regions accumulates and forms snowpack. There are a lot of influencing factors on snow cover change. The blowing snow which is influenced by wind and topography re-allocates snow. Temperature indirectly affects the snow cover because temperature influences the snowfall and snowmelt processes. The snowfall increases the snow cover area under lower temperature, and the snowmelt process decreases the snow cover area under higher temperature (David and Albert, 2001).

The Kaidu river basin is a typical middle latitude alpine basin. The snow cover area varies with seasons (Li et al., 2012; Bai et al., 2012). The snow cover area influences the hydrothermal balance, surface runoff generation and the ecological environment of Kaidu river basin (Li et al., 2012). The snow cover determines the snowmelt water source, which has great influences not only on the ecological system of the Bayinbuluk meadow (Wu, 2005) and Bosten Lake - the greatest inland fresh water lake in China (Sun et al., 2010), but also on the water discharge to the downstream of the Tarim River (Zuo et al., 2004).

There are a lot of studies on snow cover change (Cai et al., 2009; Ma et al., 2013), including the changing patterns of the snow cover area with topography, elevation and time. These studies were based on the spatial/temporal variation of the snow cover status. Few studies applied the remote sensing data to study the change of snow cover in the Kaidu River basin. Nor any studies concerned about the change of the increased and decreased snow cover quantitatively. Based on the preview study of the spatial and temporal changes of the snow cover and the D-value of the snow cover area extracted from the 8-day synthetized MODIS snow cover product, this study tries to analyze the change of the snow cover area with different seasons and aspects.

2. STUDY AREA

The Kaidu River basin is located in the central section of Tianshan Mountains in Xinjiang, China with co-ordinates of 42° 43′ N-43° 21′ N and

* *Corresponding author address:*
Lanhai Li, Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi 830011, China;
tel: 0991-7823125; fax: 0991-7823125;
email: lilh@ms.xjb.ac.cn

82° 58′ E - 86° 05′ E. As a typical inland river, the Kaidu River originates from the Armin mountain of the Tianshan Mountains, and flows into the Bosten lake. The length of the river is 560 kilometers. The catchment area is approximately 190,000 km2.The elevation of Kaidu river basin decreases gradually from the north to south (Figure 1). The streamflow in the Kaidu river basin is contributed by spring snowmelt water, summer rainfall and glacier melt water. The Bayinbuluk meadow which feeds the local livestock is situated in the upper and middle reaches of Kaidu River basin.

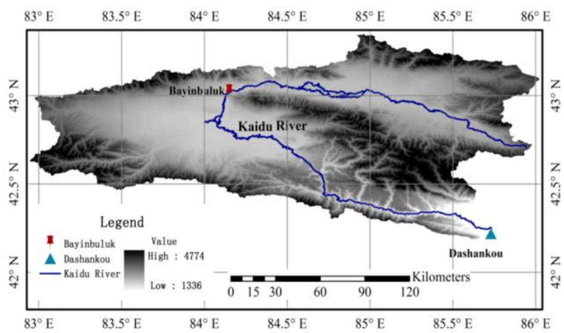

Fig. 1 Location of study area

3. DATA AND METHODOLOGY

3.1 Data Used

A sequence of 8-day synthetic snow product (MOD10A2) with spatial resolution of 500mand Digital Elevation Model (DEM) data with spatial resolution of 90m are used in this study. MOD10A2which is provided by the Earth Observation System (EOS) in America is obtained from the moderate resolution imaging spectroradiometer (MODIS) in Terra satellite. The MOD10A2 data used in this study is from the 57thday of 2000 to the 361stday of 2010. The DEM data is downloaded from the platform of scientific data service.

3.2 Methodology

The DEM data is resampled into the same spatial resolution as that of MOD10A2 data. Eight aspects are extracted through DEM data in a clockwise direction (north is set as 0), i.e. 0°~45°, 45°~90°, 90°~135°, 135°~180°, 180 ~225°, 225°~270°, 270°~315°, 315°~360°.The specific steps of extracting snow cover from MOD10A2 are: 1) transforming the projection of the MOD10A2 data and tailoring all the MOD10A2 data in the study area; 2) setting the grids within snow cover into 1 and the other grids into 0. After these two steps, the snow cover data in Kaidu river basin has been changed into two value matrix data. In order to analyze the change of snow cover in different aspects, the snow cover area is divided into 8 different aspects by superposing the snow cover data and DEM data. The increased and decreased snow cover from the 57thday of 2000 to the 361stday of 2010 and seasonal variation in different aspects has been calculated to analyze the changes of snow cover in Kaidu river basin. The increased and decreased snow cover is calculated by getting the D-value of the present 8-day snow cover and the previous 8-day snow cover. It is identified as snow cover increased if D-value >0, otherwise, as snow cover decreased. The seasonal variation is the average of the increased and decreased snow cover from 2000 to 2010.The ratio of increased and decreased snow cover in different aspects in different seasons is calculated through dividing the snow cover in one aspect by the snow cover in all aspects.

4. RESULTS AND DISCUSSION

4.1 Temporal changes of snow cover in Kaidu river basin

The changes of the total snow cover area in Kaidu river basin from the 57th day of 2000 to the 361st day of 2010 are shown in Figure 2. The total snow cover increases from autumn to winter, and then decreases from spring to summer. The maximum of the total snow cover occurs in winter while the minimum of the total snow cover occurs in summer. The trend of the total snow cover area has been tested by Mann-Kendall (non-parametric test). The total snow cover area from 2000 to 2010 has a slightly increase trend, even though it is not significant.

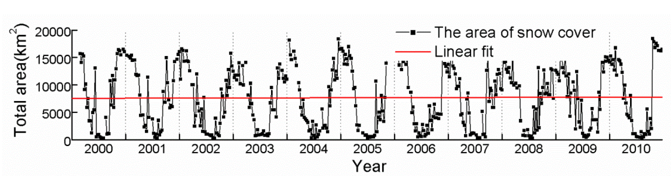

Fig. 2 The changes of the total snow cover area from 2000 to 2010 in Kaidu river basin.

4.2 Changes of the ratio of snow cover in different elevations

The changes of snow cover in different elevations from 2000 to 2010 are shown in Figure 3.The study area is divided into three zones based on elevation: < 2500 m, 2500 ~ 4000 m and > 4000 m. The ratio of the snow cover in a zone is calculated through dividing the snow cover area by whole area in the zone. From Figure 3, the ratio of snow cover decreases from high elevation to low elevation. The average ratio of snow cover in higher elevation (> 4000 m) is 0.76, while that in middle (2500 ~ 4000 m) and low (< 2500 m) elevation are 0.29 and 0.27, respectively.

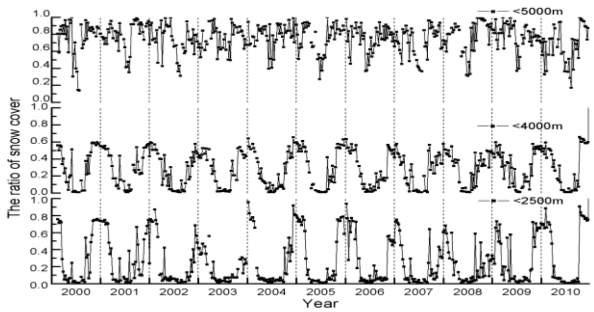

Fig. 3 The changes of the snow cover in different elevations from 2000 to 2010.

4.3 <u>Changes of snow cover in 8 different aspects</u>

According to MODIS data and DEM data, the changes of snow cover in different aspects are calculated. The changes of snow cover area in different aspects from 2000 to 2010 are different. In Figure 4, the slid black line is set as a reference line with snow cover area of 2000 km2. In these 8 different aspects, snow cover with less than 2000 km2 takes place in aspect 270°~315°. The greatest change of snow cover in all aspects occurs in aspect 45°~90°. In 8 different aspects, the greatest change of snow cover appears in winter.

However, the changes of the increased and decreased snow cover area with aspects in clockwise direction in different seasons are different. The ratios of increased and reduced snow cover changes with the total change of snow cover are used in this study to analyze the variation of increased and decreased snow cover with aspect in different seasons (Figure 5).

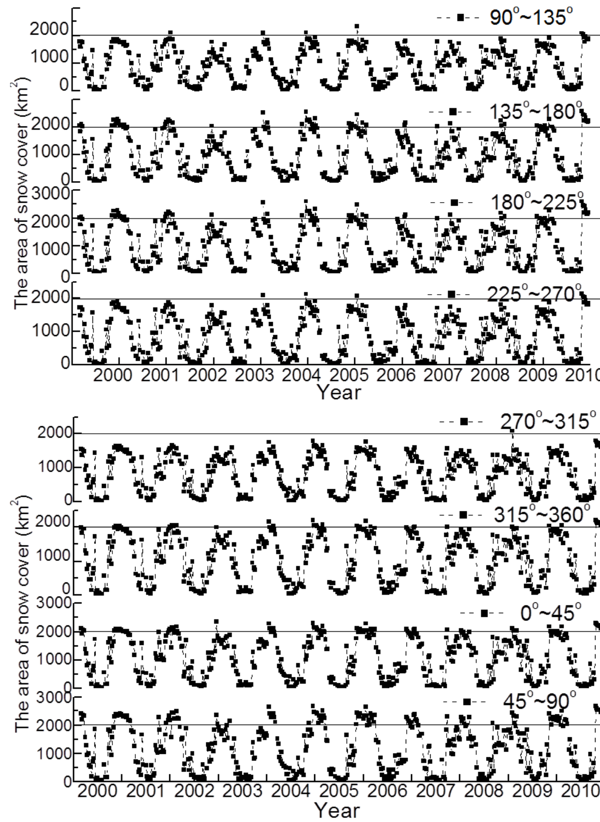

Fig. 4 The changes of the snow cover in different aspects from 2000 to 2010.

As the change of aspect in clockwise direction(east is set as 90°), the ratios of increased and decreased snow cover change climb up firstly and then decline in spring except that in aspect 90 ~ 135°. The ratio of increased snow cover change is less than the ratio of decreased snow cover change in different aspects. Both of the increased and decreased snow cover change has the maximum ratio in aspect 270° ~ 315°. The maximum ratio of increased snow cover change is 15.86%, while the maximum ratio of decreased snow cover change is 23.61%. The minimum ratios of increased and decreased snow cover change are in aspect 0° ~ 45° with value of 12.96% and in aspect 135° ~ 180° with value of 17.77%, respectively. The variation of the increased and decreased snow cover change in autumn is similar to that in spring. The ratio of increased snow cover change is more than that of decreased snow cover change in autumn. The maximum ratio of increased snow cover change is 24.06% in aspect 315° ~ 360°, while the maximum ratio of decreased snow cover change is 16.04% in aspect 270° ~ 315°. The minimum ratio of increased snow cover change is 19.38% in aspect 180° ~ 225°, while the minimum ratio of reduced snow cover change is 14.63% in aspect 0° ~ 45°. In summer, the ratios of increased and decreased snow cover change present decreasing – increasing – decreasing trends, while they show contrary patterns in winter, i.e. an increasing – decreasing - increasing. Both of the ratios of increased and decreased snow cover have the minimum ratio in aspect 135° ~180° in summer. The minimum ratios of increased and decreased snow cover change are 7.82% and 7.76%, respectively. In winter, the ratio of snow cover change shows an increasing-decreasing-increasing pattern. The ratio of increased snow cover change is less than the ratio of decreased snow cover change. The ratios of increased snow cover change are less than the ratios of decreased snow cover change in every season except for that in autumn.

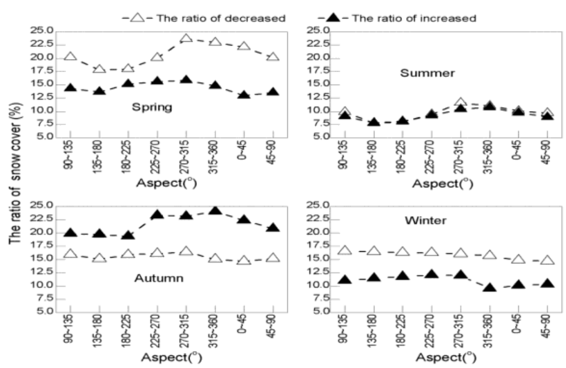

Fig. 5 The results of the ratio of change area for snow cover in different seasons

5. CONCLUSIONS

The changes snow cover in Kaidu river basin has a slightly increased trend even though it is not significant from 2000 to 2010. In different elevations, the ratios of snow cover accounting for the whole area are different. The ratio of snow cover in high elevation is higher than that in middle elevation, while the ratio in middle elevation is higher than that in low elevation. With the change of snow cover area in 8 different aspects from 2000 to 2010, the snow cover areas are less than 2000 km2 in aspect 270°~315°. The changes of snow cover in aspect 45°~90° are higher than in other aspects. The snow cover change which is higher than 2000 km2 mostly occurs in winter. Due to the snowmelt period in spring, the ratio of decreased snow cover change is more than the ratio of increased snow cover change. In autumn, because the temperature is gradually decreased, the ratio of increased snow cover change is greater than the ratio of decreased snow cover change. In summer, as a result of stable period of snow cover, the ratio of increased snow cover change is almost equal to the ratio of decreased snow cover change. In winter, because of low temperature, snowfall is the main form of precipitation. The snow cover area keeps in an almost steady state, i.e., the snow cover changes little in winter. However, according to the redistribution of the blowing snow which is controlled by wind and topography, the ratio of increased snow cover is less than the ratio of decreased snow cover. Overall, the ratio of increased snow cover is less than the ratio of decreased snow cover. According to the results of present studies, climate change may be the main reason for this result.

Because the image resolution of MODIS is 500m×500m, the resolution of aspect data generated by DEM which resolution is 90m×90m has been resampled to 500m×500m. The resample process makes the aspect data have error that will affect the accuracy of statistical results of snow cover in different aspects. In addition, the snow cover of different aspects are calculated by averaging the aspect from 0° to 360°.

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