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Analysis of Snow Depth and Temporal-spatial Distribution Along Tianshan Highway Based on MODIS Data

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Abstract. Most of Tianshan highway is located in Xinjiang where is the high and cold mountain area. Drifting snow and other disaster continue to occur, seriously affecting road traffic. Conventional monitoring is difficult to meet the emergency needs due to the influence of climate, topography, etc. The article selected MODIS data to inverse snow depth and temporal-spatial distribution in Dushanzi-Kuqa region of Tianshan Highway in recent years. Analysis revealed that the snowfall mainly was concentrated from the end of October to the beginning of April in the next year. The snow area is the least in summer of July, but the largest in winter, accounting for about 35.7% of the entire study area, the snow depth in most areas at 12 to 15 cm, the maximum snow cover depth is about 23 cm in the Dushanzi region of Wusu County. The results of study has a very important theoretical and practical significance to monitoring and control of diseases.

Introduction

Tianshan highway known as Duqa road (Dushanzi--Kuqa area in northern Xinjiang), is a important traffic line in Xinjiang province, most located in high and cold mountain area with elevation higher than 2000 meters. There are complex geological textures, steep landform, many folds and faults on the way. Consequent disaster happened by the influence of landform, geological conditions, climate and environment, construction-funds, technology, especially the drifting snow disaster, geohazard, floods and so on. Snowslide and drifting snow disaster as a result of accumulative snow often block and damage roads. Some part of Tianshan highway can only maintain 3-4 months traffic per year, which hinder the development of the national economy.

Snow cover is an important factor in the process of global climate change [1]. Because of the effect of climate and the topography, traditional monitoring method is difficult to meet emergency need. With the development of the space-technology, remote sensing has been used to extract large areas of snow disaster. Remote sensing extract the snow information is based on the high reflectance of snow in the visible band and low in the near infrared band, and snow cover area and depth also can be obtained by regression equations. Previous scholars had used the remote sensing data to research snow cover[2-8]. Such as MA Yonggang used the moderate resolution imaging spectroradiometer (MODIS) snow cover products to extracted the snow cover information during the last 10 years in Xinjiang and evaluated the accuracy of MOD10A2 products [4]; Wang Lihong used NOAA/AVHRR to get the snow cover information in na-qu of Tibet in February to March, 1995, and it's almost same with the report of the local government[5]; Zhou Yongmei used the AVHRR to estimate the snow depth and area, and verify its accuracy[6]; Wang Xing used the July 2003 to March 2005 MODIS data to detect the snow cover, provided is effective[8]. Predecessors' research results show that the spatial resolution and the inverse algorithms of snow of MODIS data is better than the AVHRR data[9]. Basis on the analysis of remote sensing data sources and environment of study area, the article showed how to use middle resolution of MODIS to research the space-time distribute and depth of snow.

The Study Area

Tianshan highway was constructed in 1969 and finished in 1983, is a main traffic trunk lining the north and south Xinjiang area, traversing Tielimaiti, Laerdun, Yuximolegai, Haxilegen areas and Bayinbuluke, Gongnaisi and Qiaoerma grassland, the total 532Km. Most of Tianshan road sits at those areas higher than 2000m elevation, there are complex geological textures, steep landform, many folds and faults, outcrops, forceful physical-chemical erosion on the way. Vegetation is exiguous, mainly in coniferous forest and grassland, alpine cold vegetation. Regional weather belongs to temperate continental arid mountain climate, temperature difference of day and night and four seasons are large, the highest temperature ≥ 30 ℃, the lowest temperature ≤ -40 ℃, rainy seasons maintain from May to September, most are persistent rainstorm weather; snow season mainly from October-May. The average temperature of areas around Tianshan road is below zero. Abundant snowfall accumulated into deep snow, provides the material basis for avalanche of this region. Distribution of seasonal accumulated snow has obvious regional difference of vertical and horizontal direction. By the limited of construction funds, technology and other factors, coupled with the complex terrain, bad geological and climate factors, consequent diseases happened frequently, affecting the traffic seriously.

Inversion of Snow Depth

Inversion Principle of Snow Depth

With the development of technology, remote sensing is widely used in real-time monitoring snow cover[10-13]. By spectrum curve analysis, snow has higher reflectivity in visible band and lower reflectivity in shortwave and infrared band, snow information can be extracted by using spectral differences. At present, AVHRR and MODIS data is used in optical remote sensing. Compared with AVHRR, MODIS has higher time resolution and spatial resolution. Especially MODIS can provide daily and synthesis snow product, has wide spectrum and narrow channel, it is also better for solving the AVHRR sensor saturation problems caused by high reflectivity of new snow[14,15]. MODIS snow product is improved to monitoring snow algorithms, and improve the sensitivity of snow and reduce the influence of atmospheric, solar angle, observation angle, cloud, provide global continuous time and space data of snow. The third-class product including 1-day product MOD10A1 with 500m resolution, 8-day synthesis product MOD10A2 with 500m resolution and 1-day product MOD10C1 with 5000m resolution, 8-day synthesis product MOD10C2 with 5000m resolution and 8 days synthetic products MOD10C2 with 5km resolution.

There are correlation between snow depth and reflected spectrum of snow. For example, Giddings etc. used specific instrument to test the relevant between snow depth and reflected spectrum. The result showed, when the underlying surface is black that is completely absorbed, and the snow depth is less than 30cm, the reflectivity of snow is increase with snow depth. When the snow depth more than 30cm, the reflectivity of the surface with the snow depth increasing tends to slow change, and gradually become saturated[14]. If we not consider the impact such as the atmosphere in the clear weather, there is a following relationship of the solar radiation reach to the snowy surface:

$$Rsun = Rsa + Rsr + Rua + Rur + Rga + Rgr \tag{1}$$

$Rsun$ is the total sun radiation of the pixel, Rsa is the absorbed radiation of the snow grains, Rsr is the reflected radiation of the snow grains, Rua is the absorbed radiation of surface underlying snow grains, Rur is the reflected radiation of surface underlying snow grains, Rga is the absorbed radiation of the objects not covered by the snow, Rgr is the reflected radiation of the objects not covered by the snow. Meanwhile, received the reflected radiation by the satellite has the following relationship:

$$Rsat = Rsr + Rur + Rgr \tag{2}$$

$Rsat$ is the reflected radiation received by the satellite. Rsr is the main radiation when in the visible and near-infrared bands, however, in the short infrared bands, Rsa is the main radiation.

Inversion of Snow Depth Using MODIS

The analysis shows that MODIS band 1 and band 3 are more suitable as an inversion of snow depth, by the analyzing spectral reflectance value of band 1 and band 3 with snow depth data of 80 samples in 35 sites, building the inversion regression equation of snow depth (Formula 3).

$$S = -0.18 + 15 \times ch1 + 24 \times ch3 \tag{3}$$

S is the snow depth, $ch1$ and $ch3$ is the reflected value of MODIS band 1 and band 3.In the inversion of snow depth, selecting the snow product of three-class data MOD10A2 with eight days synthesis (Maximum Snow Cover) in 2010 (Figure 1). Using of the mathematical inversion model of snow depth (Formula 3), producing the snow depth map in the study area (Figure 2). By analyzing, the snow depth is at 12-15cm in the most of highway areas, the deepest place is located in Dushanzi region of WuSu country, and the Maximum place reaches 23cm.

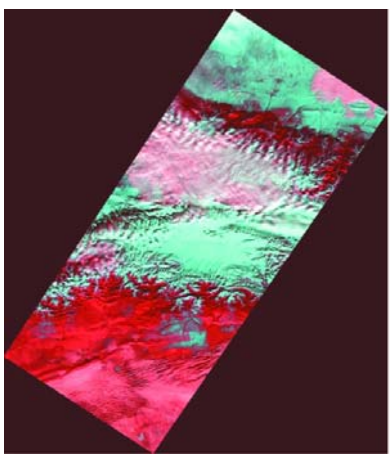


Figure 1. The 337th day image data of study area in 2010.

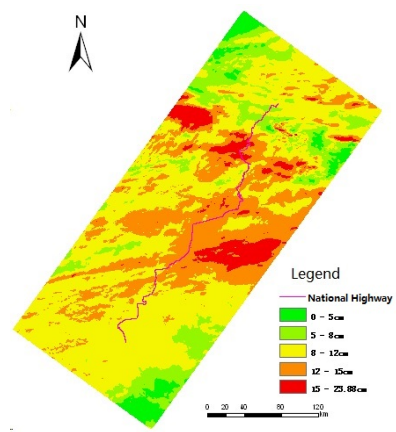


Figure 2. The 337th day snow depth of study area in 2010.

The Research of Snow Cover in Time and Space Distribution

In this paper, the distribution of snow-cover area is analyzed by MODIS data from 2002 to 2011 (figure 3). The seasonal change of snow-cover area is significant. Snowfall are mainly concentrated in the end of October to the April of next year, so the snow-cover area reach the peak form mid-October to early March, while snow-cover area declines sharply as the rise of temperature from April to June, so snow-cover area reaches the minimum as its temperatures continuing to rise from early June to October. The maximum annual average of snow-cover area is 2006 year, and covers an area of 27413.2km^2, accounting for 17.2% of the study area. But the Minimum value is 2007 year, and covers area of 24221.3 km^2, accounting for 15.1% .

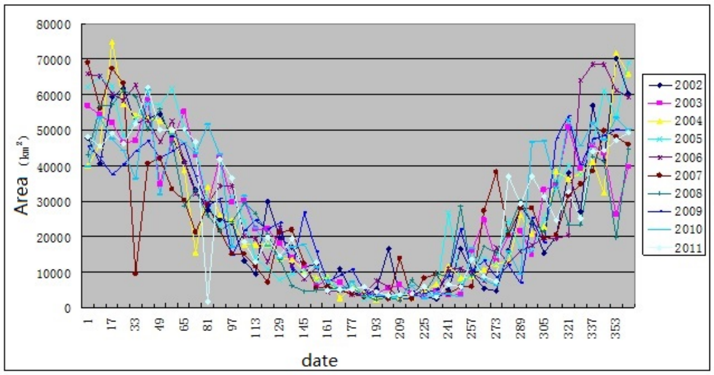
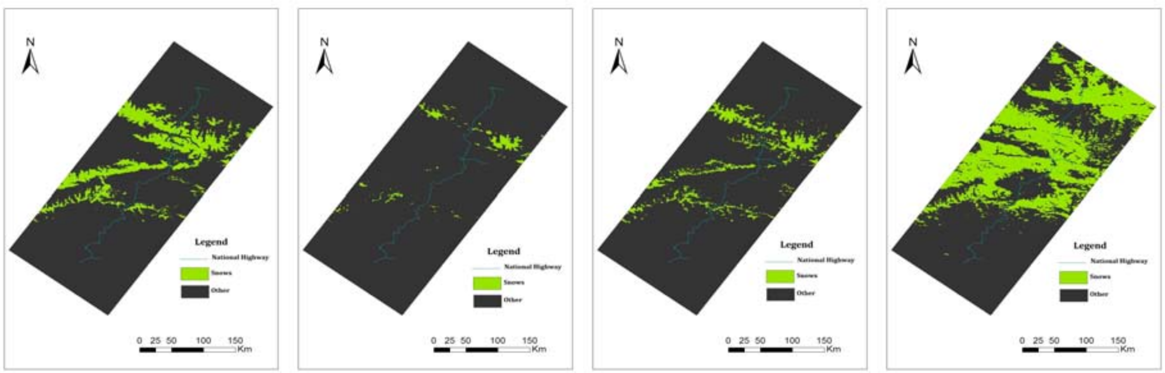


Figure 3. Snow area change over 10 years.

Snow cover was analyzed according to the four seasons in 2010. From the last year's the 345 to 57 days belong to the winter, the 153 ~ 65 days is the spring, the161 ~ 249 days is the summer, the 257 ~ 337 days is the fall. Through analysis, we can see the changes of snow cover at all seasons (figure 4) :



a.Spring b.Summer c.Fall d.Winter

Figure 4. Changes of snow in 2010.

In Spring: The distribution of snow is wider, accounting for 12.29% of the total area. Snow mainly distributed in the northern in the study area, and in the northern of YiLianhabierga mountain which located in the central of the study area. But the snow distribution in the high altitudes of the mountain is less. Youledusi basin in the middle of the research area and the southern of XinJiang regions do not have snow.

In Summer: the smallest snow area is the summer, accounting for 1.86% of the total area in the study area. Snow mainly distributed in high mountains of YiLianhabierga mountain, the south of Keketieke mountain with a small amount of snow.

In Autumn: the snow distributed less, accounting for 6.29% of the total study area. Snow mainly distributed in the higher mountains, such YiLianhabierga mountain which wider distribution. Central of the study has snow distribution in the high altitudes of Keketieke mountain,but the area of Youledusi basin have less snow or no snow by the impacts of climate.

In Winter: The most extensive distribution, snow mainly distributed in northern and central, accounting for 35.7% of the total area in the study area. The northern area in YiLianhabierga mountain basically covered by the snow, but snow is less in the south slope of high altitude YiLianhabierga mountain and Youledusi basin. At the same time, due to the north water vapor is block by mountain, snow of southern Xinjiang region is rarely distributed in the study area.

Conclusion

Using remote sensing technology can undertake the task of large range, real-time monitoring of snow, and has obvious advantages especially in bad weather and treacherous terrain. Tianshan highway is located in the alpine region in Xinjiang, avalanche area along the road, coupled with drifting snow disaster occurring frequently, which seriously affect the highway traffic. This paper inverses snow depth and distribution of the Tianshan road in northern of Xinjiang Dushanzi - kuqa area by MODIS remote sensing data. Analysis shows that the maximum snow area appeared in 2006, 27413.2 km^2area, accounting for 17.2% of the total area in the study area, 2007 snow-cover area is smallest, about 24221.3 km^2, accounting for 15.1% of the total area. The analysis of the snow-cover area in 2010, has wider distribution in spring, accounting for 12.29% of the total area; Summer snow area is smallest, accounted for 1.86%. In the fall, snow distribution is less, accounting for 6.29% of the area. In winter, snow is widely distributed, accounted for 35.7%, most area of the snow depth is 12 to 15 cm, the deepest in WuSu county of dushanzi mountain, about 23 centimeters.

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