Variations in Snow Cover Days and Topographic Differentiation in the Sanjiangyuan Region, 2001-2020 Postprint

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Abstract

Based on daily cloud-free remote sensing products of snow cover area and meteorological observation data, we analyzed the horizontal and vertical distribution characteristics and variation patterns of snow cover days in the Sanjiangyuan region from 2001 to 2020, and conducted a correlation analysis between snow cover days and temperature and precipitation. The results show that: (1) From 2001 to 2020, the snow cover days in the Sanjiangyuan region exhibited a distribution pattern of high in the west and low in the east, with high-altitude mountains greater than basin plains. The mean snow cover days in high-altitude mountain areas were generally greater than 200 d, 85.48% of the region showed a fluctuating increasing trend in snow cover days, the proportion of significantly increasing areas was 16.59%, and the average increase rate was 0.98 $d \cdot a^{-1}$. (2) There are obvious altitude and aspect differentiations in snow cover days and their variation trends. Snow cover days increase exponentially with altitude. Areas with lower altitude (<3.0 km) have fewer snow cover days, show a decreasing trend, and the decreasing rate accelerates with increasing altitude; high-altitude areas have more snow cover days and show an increasing trend, but when altitude exceeds 4.4 km, the increasing rate of snow cover days slows down with altitude, and areas at 5.5–6.0 km show a decreasing trend in snow cover days. There exists a certain degree of "altitude dependence" in snow cover days in high-altitude regions. Snow cover days on north-facing slopes are greater than those on south-facing slopes, and west-facing slopes are greater than east-facing slopes, with northwest-facing slopes having the most snow cover days at 78.30 d. Snow cover days on all aspects show an increasing trend, with the fastest increase rate on west-facing slopes, reaching 1.04 $d \cdot a^{-1}$. (3) The obvious "warming and humidification" climate characteristic in the Sanjiangyuan region in the past 20 years is the main reason affecting the change in snow cover days, among which precipitation is the main driving factor. The increase in snow

cover days is closely related to the increase in precipitation, and snow cover days in high-altitude areas are more dependent on precipitation.

Full Text

Variation of Snow Cover Days and Topographic Differentiation in the Sanjiangyuan Area from 2001 to 2020

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Abstract

Based on daily cloud-free remote sensing products of snow cover area and meteorological observation data, this study analyzes the horizontal and vertical distribution characteristics and variation patterns of snow cover days in the Sanjiangyuan area from 2001 to 2020, and examines the correlation between snow cover days and temperature and precipitation. The results indicate that: (1) From 2001 to 2020, snow cover days in the Sanjiangyuan area exhibited a distribution pattern of higher values in the west and lower values in the east, with high-altitude mountainous regions showing greater snow cover days than basin plains. The mean snow cover days in high-altitude mountainous areas generally exceeded 200 days, with 85.48% of the region showing a fluctuating increasing trend. The significantly increasing area accounted for 16.59% of the total, with an average increase rate of 0.98 $d \cdot a^{-1}$. (2) Snow cover days and their variation trends showed significant altitudinal and aspect-dependent differentiation. Snow cover days increased exponentially with altitude. Areas at lower elevations (<3.0 km) had fewer snow cover days and exhibited a decreasing trend, with the rate of decrease accelerating as altitude increased. High-altitude areas had more snow cover days and showed an increasing trend, but the rate of increase slowed when altitude exceeded 4.4 km, with the 5.5–6.0 km range showing a decreasing trend. This indicates a certain degree of "altitude dependence" in snow cover days at high elevations. Snow cover days were greater on north-facing slopes than south-facing slopes, and greater on west-facing slopes than east-facing slopes, with northwest-facing slopes having the maximum value of 78.30 days. Snow cover days on all aspects showed increasing trends, with the fastest increase on west-facing slopes at 1.04 $d \cdot a^{-1}$. (3) The prominent climatic characteristics of the Sanjiangyuan area in recent decades constitute the primary factor influencing snow cover day variation, with precipitation being the main driving factor. The increase in snow cover days is closely related to increased precipitation, and high-altitude areas show stronger dependence of snow cover days on precipitation.

Keywords: Sanjiangyuan area; snow cover days; climate change; topographic differentiation; altitude dependence

1. Introduction

Snow cover plays a crucial role in controlling energy cycles, global water cycles, and material cycles, exerting significant impacts on regional and global socioeconomic development, ecological environments, and climate change. Snow cover days directly affect snow storage and the development and maintenance of modern glaciers, thereby regulating runoff in surrounding and downstream rivers and lakes. Additionally, snow cover days alter energy exchange processes in regional land-atmosphere systems and profoundly influence radiation and energy balance, making it one of the important variables in Earth system research. Studies have shown that the Sanjiangyuan area has experienced an average warming rate of $0.37°C \cdot (10a)^{-1}$ over the past 60 years, more than twice the global average [$0.16°C \cdot (10a)^{-1}$] and substantially higher than the same latitude [$0.19°C \cdot (10a)^{-1}$] and China as a whole [$0.28°C \cdot (10a)^{-1}$]. Since the 21st century, precipitation in the Sanjiangyuan area has increased significantly, with all subsource regions showing enhanced precipitation signals. Against this background, the impact of climate change on snow cover has attracted widespread attention from scholars both domestically and internationally through field investigations, meteorological station observations, remote sensing monitoring, and model simulations.

However, previous studies have primarily focused on the spatiotemporal evolution patterns and driving factors of snow cover, while research on the relationship between snow cover days and topographic factors, particularly altitude and slope aspect, remains insufficient. The complex terrain of the Tibetan Plateau inevitably leads to substantial differences in the distribution patterns and variation characteristics of snow cover days. Moreover, climate warming on the Tibetan Plateau exhibits an "altitude dependence" phenomenon, particularly between 3000–5000 m, but whether snow cover variation trends in the region also show altitude dependence remains unclear. Recent research indicates that with intensified global warming, snow depth in high-altitude areas has significantly decreased, exhibiting a certain degree of altitude dependence. Whether this phenomenon exists in the Sanjiangyuan area warrants further investigation.

Remote sensing technology, with its multi-scale, multi-temporal, multi-spectral, and multi-level characteristics, provides high-quality data sources for snow cover research in high-altitude mountainous areas. NOAA-AVHRR, MODIS, TM, FY series satellite data are commonly used snow cover remote sensing data sources, with MODIS snow cover products being widely applied. While remote sensing products offer high spatial resolution, they are affected by cloud cover that prevents identification of snow beneath clouds, posing a major obstacle to real-time snow monitoring, particularly in the Tibetan Plateau region where accuracy is compromised by terrain and mixed pixels. Therefore, there is an urgent need for a high-precision MODIS snow cover product for the Tibetan Plateau. The China 2001–2020 Snow Cover Area 500m Daily Cloud-Free Product Dataset has effectively improved snow cover area accuracy in mountainous regions, achieving complete cloud removal using a Hidden Markov algorithm and multi-source data fusion, making it highly applicable for snow cover day research in the topographically complex Sanjiangyuan area.

The Sanjiangyuan area (31°39 –36°12 N, 89°45 –102°23 E) is located in the hinterland of the Qinghai-Tibet Plateau, covering approximately 30.25$×10^{4}$ km^2 with an average altitude of 3500–4800 m. The terrain is complex, with an overall topography that is higher in the northwest and lower in the southeast. The Kunlun, Tanggula, Bayan Har, and Hoh Xil mountain ranges traverse the region, all exceeding 5000 m in elevation with permanent snow lines. The area is one of China' s concentrated glacier distribution zones, with widespread snow-capped mountains and glaciers. The Yangtze River, Yellow River, Lancang River, and Mekong River all originate here, and the region is densely covered with marshes, wetlands, and lakes, serving as an important water source conservation area for China and even East Asia, known as the "Chinese Water Tower." Glacial meltwater is an important recharge source. The Sanjiangyuan area has a typical plateau continental climate characterized by alternating cold and warm seasons, distinct wet and dry seasons, small annual temperature differences, large diurnal temperature differences, long sunshine hours, intense radiation, and weak seasonal distinctions. The region is dominated by alpine grasslands, wetlands, glaciers, and permanent alpine snow, forming an important ecological barrier and ecological regulation zone (Fig. 1 [Figure 1: see original paper]).

Therefore, based on daily cloud-free remote sensing products of snow cover area and meteorological observation data, this study analyzes the spatiotemporal distribution, evolution characteristics, topographic differentiation of snow cover day distribution and variation, and the response of snow cover days to climate change in the Sanjiangyuan area from 2001 to 2020 from three perspectives. The aim is to provide a scientific basis for rational utilization of ice and snow water resources, ecological security barrier construction, and high-quality green development in the Sanjiangyuan area.

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2. Data and Methods

2.1 Data Sources and Processing 2.1.1 China 2000–2020 Snow Cover Area 500m Daily Cloud-Free Product

The China 2001–2020 Snow Cover Area 500m Daily Cloud-Free Product was developed specifically for China' s snow cover characteristics. Based on MODIS reflectance products MOD/MYD09GA and using Landsat TM data as ground truth, combined with MODIS land cover classification product MCD12Q1, the product employs a multi-index snow discrimination algorithm developed under different land cover type conditions to effectively improve snow cover area accuracy in forested and mountainous areas. Complete cloud removal was achieved using a Hidden Markov algorithm and multi-source data fusion methods. The dataset is stored in HDF5 format, with each file containing 18 data elements including data values (0=land, 1=snow, 2=snow water equivalent interpolated snow, 3=inland water or ocean, 4=glacier, 255=fill value), start date, latitude and longitude, etc. The dataset is freely available from the National Cryosphere Desert Data Center and meets scientific research accuracy requirements.

2.1.2 Digital Elevation Model (DEM) Data

DEM data from the Shuttle Radar Topography Mission (SRTM) Version 003 were obtained from the USGS (https://lpdaac.usgs.gov/products/srtmgllv003/) with a spatial resolution of 90 m. The DEM data were used to investigate relationships between different topographic factors and the spatial distribution and variation characteristics of snow cover days. For overlay analysis, the DEM was resampled and reprojected to match the spatial resolution and projection of the snow cover data. Using ArcGIS software, altitude and aspect distribution maps were generated, with altitude divided into 14 levels from 0–6.5 km at certain intervals (Fig. 2a [Figure 2: see original paper]) and aspect divided into 8 categories at 45° intervals (Fig. 2b).

2.1.3 Meteorological Data

Daily temperature and precipitation data from 134 meteorological stations surrounding the Sanjiangyuan area from January 1, 2001 to December 31, 2020 were selected. The ANUSPLIN specialized climate interpolation software was used with the thin-plate spline function method to spatially interpolate the meteorological data, with DEM data as a covariate to improve interpolation accuracy. Gridded meteorological data with a spatial resolution of 500 m × 500 m were obtained and clipped to the study area. The distribution of meteorological stations in the Sanjiangyuan area is shown in Fig. 1, and the data were obtained from the China Meteorological Administration' s Comprehensive Meteorological Information Sharing Platform (CIMISS) after strict quality control, with accuracy and completeness meeting scientific research requirements.

2.2 Research Methods 2.2.1 Trend Analysis

Based on the least squares method, the interannual variation trend of snow cover days was calculated pixel by pixel using the formula:

$$\text{slope} = \frac{n \times \sum_{i=1}^{n} i \times \text{SCD}_i - \sum_{i=1}^{n} i \times \sum_{i=1}^{n} \text{SCD}_i}{n \times \sum_{i=1}^{n} i^2 - (\sum_{i=1}^{n} i)^2}$$

where slope represents the change rate, i is the year number from 1–20, and

SCD is the snow cover days in year i. When slope > 0, snow cover days show an increasing trend over the 20-year period; when slope < 0, snow cover days show a decreasing trend. The absolute value of slope indicates the magnitude of change. Finally, F-test was used for significance testing of the trend.

2.2.2 Partial Correlation Analysis

Partial correlation coefficients were used to analyze the correlation between snow cover days and temperature and precipitation while controlling for the effect of the other variable. The formula is:

$$R_{xy,z} = \frac{R_{xy} - R_{xz}R_{yz}}{\sqrt{(1 - R_{xz}^2)(1 - R_{yz}^2)}}$$

where R $_{,2}$ represents the partial correlation coefficient between snow cover days and precipitation when temperature is held constant (i.e., excluding the influence of temperature when analyzing the correlation between snow cover days and precipitation). R , R $_2$, and R $_2$ represent the correlation coefficients between snow cover days and precipitation, snow cover days and temperature, and temperature and precipitation, respectively. Finally, F-test was used for significance testing.

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3. Results and Analysis

3.1 Spatiotemporal Distribution and Evolution of Snow Cover Days

From 2001 to 2020, the spatial distribution of snow cover days in the Sanjiangyuan area showed significant regional differences, characterized by higher values in the west and lower values in the east, with high-altitude mountainous regions showing greater snow cover days than basin plains. The Hoh Xil Mountains, Tanggula Mountains, Anyemaqen Mountains, Bayan Har Mountains, and Geladandong Glacier were high-value areas for snow cover days, with mean values generally exceeding 200 days and some areas even exceeding 300 days. In contrast, the southern area around Qinghai Lake, Gonghe Basin, and central Hoh Xil had snow cover days of less than 100 days (Fig. 3a [Figure 3: see original paper]). This pattern occurs because the western and central parts of Sanjiangyuan are affected by the convergence of cold northwestern air and warm, moist air from the southwestern Indian Ocean and Bay of Bengal, which easily creates weather conditions favorable for snowfall. Meanwhile, low temperatures caused by high altitude and local terrain and circulation effects facilitate snow replenishment and maintenance, resulting in higher snow cover days. In contrast, the Gonghe Basin and central Hoh Xil are blocked by numerous high mountains that weaken monsoon influence, and altitude also affects temperature and precipitation characteristics, collectively leading to lower snow cover days.

Overall, snow cover days in the Sanjiangyuan area from 2001 to 2020 showed a fluctuating increasing trend with an interannual variation rate of 0.98 $d \cdot a^{-1}$ ($P < 0.1$) (Fig. 3b [Figure 3: see original paper]). Snow cover days increased in 85.48% of the region, with significantly increasing areas accounting for 16.59% of the total. The fastest increase occurred in Maduo County in the Yellow River source region, with an average increase rate of 2.03 $d \cdot a^{-1}$, followed by Chengduo, Dari, Yushu, Qumarlêb, Maqên, and Jiuzhi counties, all with average increase rates exceeding 1.00 $d \cdot a^{-1}$. The most significant increases were observed in central Maduo, southern Dari, northwestern Qumarlêb, southeastern Zhiduo, northern Yushu, northern Maqên, and southwestern Xinghai. However, snow cover days showed significant decreasing trends in some local high-altitude mountain areas, particularly at the edges of the Geladandong Glacier and some high-altitude mountain regions, with significantly decreasing areas accounting for 0.44% of the total and a decrease rate of 3.32 $d \cdot a^{-1}$ (Fig. 4 [Figure 4: see original paper]). Research indicates that water vapor transport from the southwest to Sanjiangyuan has strengthened over the past 30 years, especially since the 21st century, with precipitation increasing significantly, which may be the main reason for the significant increasing trend in snow cover days in central Sanjiangyuan. The significant decrease in snow cover days at the edges of the Geladandong Glacier and some high-altitude mountain regions may be related to the altitude dependence of temperature increase and the spatial pattern differences in precipitation.

3.2 Topographic Differentiation of Snow Cover Days Snow cover days in the Sanjiangyuan area showed substantial differences across various altitude levels. Overall, snow cover days increased exponentially with altitude ($R^2 > 0.92$). The altitude range of 3.0–5.2 km was the main distribution zone for snow cover days, accounting for 93.67% of the area. Areas below 3 km had snow cover days of less than 10 days; the 3.0–5.2 km range had snow cover days of 11.71–107.27 days, increasing in a stepwise manner; the 5.2–5.5 km range had 153.73 days; the 5.5–6.0 km range had 284.74 days; and the 6.0–6.5 km range had the highest value of 328.01 days (Fig. 5 [Figure 5: see original paper]). Analysis suggests that lower altitude (<3.0 km) regions have higher temperatures that are unfavorable for snow preservation, resulting in relatively few snow cover days. The 3.0–5.5 km altitude range has lower temperatures and is affected by terrain-induced atmospheric circulation that increases precipitation, creating conditions favorable for snow accumulation. Areas above 5.5 km are mostly snow-capped mountains and glaciers, representing permanent or semi-permanent snow zones, thus having the highest snow cover days.

As shown in Fig. 6, areas below 3.0 km in the Sanjiangyuan region showed a decreasing trend in annual average snow cover days from 2001 to 2020, with the rate of decrease accelerating with altitude. The 2.5–3.0 km range had a relatively fast decrease rate of 0.09 $d \cdot a^{-1}$, with significantly decreasing areas accounting for 4.70% of the region. The 3.0–5.5 km range showed increasing trends in snow cover days, with the increase rate accelerating with altitude up to 4.4 km, reaching 1.34 $d \cdot a^{-1}$ in the 4.2–4.4 km range, where significantly increasing areas accounted for 22.59%. Above 4.4 km, the average increase rate slowed with altitude; the 5.5–6.0 km range showed a decreasing trend with a rate of 0.13 $d \cdot a^{-1}$, with significantly decreasing areas accounting for 11.83%. This indicates a certain degree of "altitude dependence" in snow cover day variation at high altitudes. The 6.0–6.5 km range showed a faster increase rate of 1.14 $d \cdot a^{-1}$, with significantly increasing areas accounting for 63.97%. The 5.5–6.0 km range is mostly at the edges of glaciers and snow-capped mountains, suggesting that under overall abundant water vapor conditions, glacier and snow mountain edges still show retreat trends due to warming.

Analysis of area proportion and snow cover days by slope aspect in the Sanjiangyuan area reveals significant differences in annual average snow cover days among different aspects. Although the region is dominated by north-facing, south-facing, northeast-facing, and southwest-facing slopes, with area proportions of 16.53%, 16.17%, 15.28%, and 13.01% respectively (Fig. 7a [Figure 7: see original paper]), the multi-year average snow cover days showed a pattern of north > south and west > east. Northwest-facing slopes had the maximum snow cover days of 78.30 days, followed by north-facing (76.84 days), northeast-facing (73.98 days), west-facing (71.14 days), east-facing (70.61 days), southeast-facing (62.94 days), southwest-facing (59.62 days), and south-facing slopes (55.68 days) (Fig. 7b [Figure 7: see original paper]). Snow cover distribution is primarily influenced by temperature, terrain, and water vapor transport, while slope aspect affects snow distribution mainly through its impact on solar radiation and terrain-induced airflow uplift. Although the region is affected by the convergence of cold northwestern air and warm, moist air from the southwestern Indian Ocean and Bay of Bengal, southwest-facing warm, moist airflow results in greater snowfall on west-facing slopes than east-facing slopes, which is the main reason why west-facing slopes have more snow cover days than east-facing slopes.

From 2001 to 2020, snow cover days on all aspects in the Sanjiangyuan area showed increasing trends, with the fastest increase on west-facing slopes at 1.04 $d \cdot a^{-1}$, followed by northwest-facing (1.02 $d \cdot a^{-1}$), northeast-facing (1.01 $d \cdot a^{-1}$), east-facing (0.10 $d \cdot a^{-1}$), north-facing (0.99 $d \cdot a^{-1}$), southwest-facing (0.95 $d \cdot a^{-1}$), southeast-facing (0.92 $d \cdot a^{-1}$), and south-facing slopes (0.89 $d \cdot a^{-1}$) (Fig. 8a [Figure 8: see original paper]). Analysis of variation direction and magnitude shows that all aspects were dominated by non-significant increases, with area proportions of 68.25%–69.82%, while significantly increasing areas accounted for 15.83%–17.07%, showing small differences (Fig. 8b [Figure 8: see original paper]). South-facing slopes, affected by intense solar radiation, experience rapid snowmelt that is unfavorable for snow accumulation. Under the background of enhanced water vapor transport from the southwest, south-facing slopes showed the slowest increase rate. Compared with northwest-facing slopes, west-facing slopes are less affected by wind-blown snow from cold northwestern air, thus showing the fastest increase rate.

3.3 Response of Snow Cover Days to Climate Change From 2001 to 2020, the annual average temperature in the Sanjiangyuan area ranged from 0.74°C to 1.59°C, and annual precipitation ranged from 383.04 mm to 608.07 mm. Over the past 20 years, the region experienced significant warming at a rate of 0.35°C $\cdot$ (10a)$^{-1}$ ($P < 0.01$) and a significant increase in precipitation at a rate of 49.13 mm $\cdot$ (10a)$^{-1}$ ($P < 0.05$), with large interannual fluctuations. Comparison with annual snow cover days reveals that "cold-wet" years (such as 2008, 2019, and 2020) had more snow cover days, while "warm-dry" years (such as 2010, 2015, and 2016) had fewer snow cover days (Fig. 9 [Figure 9: see original paper]), indicating that the region' s prominent climatic characteristics are a major factor affecting snow cover day variation.

Further analysis of partial correlation coefficients and significance distributions between snow cover days and concurrent temperature and precipitation shows that 86.18% of the region exhibited negative correlations between snow cover days and temperature, with 36.38% showing significant negative correlations ($P < 0.1$), mainly distributed in central and eastern Sanjiangyuan. This indicates that temperature has a relatively large impact on snow cover days in these areas, with temperature increases leading to reduced snow cover days. In contrast, northern Zhiduo, Tanggula Town, western Zadoi, southern Dari, and parts of Jiuzhi and Baima showed low correlations between snow cover days and temperature (Fig. 10a–b [Figure 10: see original paper]). Regarding precipitation, 95.71% of the region showed positive correlations between snow cover days and precipitation, with 60.18% showing significant positive correlations ($P < 0.1$), mainly distributed across most areas except northern Zhiduo, Tanggula Town, western Zadoi, southern Nangqên, southern Dari, and parts of Jiuzhi and Baima. This indicates that increased precipitation is the main reason for increased snow cover days in these regions (Fig. 10c–d [Figure 10: see original paper]).

The average partial correlation coefficient between snow cover days and precipitation was 0.42 ($P < 0.05$), with the coefficient increasing linearly with altitude. The average partial correlation coefficient between snow cover days and temperature was -0.28, with the coefficient decreasing linearly with altitude (Fig. 11 [Figure 11: see original paper]). This demonstrates that precipitation is the main driving factor for snow cover day variation in the Sanjiangyuan area. The increase in snow cover days over the past 20 years is closely related to increased precipitation, and the correlation between snow cover days and temperature and precipitation shows altitude dependence, with high-altitude areas showing stronger dependence on precipitation and low-altitude areas showing stronger dependence on temperature.

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4. Conclusion

Based on daily cloud-free remote sensing products of snow cover area and meteorological observation data, this study analyzed the horizontal and vertical distribution characteristics and variation patterns of snow cover days in the Sanjiangyuan area from 2001 to 2020, and examined the correlation between snow cover days and temperature and precipitation. The main conclusions are as follows:

(1) From 2001 to 2020, snow cover days in the Sanjiangyuan area showed a distribution pattern of higher values in the west and lower values in the east, with high-altitude mountainous regions having greater snow cover days than basin plains. High-value areas were concentrated in the Hoh Xil Mountains, Tanggula Mountains, Anyemaqen Mountains, Bayan Har Mountains, and Geladandong Glacier, with mean snow cover days generally exceeding 200 days. Snow cover days increased in 85.48% of the region, with significantly increasing areas accounting for 16.59% and an average increase rate of 0.98 $d \cdot a^{-1}$. The most significant increases occurred in central Maduo, southern Dari, northwestern Qumarlêb, and other central Sanjiangyuan regions.

(2) The average snow cover days and their variation trends showed significant altitudinal and aspect-dependent differentiation. Snow cover days increased exponentially with altitude overall. Lower altitude (<3.0 km) regions had fewer snow cover days and showed decreasing trends, with the rate of decrease accelerating with altitude. High-altitude regions had more snow cover days and showed increasing trends, but the average increase rate slowed when altitude exceeded 4.4 km, with the 5.5–6.0 km range showing decreasing trends. This indicates a certain degree of "altitude dependence" in snow cover days at high altitudes. Under overall abundant water vapor conditions, glacier and snow mountain edges still show retreat trends due to warming. Snow cover days were greater on north-facing slopes than south-facing slopes, and greater on west-facing slopes than east-facing slopes, with northwest-facing slopes having the maximum value of 78.30 days. Snow cover days on all aspects showed increasing trends, with the fastest increase on west-facing slopes at 1.04 $d \cdot a^{-1}$, followed by northwest-facing, northeast-facing, east-facing, north-facing, southwest-facing, and southeast-facing slopes.

(3) From 2001 to 2020, the Sanjiangyuan area experienced significant warming at a rate of $0.35°C \cdot (10a)^{-1}$ and a significant precipitation increase at a rate of $49.13\ mm \cdot (10a)^{-1}$. The region' s prominent climatic characteristics are one of the main factors affecting snow cover day variation. Precipitation is the main driving factor for snow cover day variation in the Sanjiangyuan area. The increase in snow cover days over the past 20 years is closely related to increased precipitation, and the correlation between snow cover days and temperature and precipitation shows altitude dependence, with high-altitude areas showing stronger dependence on precipitation.

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Note: Figure translations are in progress. See original paper for figures.