Snow Cover Distribution and Change Trends in Inner Mongolia from 2001 to 2016 Based on MODIS Data (Postprint)

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Abstract

Snowmelt water constitutes one of the critical water resources in arid regions, and monitoring variations in snow cover distribution is essential for the rational utilization of regional snow and ice resources as well as disaster prevention and mitigation. Based on MOD10A2 snow cover data from 2001 to 2016 for the Inner Mongolia region, zonal extraction was conducted on the study area to analyze intra-annual and inter-annual variation characteristics of snow cover at different altitudes, and to examine the underlying causes of its distribution changes in conjunction with meteorological factors of air temperature and precipitation. The results indicate that: the intra-annual distribution of both snow cover area and snow cover fraction exhibits a unimodal pattern; the snow cover period across ten elevation zones extends from September to May of the following year, with peak values occurring in winter; the critical altitude for the increase and decrease of snow cover fraction ranges between 952–1,114 m. The snow cover area in different elevation zones demonstrates an overall inter-annual variation pattern of 'increase–decrease–increase–decrease' during spring, summer, and autumn, whereas winter shows an overall pattern of 'decrease–increase–decrease' . Snow cover area is influenced by the interaction between precipitation and air temperature, with altitude potentially playing an indirect role. In the Inner Mongolia region, snow cover fractions in both spring and winter exhibit significant positive correlations with winter precipitation, while snow cover fractions across all seasons are generally negatively correlated with temperature.

Full Text

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Abstract

Meltwater is one of the most important water sources in arid areas. Monitoring changes in snow cover distribution is crucial for the utilization of regional ice and snow resources and the prevention of ice and snow disasters. In this study, we analyzed snow cover collection across different altitude zones in Inner Mongolia using MOD10A2 snow cover data from 2001 to 2016. The annual and inter-annual variations of snow cover distribution in different altitude zones and their influencing factors were examined in combination with meteorological data (temperature and precipitation). The results revealed that the annual distribution curves of both snow cover area and snow coverage rate were unimodal. Snow cover duration in the ten altitude zones extended from September to the following May, with peak snow depth occurring in winter. The critical elevation threshold for increases and decreases in snow coverage rate was between 952-1114 m a.s.l. Inter-annual snow cover changes in different altitude zones followed an "increase-decrease-increase-decrease" pattern in spring, summer, and autumn, but a "decrease-increase-decrease" pattern in winter. Snow cover area was affected by the interaction between precipitation and air temperature, and might also be indirectly influenced by altitude. In Inner Mongolia, snow coverage rate in spring and winter showed a significantly positive correlation with winter precipitation, but a fundamentally negative correlation with temperature.

Keywords: MOD10A2; air temperature; precipitation; snow coverage rate; snow cover area; Inner Mongolia

3 Results and Analysis

3.1 Spatial Distribution Characteristics

Analysis of snow cover distribution across different altitude zones revealed distinct vertical zonation patterns. The critical elevation range of 952-1114 m represented a transitional zone where snow coverage rate changed significantly. Above this elevation, snow cover remained relatively stable, with coverage rates

approaching 100% during winter months. Below this threshold, snow cover exhibited greater variability and increased sensitivity to temperature fluctuations.

The altitude zones below 349 m and between 349-560 m displayed the most dynamic snow cover patterns, with substantial seasonal variations in coverage rates. In contrast, zones above 1420 m maintained persistent snow cover throughout the winter season. The spatial analysis demonstrated that elevation fundamentally controls snow cover distribution patterns, with secondary influences from local topography and vegetation.

3.2 Temporal Variation Characteristics

Temporal analysis of snow cover from 2001 to 2016 revealed significant inter-annual and seasonal variations across all altitude zones. The annual cycle typically commenced in September, reached maximum extent during winter months (December-February), and persisted until May of the following year.

Seasonal patterns exhibited distinct characteristics: - **Spring, Summer, and Autumn:** Followed an "increase-decrease-increase-decrease" pattern - **Winter:** Followed a "decrease-increase-decrease" pattern

The most pronounced variations occurred in mid-altitude zones (560-1420 m), where snow cover was most sensitive to climatic fluctuations. Low-altitude zones (<560 m) showed inconsistent snow cover with high inter-annual variability, while high-altitude zones (>1420 m) demonstrated stable, persistent snow cover.

Correlation analysis with meteorological factors indicated that precipitation and temperature jointly influenced snow cover dynamics. Winter precipitation showed a strong positive correlation with snow coverage rate in both winter and the subsequent spring. Conversely, temperature exhibited a negative correlation with snow cover, particularly during the accumulation and melt phases.

Table 1. Altitude zones based on SRTM DEM data

Altitude Range (m)	Area (km^2)	Percentage (%)
80-349	13.06	13.52
349-560	20.25	14.53
560-767	19.26	11.66
767-952	11.43	11.85
952-1114	17.71	12.71
1114-1269	16.85	10.20
1269-1420	-	-
1420-1603	-	-
1603-1948	-	-
1948-3618	-	-

Table 4. Correlation coefficient between snow coverage rate and air temperature and precipitation in different seasons

Altitude Zone	Spring Temp	Spring Precip	Summer Temp	Summer Precip	Autumn Temp	Autumn Precip	Winter Temp	Winter Precip
80-349 m	0.680**	-0.246	0.149	-0.059	-0.093	0.224	0.263	0.123
349-560 m	0.309	-0.074	0.305	0.477	-0.681**	-0.483*	-0.130	-0.296
560-767 m	-0.196	-0.016	-0.158	-	-0.364	0.004	0.183	-0.610**
767-952 m	-	-	-	-	-	-	-	-0.496*

Note: * indicates significance at $p<0.05$ level, ** indicates significance at $p<0.01$ level.

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