Snow Albedo Variations in the Tianshan Mountains and Northern Xinjiang Region: A Postprint

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Date: 2019-08-02T00:00:00+00:00

Abstract

The Tianshan Mountains and Northern Xinjiang region constitutes one of China's three major stable snow cover areas, where variations in snow albedo significantly influence the solar radiation energy absorbed by the surface. Snow albedo observations conducted from January to March 2018 in this region revealed pronounced spatiotemporal heterogeneity in snow albedo across the study area. Temporally, influenced by temperature variations, snow albedo exhibited an overall declining trend, with differing rates of decrease across periods; the reduction from late January to early March was more pronounced than that from early January to late January. Spatially, due to the effects of contaminants, snow albedo varied among subregions (Altay Prefecture, Tacheng Prefecture, northern slope of the Tianshan Mountains, and Ili River Valley), with snow albedo in the Tianshan region (northern slope of the Tianshan Mountains and Ili River Valley) being lower than that in Northern Xinjiang (Altay Prefecture and Tacheng Prefecture), and the northern slope of the Tianshan Mountains showing the lowest albedo; the impact of contaminants on snow albedo was most conspicuous during the stable snow and ablation periods.

Full Text

Differences in Snow Albedo between Tianshan Mountains and Northern Xinjiang

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Abstract

The Tianshan Mountains and Northern Xinjiang represent one of China' s three stable snow-covered regions in winter. Changes in snow albedo in this area significantly affect the solar radiation energy absorbed by the surface. Based on snow albedo observations from the Tianshan Mountains and Northern Xinjiang collected between January and March 2018, combined with temperature data, industrial structure, and urban distribution information for Xinjiang, this study summarizes the spatial and temporal differences in snow albedo and analyzes its changing patterns. The findings help explore the relationship between snow albedo and snow cover in this region and provide a scientific basis for further study of snow's role in surface energy balance, hydrological processes, and global change.

The analysis utilizes 57 observation points distributed across the Tianshan Mountains and Northern Xinjiang, where measurements of snow albedo, temperature, snow surface density, snow depth, and snow particle size were obtained. Methodologically, the study examines albedo differences in the research area from both temporal and spatial perspectives. Temporally, the albedo distribution range is divided into four intervals, and the relationship between snow albedo and temperature, snow surface density, snow depth, and snow particle size is summarized by analyzing albedo distribution patterns across three periods within these four intervals. Spatially, the study area is divided into four regions: the Altay region, the Tacheng region, the northern slope of the Tianshan Mountains, and the Ili River Valley. Combined with Xinjiang' s industrial structure and urban distribution, the study concludes that differences in pollutant content constitute the primary factor causing variations in snow albedo across these four regions.

From a temporal perspective, snow albedo in the study area exhibited a downward trend due to the influence of temperature changes. The rate of decline varied across different periods, with albedo changes from late January to early March being more pronounced than those from early January to late January. From a spatial perspective, regional differences in snow albedo exist among the various areas (Altay region, Tacheng region, northern slope of the Tianshan Mountains, and Ili River Valley) due to the influence of pollutant content. Snow albedo in the Tianshan region (encompassing the northern slope of the Tianshan Mountains and the Ili River Valley) is lower than that in the Northern Xinjiang region (comprising the Altay and Tacheng regions), with the northern slope of the Tianshan Mountains showing the lowest albedo values. Furthermore, during both the stable period and the ablation period, the effect of pollutant content on snow albedo is most pronounced.

Keywords: snow cover; albedo; spatiotemporal difference; snow changes; Xinjiang

1. Introduction

Snow cover in China is primarily distributed across three stable regions in winter, with the Tianshan Mountains and Northern Xinjiang representing one of these major snow-covered areas, spanning approximately 4.2×10 km². Snow albedo is a critical parameter in climatic and hydrological models, as it directly influences the surface radiation balance and energy exchange processes. Previous research has demonstrated that snow albedo exhibits significant spatiotemporal variability, with numerous studies investigating its relationship with various influencing factors.

Existing research on snow albedo can be categorized into two main approaches. The first approach focuses on analyzing the physical characteristics of snow albedo, including its spectral reflectance properties, snow grain size effects, and the influence of snow impurities. These studies have established that snow albedo is sensitive to multiple factors including snow grain size, density, liquid water content, and the presence of light-absorbing impurities such as black carbon and dust. The second approach employs remote sensing techniques to retrieve snow albedo over large spatial scales, utilizing data from sensors such as MODIS to analyze spatial and temporal distribution patterns. However, most studies have concentrated on either physical process understanding or remote sensing retrieval, with limited integrated analysis combining ground-based observations with regional socioeconomic factors.

This study addresses this gap by examining snow albedo variations in the Tianshan Mountains and Northern Xinjiang during the period from January to March 2018. The region's unique combination of natural snow cover and anthropogenic influences from industrial activities and urban development provides an ideal setting for investigating how pollutant deposition affects snow optical properties. The research integrates ground-based measurements of snow physical properties with regional industrial and urban distribution data to quantify the relative contributions of natural and anthropogenic factors to snow albedo variations.

2. Data and Methods

The study employs observational data from 57 measurement points distributed across the Tianshan Mountains and Northern Xinjiang region. At each point, comprehensive measurements were obtained for snow albedo, air temperature, snow surface density, snow depth, and snow particle size distribution. The temporal analysis divides the observation period into four intervals, allowing for examination of albedo evolution throughout the winter season. For spatial analysis, the study area is partitioned into four distinct regions: the Altay region, the Tacheng region, the northern slope of the Tianshan Mountains, and the Ili

River Valley.

The methodological framework combines statistical analysis of the observational data with geographic information system (GIS) techniques to correlate snow albedo variations with regional patterns of industrial activity and urban development. This approach enables identification of pollution sources and their potential impact on snow optical properties through deposition of light-absorbing particles.

3. Results and Analysis

3.1 Temporal Variations in Snow Albedo Analysis of temporal patterns reveals that snow albedo in the study area exhibited a consistent downward trend during the observation period, primarily driven by temperature variations. The rate of albedo decline differed significantly between periods, with more substantial decreases observed from late January to early March compared to the early January period. This accelerated decline coincides with rising temperatures and the onset of snow metamorphism and melt processes.

The relationship between snow albedo and physical properties shows that as temperature increases, snow grain size tends to coarsen, leading to reduced albedo. Similarly, increases in snow density and depth, along with changes in particle size distribution, contribute to the observed albedo reduction. The temporal analysis demonstrates that during the stable period and the ablation period, the influence of pollutant content on snow albedo becomes particularly pronounced, suggesting that anthropogenic factors amplify the natural albedo decline.

3.2 Spatial Differences in Snow Albedo Spatial analysis reveals significant regional differences in snow albedo across the four study regions. The Tianshan region (encompassing the northern slope of the Tianshan Mountains and the Ili River Valley) consistently shows lower albedo values compared to the Northern Xinjiang region (comprising the Altay and Tacheng regions). Among all regions, the northern slope of the Tianshan Mountains exhibits the lowest snow albedo.

These spatial differences are strongly correlated with regional patterns of industrial structure and urban distribution. Areas with higher industrial activity and urban density show elevated levels of pollutants, including black carbon and other light-absorbing aerosols, which deposit on snow surfaces and reduce albedo. The Altay and Tacheng regions, with relatively lower industrial development, maintain higher snow albedo values, while the more industrialized Ili River Valley and the northern slope of the Tianshan Mountains show greater albedo reduction.

4. Discussion

The findings highlight the complex interplay between natural snow processes and anthropogenic pollution in controlling snow albedo dynamics. While

temperature-driven snow metamorphism explains the general downward trend in albedo, the spatial heterogeneity in albedo values points to pollution deposition as a critical modifying factor. The lower albedo observed in the Tianshan region has important implications for regional climate, as reduced snow reflectivity leads to increased energy absorption, potentially accelerating snowmelt and altering hydrological cycles.

The study' s integration of ground-based observations with regional socioeconomic data provides a more comprehensive understanding of snow albedo variations than either approach alone. This methodology can be extended to other snow-covered regions to assess the global significance of pollution impacts on snow-covered surfaces.

5. Conclusion

This study demonstrates that snow albedo in the Tianshan Mountains and Northern Xinjiang exhibits both temporal decline and spatial heterogeneity. Temperature changes drive the overall decreasing trend, while differences in pollutant content across regions create significant spatial variations. The Tianshan region shows lower albedo than Northern Xinjiang, with the northern slope of the Tianshan Mountains having the lowest values. The effect of pollutants on snow albedo is most evident during the stable and ablation periods. These results underscore the importance of considering both climatic and anthropogenic factors in snow albedo studies and provide a scientific basis for understanding snow' s role in surface energy balance and hydrological processes.

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