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Dataset Development and Analysis of Snowfall in the Agro-Pastoral Zig-zag Region of North China (1961/62–2011/12)

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Abstract: The temporal-spatial dataset of snowfall in the agro-pastoral zig-zag region of North China (1961/62–2011/12) was derived from half a century of precipitation records from the 284 meteorological stations located in North China. The dataset is based on temperature threshold indicators. The stations are located at Beijing City, Tianjin City, Hebei Province, Shanxi Province and the Inner Mongolia Autonomous Region. The data covers the winter months from November of the current year to February in the following year from November 1961 to February 2012. The items of the dataset are: monthly mean snowfall in January, February, November and December; annually snowfall, annual snowfall in light snow, moderate snow and heavy snow. The data is archived in .xlsx format with data size of 394 KB. The data result indicates that the high value areas for annual average snowfall days in the agro-pastoral zig-zag region zone of North China are primarily located from the northeastern to the central regions of Inner Mongolia. Two high value centers for winter snowfall amounts are found in northeastern Inner Mongolia and from southern Shanxi to the southern foothills of the Taihang Mountains. Over the past 51 years, the increase in winter snowfall amounts in the agro-pastoral zig-zag region of North China is mainly attributed to the rise in heavy snowfall and above.

Keywords: snowfall; North China; agro-pastoral; zig-zag region; 1961–2012

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Dataset Availability Statement:

The dataset supporting this paper was published and is accessible through the *Digital Journal of Global Change Data Repository* at: https://doi.org/10.3974/geodb.2016.02.01.V1 or https://cstr.escience.org.cn/CSTR:20146.11.2016.02.01.V1.

1 Introduction

Snowfall is the primary form of precipitation during the winter half-year in China. Currently, most climatology studies use snowfall day data derived from weather phenomenon statistics[1–4], with few employing objective identification methods. However, with the

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[2] He, L. Y., Wang, J., Li, X. C., *et al*. Temporal-spatial dataset of snowfall in zig-zag region between farm and grasslands in North China (1961–2012) [J/DB/OL]. *Digital Journal of Global Change Data Repository*, 2016. https://doi.org/10.3974/geodb.2016.02.01.V1. https://cstr.escience.org.cn/CSTR:20146.11.2016.02.01.V1.

widespread use of automated observation stations and the expansion of research areas from national to global scales, the issues of missing or incomplete weather phenomenon records have become more prominent. Therefore, obtaining fundamental data for snowfall research now relies on the objective identification of snowfall days using other observational variables.

Temperature is a crucial factor in determining the phase of precipitation, particularly the temperature in the lower atmosphere[5]. The temperature threshold at 850 hPa is often used as a criterion for distinguishing between rain and snow in weather forecasting[6]. However, there have been few studies applying this standard for climatic statistics of snowfall data. This paper selects the average temperature at 850 hPa as the identification criterion and uses it to statistically analyze snowfall days in the agro-pastoral zig-zag region of North China. By evaluating the ability of this data to depict the distribution characteristics and trends of snowfall in the agro-pastoral zig-zag region, and comparing it with snowfall day data derived from weather phenomenon statistics, we explore the applicability of the temperature threshold identification method in snowfall statistics. This provides a methodological reference for the objective identification of snowfall days in climate research and lays a data foundation for related snowfall studies in North China.

2 Metadata of the Dataset

The metadata of the temporal-spatial dataset of snowfall in zig-zag region between farm and grasslands in North China (1961–2012)[7] is summarized in Table 1.

3 Methods

Using daily precipitation data from 284 meteorological stations in the agro-pastoral zig-zag region of North China (the geographical region covers Beijing City, Tianjin City, Hebei Province, Shanxi Province and the Inner Mongolia Autonomous Region) provided by the National Meteorological Information Center, and the Reanalysis 1 daily reanalysis data[1] jointly produced by the National Centers for Environmental Prediction and the National Center for Atmospheric Research (NCEP/NCAR), with a horizontal resolution of 2.5°×2.5°[9]. The study period covers the winters (from November of the current year to February of the following year) from November 1961 to February 2012.

3.1 Algorithm

3.1.1 Method for Determining Snowfall Days

In diverse regions and seasons of China, the temperature threshold for determining snowfall varies. However, from a statistically significant perspective, using 0 °C as the upper limit for the snowfall threshold can effectively distinguish between rain and snow[6,10]. Therefore, this study adopts 0 °C as the critical value for differentiating between rain and snow, using the average temperature at 850 hPa as the determining indicator. We collected snowfall day data for the agro-pastoral zig-zag region in North China: specifically, on days when precipitation (including trace amounts) occurs and the average temperature at 850 hPa is ≤ 0 °C, that day is recorded as a snowfall day. Data recorded in the formats 31xxx and 30xxx are both considered as precipitation for this determination. Based on this criterion, we calculated the number of snowfall days at meteorological stations in the agro-pastoral zig-zag region of North China for the winters from November 1961 to February 2012.

[1] NCEP/NCAR Reanalysis 1. https://psl.noaa.gov/data/gridded/data.ncep.reanalysis.html.

Table 1 Metadata summary of the temporal-spatial dataset of snowfall in zig-zag region between farm and grasslands in North China (1961–2012)

Items	Description
Dataset full name	Temporal-spatial dataset of snowfall in zig-zag region between farm and grasslands in North China (1961–2012)
Dataset short name	SnowfallData_NorthChina_1961–2012
Authors	He, L. Y., Tianjin Climate Center, heliyehly@163.com Wang, J., Beijing Climate Center, wangji_zl@163.com Li, X. C., Inner Mongolia Autonomous Region Climate Center, qkslxc@163.com Guo, J., Tianjin Climate Center, guojun@cma.gov.cn
Geographical region	Agro-pastoral zig-zag region in North China (the geographical region covers Beijing City, Tianjin City, Hebei Province, Shanxi Province and the Inner Mongolia Autonomous Region)
Year	1961–2012
Temporal resolution	Year, Monthly
Data format	.xlsx
Data size	394 KB
Data files	(1) annual snowfall data during winter, (2) annual winter snowfall data for each level (light snow, moderate snow, heavy snow and above), (3) multi-year average monthly snowfall data for the winter months (January, February, November, and December) from 284 meteorological stations in the agro-pastoral zig-zag region of North China
Computing environment	Fortran; Microsoft Excel
Data publisher	Global Change Research Data Publishing & Repository, http://www.geodoi.ac.cn
Address	No. 11A, Datun Road, Chaoyang District, Beijing, 100101, China
Data sharing policy	(1) *Data* are openly available and can be free downloaded via the Internet; (2) End users are encouraged to use *Data* subject to citation; (3) Users, who are by definition also value-added service providers, are welcome to redistribute *Data* subject to written permission from the GCdataPR Editorial Office and the issuance of a *Data* redistribution license; and (4) If *Data* are used to compile new datasets, the 'ten percent principal' should be followed such that *Data* records utilized should not surpass 10% of the new dataset contents, while sources should be clearly noted in suitable places in the new dataset[8]
Communication and searchable system	DOI, CSTR, Crossref, DCI, CSCD, CNKI, SciEngine, WDS, GEOSS, PubScholar, CKRSC

3.1.2 Daily Average Temperature at 850 hPa for Meteorological Stations

The temperature field from the NCEP/NCAR reanalysis data has high applicability and reliability in eastern China, especially in the northern regions[11,12]. At the 850 hPa level, compared to temperature data from radiosonde observations, the interpolation error of the NCEP/NCAR reanalysis data is smaller. Therefore, it can be used to analyze temperature changes in areas without actual radiosonde data[13].

Therefore, when calculating the daily average temperature at 850 hPa for weather stations, the values from the 4 grid points adjacent to the station are selected. Using the bilinear interpolation method, the reanalysis grid data for the daily average temperature at 850 hPa is interpolated to the station. This process yields the daily average temperature at 850 hPa for each station in the agro-pastoral zig-zag region of North China. The algorithm is as follows.

Let the daily average temperature at 850 hPa for station P be $T(P)$, with the coordinates of the station being (x, y). The 4 grid points adjacent to the station are $Q_{11}=(x_1, y_1)$, $Q_{12}=(x_1, y_2)$, $Q_{21}=(x_2, y_1)$, and $Q_{22}=(x_2, y_2)$. The daily average temperature values at these grid points are $T(Q_{11})$, $T(Q_{12})$, $T(Q_{21})$, and $T(Q_{22})$, respectively. These 4 grid points are positioned with 2 points in the x-direction and 2 points in the y-direction. First, linear interpolation is performed in the x-direction to obtain the daily average temperature values at points $R_1= (x, y_1)$ and $R_2=(x, y_2)$:

$$T\left(R_1\right)=\frac{\left(x_2-x\right)}{\left(x_2-x_1\right)}T\left(Q_{11}\right)+\frac{\left(x-x_1\right)}{\left(x_2-x_1\right)}T\left(Q_{21}\right) \quad (1)$$

$$T\left(R_2\right)=\frac{\left(x_2-x\right)}{\left(x_2-x_1\right)}T\left(Q_{12}\right)+\frac{\left(x-x_1\right)}{\left(x_2-x_1\right)}T\left(Q_{22}\right) \quad (2)$$

Then, linear interpolation is performed in the y-direction to obtain the daily average temperature at 850 hPa for station $P\left(x,y\right)$:

$$T\left(P\right)=\frac{\left(y_2-y\right)}{\left(y_2-y_1\right)}T\left(R_1\right)+\frac{\left(y-y_1\right)}{\left(y_2-y_1\right)}T\left(R_2\right) \quad (3)$$

3.2 Data Development Processing

(1) Using the daily NCEP/NCAR reanalysis data from 1961 to 2012, specifically the temperature at 850 hPa, the daily average temperature at 850 hPa for 284 meteorological stations in the agro-pastoral zig-zag region of North China is calculated. This calculation is based on the geographical coordinates (latitude and longitude) of the 284 meteorological stations and employs the bilinear interpolation method.

(2) Based on the daily precipitation data from 1961 to 2012 for 284 meteorological stations in the agro-pastoral zig-zag region of North China, along with the daily average temperature data at 850 hPa calculated in step 1, snowfall days are identified using temperature threshold criteria. Subsequently, the annual and monthly snowfall amounts (for November, December, January, and February) are compiled for the winters from November 1961 to February 2012 for the 284 meteorological stations.

(3) Drawing upon the snowfall classification standards and integrating the results of snowfall day identification from step 2, the annual snowfall amounts for light snow, moderate snow, and heavy snow and above were further compiled for the winters at the 284 meteorological stations in the agro-pastoral zig-zag region of North China.

(4) Utilizing the monthly snowfall data for each winter from the 284 meteorological stations as compiled in step 2, the multi-year average monthly snowfall for November, December, January, and February was subsequently calculated.

(5) Results were compiled and analyzed to form a dataset on the temporal-spatial variations of winter snowfall in the agro-pastoral zig-zag region of North China.

4 Data Results and Validation

4.1 Data Composition

The dataset on the temporal-spatial variations of snowfall in the agro-pastoral zig-zag region of North China from 1961 to 2012[7] includes: (1) annual snowfall data from 284 meteorological stations during winter in the agro-pastoral zig-zag region of North China; (2) annual winter snowfall data for each level (light snow, moderate snow, heavy snow and above) from 284 meteorological stations in the agro-pastoral zig-zag region of North China; (3) multi-year average monthly snowfall data for the winter months (January, February, November, and December) of 284 meteorological stations in the agro-pastoral zig-zag region of North China. The dataset is archived in one excel file with data size of 394 KB.

4.2 Data Results

4.2.1 Distribution Characteristics of Snowfall

Based on the distribution of the annual average number of snowfall days in the agro-pastoral transition zone of North China, derived from the 850 hPa temperature threshold indicators

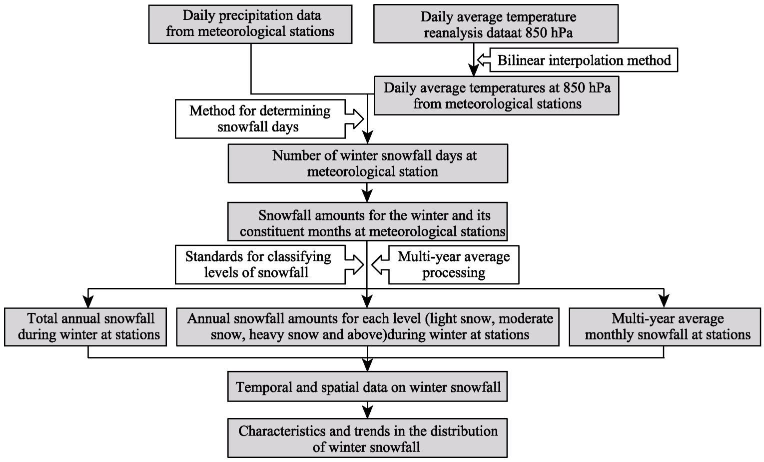

Figure 1 Flowchart of the dataset development of snowfall in the agro-pastoral zig-zag region of North China

(Figure 2a), there is a high value area of snowfall days from northeastern to central Inner Mongolia, with an annual average of over 40 days. Moving westward and southward, the number of snowfall days gradually decreases. Near the Xing'an Mountains, the annual average reaches over 100 days. This distribution pattern aligns with the snowfall days distribution obtained from weather phenomena statistics in the agro-pastoral transition zone of North China.

The distribution of the average annual snowfall is broadly similar to that of the number of snowfall days but features two distinct high value centers (Figure 2b). One is located in northeastern Inner Mongolia, where the annual average snowfall can exceed 20 mm, while the other is in the southwestern region of Shanxi, along the southern slopes of the Taihang Mountains, where the annual average snowfall exceeds 30 mm, with some areas reaching over 40 mm.

The distribution of snowfall amounts across different levels in winter is shown in Figure 3. It can be observed that in northeastern Inner Mongolia, light snowfall is relatively significant, while the southwestern region of Shanxi and the southern slopes of the Taihang Mountains are high value areas for heavy snowfall and above. In contrast, the westernmost part of Inner Mongolia experiences no heavy snowfall over the years, and there is no significant regional difference in moderate snowfall distribution within the agro-pastoral transition zone of North China.

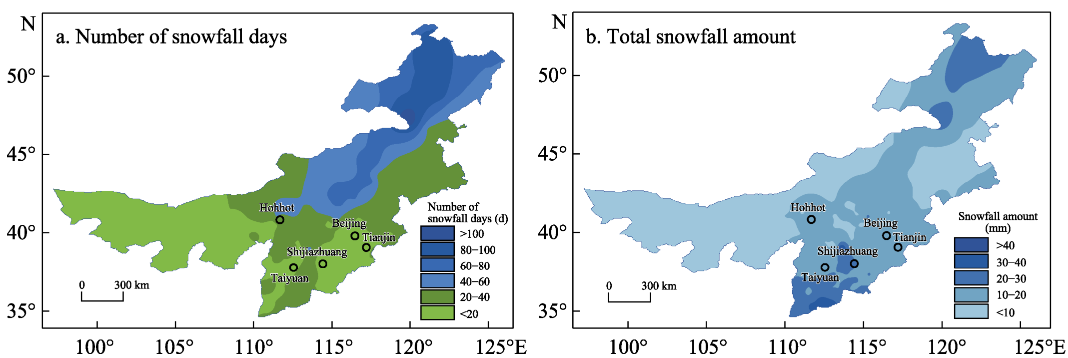

Figure 2 Maps of annual average snowfall days and winter snowfall amounts in the agro-pastoral zig-zag region of North China

Whether considering total snowfall or snowfall amounts across different levels, their distribution aligns with the conclusions of previous studies[1–2]. This indicates that the number of snowfall days and the amount of snowfall in the agro-pastoral transition zone of North China, as determined by the 850 hPa temperature threshold, effectively captures the region's snowfall characteristics. The temperature threshold method proves to be both feasible and applicable in objectively identifying and statistically analyzing snowfall day data.

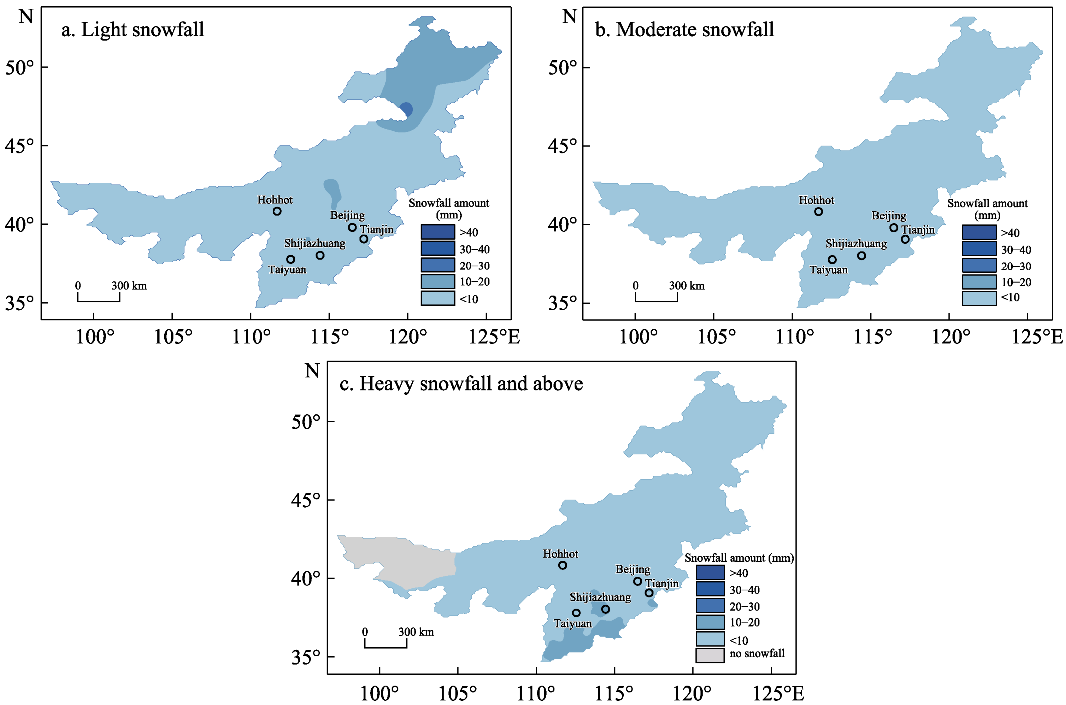

Figure 3 Maps of winter snowfall amounts for each level in the gro-pastoral zig-zag region of North China

4.2.2 Temporal Variations of Winter Snowfall

To further analyze the trends in snowfall variation in the agro-pastoral transition zone of North China, Figure 4 presents the time series of total winter snowfall and the snowfall amounts for each level. It can be observed that, on a decadal scale, the winter snowfall in this region shows an increasing trend, although not so significantly[15]. Specifically, there is no obvious trend in the snowfall amounts for light and moderate snow, while heavy snow and above show an increasing trend. Given the high intensity and low frequency of heavy snow and above, their variations significantly impact the total winter snowfall in the agro-pastoral transition zone of North China. The changes in heavy snow and above in Figure 4a and 4d align with the trends in total winter snowfall, with a correlation coefficient of 0.90, passing the 99% significance test. This indicates that the increase in total winter snowfall in the agro-pastoral transition zone of North China is primarily due to the increase of heavy snow and above.

5 Discussion and Conclusion

Snowfall can significantly impact and even jeopardize transportation and agricultural activities. Therefore, studying winter snowfall plays a fundamental role. Previous research often relied on weather phenomena records to count snowfall days. However, there was a

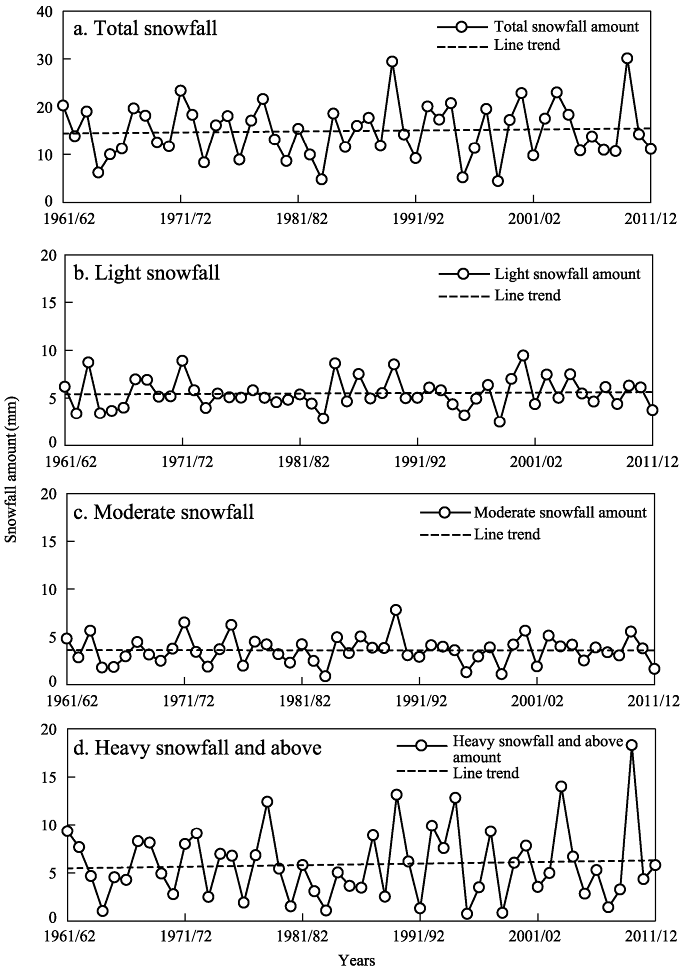

Figure 4 The time series of winter snowfall amounts in the agro-pastoral zig-zag region of North China

lack of objective methods to identify snowfall days, especially when weather records were incomplete or unavailable. This study establishes a temperature threshold indicator for identifying winter snowfall in the agro-pastoral zig-zag region of North China from a climatic statistical perspective. Snowfall data were identified and recorded based on the daily average temperature at 850 hPa. The results demonstrate that the snowfall days and amounts calculated using this method accurately depict the snowfall characteristics and trends in the agro-pastoral zig-zag region of North China. The high value areas for annual average snowfall days are primarily located from the northeast to the central regions of Inner Mongolia. Two high value centers for winter snowfall amounts are found in northeastern Inner Mongolia and from southern Shanxi to the southern foothills of the Taihang Mountains. The increase in winter snowfall amounts in the agro-pastoral zig-zag region of North China is mainly due to the rise in heavy snowfall and above. These findings are consistent with previous studies based on weather phenomena statistics. In the study, the 850 hPa temperature level was selected instead of the surface temperature as the objective threshold for determining winter snowfall days in the agro-pastoral zig-zag region of North China. This choice was made considering that the 850 hPa temperature data is not affected by non-uniformity issues caused by station relocations. Additionally, the number of annual average snowfall days determined by the objective threshold showed an average monthly error of only 2.4% when compared to the statistics based on weather phenomena. The absolute difference between the results of the two methods exhibited a significant linear relationship with altitude, with a correlation coefficient of 0.85, passing the 0.05 confidence level test. Therefore, the 850 hPa temperature threshold for determining snowfall days can be adjusted according to the station's altitude to further reduce the discrepancy between the results of the objective and weather phenomena-based methods.

In summary, the analysis indicates that the temperature threshold method is both feasible and applicable for the objective determination and statistical analysis of snowfall data. The long-term spatiotemporal dataset of winter snowfall in the agro-pastoral zig-zag region of North China, constructed based on this method, can support relevant research on snowfall in the region. It is of great significance for a deeper understanding of the climatic characteristics of snowfall in North China and for grasping the patterns of snowfall variation. The temperature threshold indicator established by the study also provides a framework for the objective determination of future snowfall.

Author Contributions

Huang, H., Wang, J. and He, L. Y. designed the algorithms of dataset. He, L. Y., Wang, J. and Guo, J. contributed to the data processing and analysis. He, L. Y. wrote the data paper.

Conflicts of Interest

The authors declare no conflicts of interest.

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