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Dataset of Cooling and Heating Degree Days in North of 18°N Latitude of China (1981–2020)

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Abstract: Climate warming can change the global heating and cooling periods. Cooling and heating degree days can be used to show the influence of climate factors on the energy consumption for building cooling and heating. These are the measurement indices of the quantitative relationship between temperature and energy, and can also be considered as the simplest and most reliable index for measuring energy demand. These two indices have been widely used in the fields of climate change, building energy demand, and thermal comfort. The cooling and heating degree days were characterized by the daily mean temperature and compared with a set reference temperature. Cooling degree days (CDDs) are the cumulative number of degrees by which the average daily temperature in a certain time range is higher than the reference temperature, whereas heating degree days (HDDs) are the cumulative number of degrees by which the average daily temperature in a certain time range is lower than the reference temperature. According to the industry standard "JGJ 134—2001 Standard for Energy Saving Design of Residential Buildings in Hot Summer and Cold Winter Areas", the base temperature for cooling and heating is set as 26 °C and 18 °C respectively in this study. Using the calculation method of cooling and heating degree days, a yearly scale dataset of CDDs and HDDs in China north of 18°N from 1981 to 2020 was produced on the Google Earth Engine (GEE) platform based on the 2 m air temperature data from the ERA5-Land reanalysis meteorological dataset (0.1°×0.1° spatial resolution). This is the first continuous dataset of CDDs and HDDs in nearly 40 years in China. The dataset includes the following data from 1981 to 2020: (1) CDDs data; (2) HDDs data. The temporal resolution of the dataset was yearly and the spatial resolution was 0.1°. The dataset was archived in .tif format and consisted of 80 data files with a data size of 75 MB (compressed to one file with 17.7 MB).

Keywords: energy consumption; climate change; thermal environment; cooling degree days; heating degree days; dataset; China

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[2] Zhao, G. S., Zhou, X. M., Li, Y. Z., *et al*. Dataset of cooling and heating degree days in north of 18°N latitude of China (1981–2020) [J/DB/OL]. *Digital Journal of Global Change Data Repository*, 2022. https://doi.org/10.3974/geodb.2022.03.08.V1. https://cstr.escience.org.cn/CSTR:20146.11.2022.03.08.V1.

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.2022.03.08.V1 or https://cstr.escience.org.cn/CSTR:20146.11.2022.03.08.V1.

1 Introduction

The sixth assessment report of the IPCC shows that since 1850–1900, the global average surface temperature has risen by approximately 1 °C. The report predicts that climate change will intensify in all regions over the next few decades, with increasing heatwaves, lengthening warm seasons and shortening cold seasons at a global temperature rise of 1.5 °C[1]. However, studies of subtropical climates have shown an increasing trend in temperature and summer discomfort over the past few decades, and have also found that the expected increase in temperature may lead to a higher demand for cooling due to the increasing demand for better thermal comfort[2,3]. More electricity for air conditioning will lead to greater emissions, which in turn will exacerbate climate change and global warming. The reduction in energy demand for heating is also likely to outweigh the increase in the energy required for cooling. As a result, the impact of climate change on overall energy demand and the environment remains uncertain[4].

Global climate change has a significant impact on natural ecosystems and human socioeconomic systems[5]. China is a vast country with complex and diverse climate types. The responses of different regions to global climate change are very different. At the same time, as a large energy-consuming country, China’s climate change has become more complex in recent years under the background of global warming, and climate change has a great impact on building energy demand[6], and China’s energy demand will also continue to grow. Among them, heating and cooling are an important part of building energy consumption[7], and heating and cooling demands, which are closely related to temperature, account for nearly 20% of total energy consumption[8]. Degree days are a simple and direct method to assess the relationship between building energy consumption and temperature. It is the actual difference between the daily average temperature and a set benchmark temperature. Thom[9,10] first used degree days to explore the relationship between energy consumption and temperature in the United States in the early 1950s, which was widely used later[11–13]. Therefore, the production of a dataset of cooling and heating degree days in China over the past 40 years is of great practical significance for buildings response to climate change in the future, assessing possible changes in energy use, and formulating energy policies. At present, based on the average temperature data of meteorological stations, some studies have analyzed the number of cooling degree days (CDDs) in summer and heating degree days (HDDs) in winter in some areas of China, such as Shandong, Chongqing, Xinjiang and other regions[14–16]. However, the research and development of continuous spatial data based on a national scale is limited. Therefore, this study aimed to develop a dataset of cooling and heating degree days across China over the past 40 years to provide important basic data for studying the impact of climate change on heating and air conditioning energy consumption[17].

This dataset is based on ERA5-Land reanalysis data, and the 2 m surface air temperature variable data was used to calculate the cooling and heating degree days in north of 18°N of China from 1981 to 2020 on the Google Earth Engine (GEE) platform based on the degree days calculation method. Finally, we produced a dataset of CDDs and HDDs in North of 18°N Latitude of China (1981–2020).

2 Metadata of the Dataset

The dataset full name, short name, authors, geographical area, year of the dataset, temporal resolution, spatial resolution, data files, data publisher, and data sharing policy, and other information of the Dataset of cooling and heating degree days in North of 18°N latitude of China (1981–2020)[18] are shown in Table 1.

Table 1 Metadata summary of the Dataset of cooling and heating degree days in north of 18°N latitude of China (1981–2020)

Items	Description
Dataset full name	Dataset of cooling and heating degree days in north of 18°N latitude of China (1981–2020)
Dataset short name	China_CDD_HDD_1981-2020
Authors	Zhao, G. S. N-3141-2019, School of Geography and Information Engineering, China University of Geosciences, Wuhan zhaogs86@126.com Zhou, X. M. GNH-5833-2022, School of Geography and Information Engineering, China University of Geosciences (Wuhan) 1094339549@qq.com Li, Y. Z. GNH-4325-2022, School of Resources and Environment, Henan University of Economics and Law yz_li@huel.edu.cn Sun, C. Y. GNH-6478-2022, National Climate Center sunchaoy@cma.gov.cn
Geographical area	North of 18°N latitude of China
Year	1981–2020
Spatial resolution	0.1°×0.1°
Data format	.tif
Data size	75 MB (compressed to one file with 17.7 MB)
Data files	The dataset contains two folders: Folder China_CDD_1981_2020 contains 40 .tif files, which are respectively the datasets of cooling degree days per year in China from 1981 to 2020 Folder China_HDD_1981_2020 contains 40 .tif files, which are respectively the annual heating degree days datasets of China from 1981 to 2020
Foundations	National Natural Science Foundation of China (41701501); Fundamental Research Funds for the Central Universities (CUG2106311)
Data computing environment	Google Earth Engine (GEE) platform, ArcGIS
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	***Data*** from the Global Change Research Data Publishing & Repository includes metadata, datasets (in the *Digital Journal of Global Change Data Repository*), and publications (in the *Journal of Global Change Data & Discovery*). ***Data*** sharing policy includes: (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 per cent 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 datase[19]
Communication and searchable system	DOI, CSTR, Crossref, DCI, CSCD, CNKI, SciEngine, WDS/ISC, GEOSS

3 Methods

3.1 Algorithms

(1) Cooling degree days

Cooling degree days (CDDs) are the cumulative degrees by which the average daily temperature in a certain time range is higher than a certain baseline temperature[20]. The formula for calculating the CDDs is as follows:

$$CDD_s = \sum_{i=1}^{n}(T_i - T_{\text{base}}) \times \text{D} \tag{1}$$

where *CDDs* is the value of cooling degree days (ºC·d); *n* is the number of days in a year (365 in a common year and 366 in a leap year), T_i is the average daily temperature on the i^{th} day of a year (ºC);   is the reference temperature (ºC), and D=1d.

According to the Industry Standard for Energy Efficiency Design of Residential Buildings in Hot Summer and Cold Winter Zone (JGJ 134—2001), the base temperature of cooling was set as 26 ºC, and CDD_{26} is used to reflect the hot level of the climate. When the value of (T_i–26) is negative, take (T_i–26) = 0.

(2) Heating degree days

Heating degree days (HDDs) are the cumulative number of degrees in which the average daily temperature within a certain time range is lower than a certain base temperature. The calculation formula is as follows:

$$HDD_s = \sum_{i=1}^{n}(T_{\text{base}} - T_i) \times \text{D} \tag{2}$$

where *HDDs* is the value of heating degree days (ºC·d), n is the number of days in a certain year (365 in a common year and 366 in a leap year), T_i is the average daily temperature on the i^{th} day of a year (ºC); T_{base} is the reference temperature (ºC), and D=1d.

According to the Industry Standard for Energy Efficiency Design of Residential Buildings in Hot Summer and Cold Winter Zone (JGJ 134—2001), the basic heating temperature was set to 18 ºC[21], and HDD_{18} is used to reflect the cold level of the climate. When (18−T_i) is negative, take (18−T_i) = 0.

3.2 Technical Route

The main process of data production included the following: (1) Preprocessing of ERA5-Land hourly reanalysis temperature data. Based on the Google Earth Engine (GEE) platform, the hourly reanalysis temperature data of ERA5-Land from 1981 to 2020 were processed into daily average temperature to prepare for calculating degree days. (2) Calculate the CDDs and HDDs. According to equations (1) and (2), degree days were calculated on the GEE platform, and the data output was saved in .tif format. (3) Accuracy verification. The index of absolute coefficient of Determination (R^2) and Root Mean Square Error (RMSEs) were used. The accuracy of the data produced was verified by comparing the ERA5-Land[22] degree day values with the degree day values of the stations based on the Daily meteorological dataset of basic meteorological elements of China National Surface Weather Station (V3.0)[23]. (4) Forming a dataset of CDDs and HDDs in north of 18°N of China (1981–2020).

4 Data Results and Validation

4.1 Dataset Composition

The China_CDD_HDD_1981-2020 file contains annual grid data of cooling and heating degree days in north of 18°N of China from 1981 to 2020.This dataset has a temporal resolution of year, a spatial resolution of 0.1°, and is archived in .tif format. The dataset is divided into two folders. The China_CDD_1981_2020 folder is the dataset of China's CDDs from 1981 to 2020, with a data amount of 37.5 MB, and the China_HDD_1981_2020 folder is the dataset of China's HDDs from 1981 to 2020, with a data amount of 37.5 MB. Each folder contains 40 .tif files with a total of 75 MB of data (compressed to 1 file of 17.7 MB). The file name of the data file contains the time period information. For example, "China_CDD_1981.tif" is the raster data of CDDs in north of 18°N of China in 1981.

4.2 Spatial and Temporal Distribution of CDDs in China

Using 1981, 1985, 1990, 1995, 2000, 2005, 2010, 2015 and 2020 as examples, Figure 1 shows the spatial and temporal distribution characteristics of CDDs in China. Owing to limited space, the spatial distribution of CDDs in other years is not shown. In terms of spatial distribution, the CDDs is closely related to altitude and latitude. The CDDs is higher in the south and lower in the north, and there is a significant difference in different regions. The high values of CDDs are mainly distributed in the Tarim Basin, where the maximum value reaches 700–900 ºC·d. This is because the Tarim Basin area has a typical continental desert climate, and the summer temperature is high, resulting in a high value of CDDs. The CDDs is also high in southeast China, mainly due to the low latitude region, which has hot, high-temperature and rainy summer. The low values of CDDs are mainly distributed in Northeast China and Qinghai-Tibet Plateau. The spatial distribution characteristics of CDDs in different years in China are roughly the same, and the main changes occur in the western Inner Mongolia and Northeast China. Compared with 1981, the CDDs in the western region of Inner Mongolia increased significantly in 2005, 2010 and 2020, and its value exceeded 200 ºC·d. The CDDs in Northeast China have also increased in the last 10 years from 2010 to 2020, with values ranging from 0–5 ºC·d to 5–80 ºC·d. Simultaneously, the area of high values of CDDs greater than 200 ºC·d in the south of the North China Plain also increased.

4.3 Spatial and Temporal Distribution of Heating Degree-days in China

Using 1981, 1985, 1990, 1995, 2000, 2005, 2010, 2015 and 2020 as examples, Figure 2 shows the spatial and temporal distribution characteristics of HDDs in north of 18°N of China. Owing to limited space, the spatial distribution of HDDs in other years is not shown. From the perspective of spatial distribution, high HDDs values are distributed in the Qinghai-Tibet Plateau and Northeast China, which are mainly due to the influence of altitude and latitude. The Qinghai-Tibet Plateau has a high altitude and very low temperature, while Northeast China has high latitude. In other regions, the HDDs increased with higher

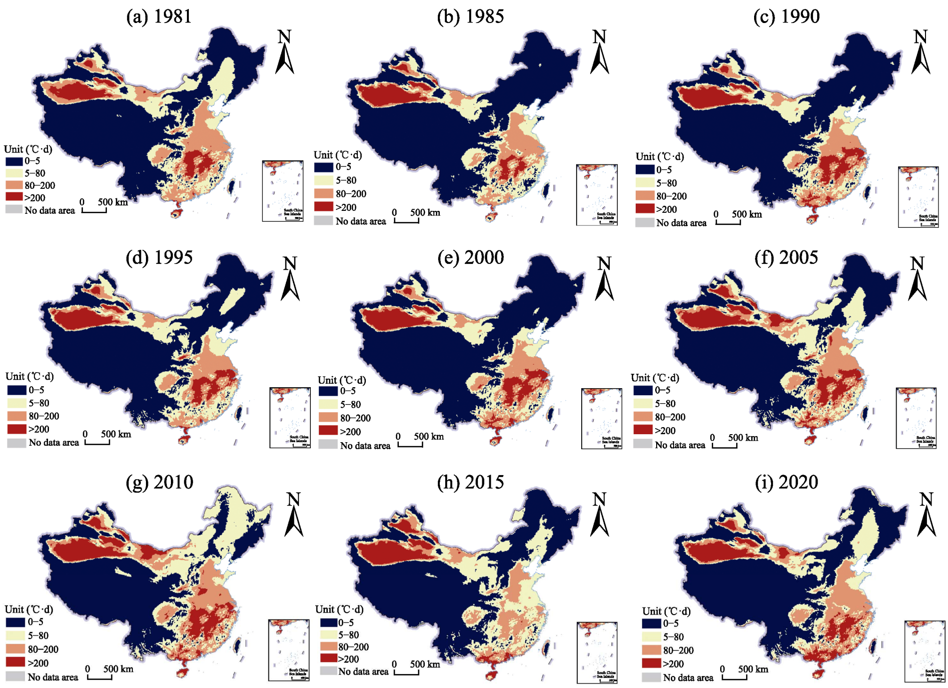

Figure 1 Spatial and temporal distribution of CDDs in north of 18°N of China from 1981 to 2020

latitude. From Figure 2, we can see that the distribution of HDDs varies greatly in different years mainly in the Qinghai-Tibet Plateau, especially in 2010, 2015 and 2020. The area of the high-value area of HDDs in the Qinghai-Tibet Plateau has been significantly reduced compared with the past years, which is due to global warming and a decrease in heating demand, resulting in a decrease in HDDs.

4.4 Data Accuracy Verification

In order to verify the accuracy of this dataset, 1,511 stations with no data missing in the past 30 years from 1981 to 2010 were selected from the Daily meteorological dataset of basic meteorological elements of China National Surface Weather Station (V3.0). Secondly, the daily average temperatures of these stations were used to calculate the station level CDDs and HDDs. Finally, the degree days based on ERA5-Land temperature were compared with those based on station temperature from 1981 to 2010 using a scatter plot. The results show that, except for a few stations with large errors, most of the stations are near the 1:1 line, indicating that the degree days data produced based on ERA5-Land reanalysis data in this study are highly consistent with the degree days data calculated based on the stations, and the data reliability is high (Figure 3).

5 Discussion and Conclusion

This dataset is innovative in comparison to previous studies that often used stations to calculate degree days. Based on ERA5-Land reanalysis of air temperature data, the GEE platform was used to calculate cooling and heating degree days. The accuracy was verified,

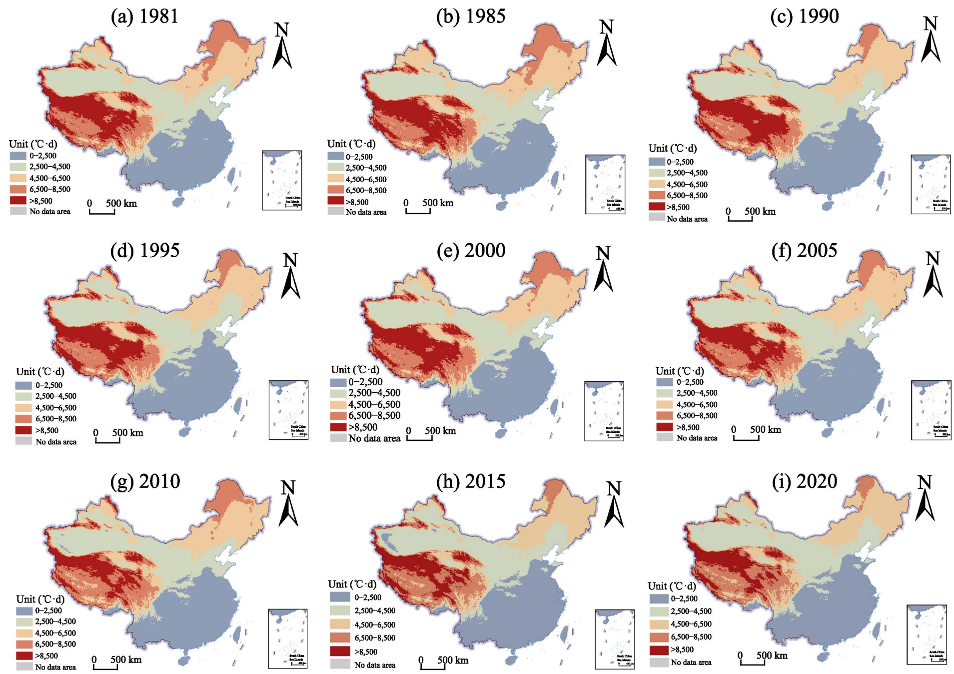

Figure 2 Spatial and temporal distribution of HDDs in north of 18°N of China from 1981 to 2020

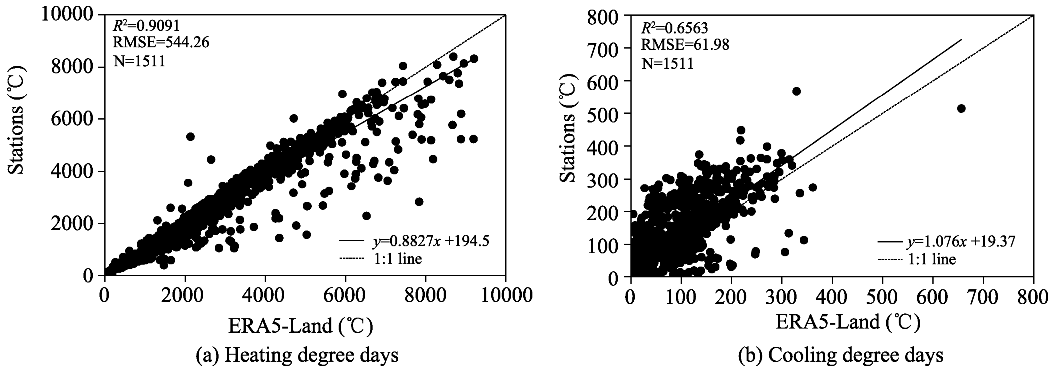

Figure 3 Scatter plot of result accuracy verification

and the data reliability was high. The dataset firstly provides the temporal and spatial distribution data of CDDs and HDDs in north of 18°N of China in the past 40 years of 1981–2020. The continuity of this dataset can reflect the impact of climate change on energy consumption demand, and can provide reliable data support for the government's better institutional energy policy.

Author Contributions

Zhao, G. S. did the overall design for the research and development of the dataset; Zhou, X. M. collected and processed the basic data. Zhou, X. M. and Zhao, G. S. wrote the data paper; Li, Y. Z. and Sun, C. Y. revised the data paper.

Conflicts of Interest

The authors declare no conflicts of interest.

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