Journal of Global Change Data & Discovery. 2022, 6(2): 225-233
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Global Change Research Data Publishing & Repository

Spatial–Temporal Mean Temperature Dataset in the China–Mongolia–Russia Economic Corridor (1982–2018, 1-km/y)

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Abstract: The Spatial-temporal Mean Temperature Dataset in the China–Mongolia–Russia Economic Corridor (1982–2018, 1-km/y) was developed based on the data integration of temperature data from 325 meteorological stations in the China–Mongolia–Russia Economic Corridor (CMREC) and on the use of ANUSPLIN meteorological interpolation software. The results show that R^2 was 0.980 and above, where R is the correlation coefficient between meteorological station data and interpolation results. The average mean absolute error (MAE) and root-mean-square error (RMSE) values were 0.348 and 0.481 ℃, respectively. The dataset includes (1) boundary data of the study area and (2) annual-mean-temperature grid data at a 1 km resolution relative to the period 1982–2018. The dataset is archived in .shp, .tif and .mdd data formats and consists of 159 data files with a data size of 8.65 GB (compressed into 2 files of 531 MB).

Keywords: annual mean temperature; **China–Mongolia–Russia Economic Corridor**; **1 km**; **1982–2018**

DOI: https://doi.org/10.3974/geodp.2022.02.08;

CSTR: https://cstr.escience.org.cn/CSTR:20146.14.2022.02.08

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.2022.01.03.V1 or https://cstr.escience.org.cn/CSTR:20146.11.2022.01.03.V1.

1 Introduction

According to the sixth report of IPCC, since 1850–1900, the global average surface temperature has increased by about 1 ℃, and extreme weather events occur frequently. Global cli-

Received: 20-02-2022; **Accepted:** 30-05-2022; **Published:** 25-06-2022

Foundations: Chinese Academy of Sciences (XDA2003020301); National Natural Science Foundation of China (42071025); Ministry of science and Technology of P. R. Chian (2017FY101301)

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Data Citation: [1] Jiao, Y., Yang, J. C., Li, G. S., *et al*. Spatial-temporal mean temperature dataset in China-Mongolia-Russia Economic Corridor (1982–2018, 1-km/y) [J]. *Journal of Global Change Data & Discovery*, 2022, 6(2): 225–233. https://doi.org/10.3974/geodp.2022.02.08. https://cstr.escience.org.cn/CSTR:20146.14.2022.02.08.

[2] Jiao, Y., Yang, J. C., Li, G. S., *et al*. Spatial-temporal mean temperature dataset in China-Mongolia-Russia Economic Corridor (1982–2018, 1-km/y) [J/DB/OL]. *Digital Journal of Global Change Data Repository*, 2022. https://doi.org/10.3974/geodb.2022.01.03.V1. https://cstr.escience.org.cn/CSTR:20146.11.2022.01.03.V1.

mate change forces humankind to face unprecedented challenges[1]. Temperature data are not only important parameter data reflecting the climate characteristics of a region but also among the basic data for the study of global warming and its effects. Therefore, high-precision meteorological observation data with high temporal and spatial resolutions are of great significance for the study of temperature changes in different regions[2,3].

In recent years, many scholars have compared the spatial interpolation methods of near-surface-temperature data to seek the optimal spatial interpolation methods, including Kriging interpolation, inverse distance weight, multiple linear regression and other methods in ArcGIS, as well as a series of special interpolation software for spatial meteorological data represented by ANUSPLIN, which has proved to be a method with high accuracy[4–9]. ANUSPLIN meteorological interpolation software is software for the surface fitting of meteorological data based on the basic principle of the thin-disk smooth spline function[10]. Zhao and Wen et al. used ANUSPLIN software to interpolate the temperature in Chongqing and Anhui. They found that the ANUSPLIN spatial interpolation method was suitable for complex terrain and showed a good fitting effect[11,12]. Chen et al. and Wang et al. conducted ANUSPLIN spatial interpolation analysis on China's temperature and precipitation and found that the interpolation results were consistent with the climate change characteristics of the Chinese mainland[13,14]. Chen and others believe that spatial interpolation with ANUSPLIN software can also better reflect the temporal and spatial distribution characteristics of meteorological elements in the China–Pakistan Economic Corridor[15].

With the increasing trend of economic globalization, regional cooperation is attracting more and more attention. As one of the “six economic corridors of the Belt and Road”, the China–Mongolia–Russia Economic Corridor has greatly promoted the process of regional economic integration in Northeast Asia[16,17]. The regional physical and geographical conditions restrict the economic development to a great extent, which also reflects the changes in many hydrological elements and vegetation surface[18]. Therefore, the study of the temperature distribution in the China–Mongolia–Russia Economic Corridor plays an important role in regional economic development. However, the existing temperature datasets cannot meet the current needs of climate change research in the China–Mongolia–Russia International Economic Corridor, which hinders the development of climate change research in this region.

At present, the interpolation of temperature is mainly carried out by domestic countries. Under the background of international cooperation, it is an inevitable trend of future scientific research to jointly analyze natural environment changes through international cooperation. This dataset contains multi-source data from meteorological stations in the China–Mongolia–Russia Economic Corridor and uses ANUSPLIN software to introduce elevation as a covariate to spatially interpolate the annual average temperature in the China–Mongolia–Russia Economic Corridor; the final result is the Spatial-temporal Mean Temperature Dataset in the China–Mongolia–Russia Economic Corridor (1982–2018, 1-km/y).

2 Metadata of the Dataset

The metadata of the Spatial-temporal mean temperature dataset in China–Mongolia–Russia Economic Corridor (1982–2018, 1-km/y)[19] are summarized in Table 1. It include the dataset’s full name and short name, authors’ names, year of the dataset, temporal resolution, spatial resolution, data format, data size, data files, data publisher, data sharing policy, etc.

Table 1 Metadata summary of the Spatial-temporal mean temperature dataset in China-Mongolia-Russia Economic Corridor (1982–2018, 1-km/y)

Items	Description
Dataset full name	Spatial-temporal mean temperature dataset in China-Mongolia-Russia Economic Corridor (1982-2018, 1-km/y)
Dataset short name	CMREC_Temperature_1982-2018
Authors	Jiao, Y., Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences, jiaoyue@iga.ac.cn Yang, J. C., Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences, yangjiuchun@iga.ac.cn Li, G. S., Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences, liguangshuai@iga.ac.cn Yu, L. X., Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences, yulingxue@iga.ac.cn Bao, Y. L., School of Geographical Sciences, Inner Mongolia Normal University, baoyulong@imnu.edu.cn Zhang, S. W., Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences, zhangshuwen@iga.ac.cn
Geographical region	The geographical range includes 27°47'N–61°57'N, 25°51′E–157°51′E
Year	1982–2018
Temporal resolution	1 year
Spatial resolution	1 km
Number of data files	159
Data format	.shp、.tif、.mdd
Data size	8.65 GB (compressed to 2 files of 531 MB)
Data files	They include the annual average temperature data files (in .tif and .mdd format) of the China–Mongolia–Russia Economic Corridor from 1982 to 2018 and a group of boundary vector files (.shp) of the mainland part of the China–Mongolia–Russia Economic Corridor. TIF: the temperature data file name is tempyyyy.tif, which contains average-temperature data of the yyyy year. The name of the .mdd air-temperature data file is XXXX yyyy MDD, which refers to the annual average temperature data from XXXX to yyyy. The vector file name is cmrec_BND. shp
Foundations	Chinese Academy of Sciences (XDA2003020301); National Natural Science Foundation of China (42071025); Ministry of science and Technology of P. R. China (2017FY101301).
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 *Digital Journal of Global Change Data Repository*) and publications (in *Journal of Global Change Data & Discovery*). ***Data*** sharing policy includes: (1) ***Data*** are openly available and can be freely 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. (4) If ***Data*** are used to compile new datasets, the 'ten percent principle' should be followed, such that ***Data*** records utilized should not surpass 10% of the new dataset's contents, while sources should be clearly noted in suitable places in the new dataset[20]
Communication and searchable system	DOI, CSTR, Crossref, DCI, CSCD, CNKI, SciEngine, WDS/ISC, GEOSS

3 Methods

3.1 Data Collection

The meteorological station data in China used in this dataset were obtained from the annual value dataset of China's surface climate data provided by National Meteorological Science Data Center[21], and 119 surface meteorological stations were selected. The data of the meteorological stations in Mongolia and Russia were derived from the daily-observation data provided by National Oceanic and Atmospheric Administration (NOAA)[22], and 28 and 178 surface meteorological stations were selected, respectively. Finally, a total of 325 surface meteorological stations were selected to interpolate the annual average temperature in the China–Mongolia–Russia Economic Corridor from 1982 to 2018 (Figure 1).

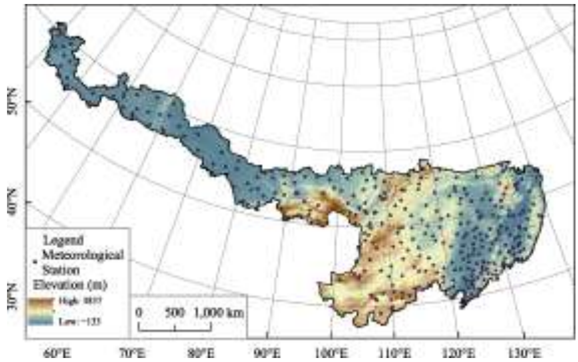

Figure 1 Distribution and DEM Map of meteorological stations in China–Mongolia–Russia International Economic Corridor

The DEM data were derived from the global multi-resolution terrain elevation dataset (gmted2010). It is a spatial dataset of global land areas jointly launched by United States Geological Survey (USGS) and National Geospatial Intelligence Agency (NGA)[23]. The dataset was published in 2010 with a spatial resolution of 30 arc seconds. The DEM data in this study are based on gmted2010 data. Through spatial processing, the spatial resolution is 1 km (Figure 1).

3.2 Algorithm Principle

3.2.1 ANUSPLIN meteorological interpolation

This dataset mainly adopts the spatial interpolation method of the local thin-disk smooth spline function. This method was first proposed by Wahba in 1979 and later improved by Australian scientist Hutchinson, and ANUSPLIN meteorological interpolation software was developed. At present, the above software is widely used in the field of spatial interpolation of climate change elements[24,25]. The above software is based on the basic principle of the thin-disk smooth spline function, and its theoretical statistical model is shown below[26]:

$$Z_i = f(x_i) + b^T y_i + e_i (i = 1, 2, \ldots\ldots, N) \quad (1)$$

where Z_i is the dependent variable located at point i in space; f (x_i) is the unknown smooth function about x_i; x_i is the d-dimensional spline independent variable; b^T is the p-dimensional coefficient about y_i; y_i is the p-dimensional independent covariate; e_i is the expected value of 0, and the variance is w_i σ2; wi is the known relative error variance; σ 2 is the error variance constant on all data points that are usually unknown; and N is the number of observations.

The above software introduces the linear sub-model of multivariate covariates, automatically selects the optimal fitting surface in the interpolation process and improves the accuracy of spatial interpolation[27].

3.2.2 Error analysis

In order to verify the interpolation accuracy of the scheme selected by ANUSPLIN, this paper uses correlation analysis and error analysis to test the accuracy of the interpolation results[28–30]. In order to test the correlation between the estimated value and the observed value of the station, the correlation coefficient (R^2) is calculated in this paper.

$$R^2 = \frac{\sum_i \left(\hat{y}_i - y_i\right)^2}{\sum_i \left(y_i - \bar{y}_i\right)^2} \quad (2)$$

The numerator of the formula represents the residual predicted by the predicted value, while the denominator represents the residual obtained by predicting all data using the sample mean. When $R^2 < 0$, the residual error of the prediction result of the model is larger than that of the benchmark model (predicting all data with the sample mean), indicating that the prediction result of the model is very poor. When $R^2 > 0$, the greater R^2 is, the smaller the residual of the prediction result of the model is, and the better the prediction effect is.

In order to test the error of the interpolation results, the root-mean-square error (RMSE) and mean absolute error (MAE) are calculated in this paper. The root-mean-square error can be used as an important index to measure the error between real value and predicted value, that is, the smaller the RMSE value is, the better the interpolation effect [31].

$$RMSE = \sqrt{\frac{1}{m}\sum_{i=1}^{m}(x^{(i)} - y^{(i)})^2} \tag{3}$$

where, m is the number of stations, and $x^{(i)}$ and $y^{(i)}$ represent the observed value and estimated value of the ith station, respectively.

The average absolute error reflects the real error and is the average value of the absolute error. The smaller the MAE is, the smaller the error is.

$$MAE = \frac{\sum_{n}^{i=1}\left|y_i - x_i\right|}{n} \tag{4}$$

where, n is the number of stations, and y_i and x_i represent the observed and estimated values of the ith station, respectively.

3.3 Data Processing

The data processing method of this dataset is mainly divided into three parts: data preparation, data preprocessing and spatial interpolation[14]. Data preparation mainly includes the integration of 325 ground meteorological station tables, annual average temperature data and DEM data of the China–Mongolia–Russia Economic Corridor from 1982 to 2018. Data preprocessing aims at sorting the meteorological data and DEM data into a data format that can be used by ANUSPLIN software. Among them, the stations with missing meteorological data are eliminated to ensure the consistency of the interpolation results, and the format is sorted by SPSS software and output in ASCII data format. The DEM data with a spatial resolution of 1 km is output in ASCII data format by ArcGIS. Spatial interpolation is completed by using ANUSPLIN software. Splina and lapgrd programs are run, and longitude and latitude are set as independent variables, while elevation is interpolated as covariate. Finally, ArcGIS is used to convert the interpolation results into .tif format raster data.

4 Data Results and Validation

4.1 Data Composition

The data set includes (1) annual average temperature data files (.tif and .mdd formats) relative to the China–Mongolia–Russia Economic Corridor in the calendar years from 1982 to 2018 and (2) a set of vector files (.shp) for the continental part of the China–Mongolia–Russia Economic Corridor. The .tif temperature data file name is tempyyyy.tif, which refers to the average temperature data in the yyyy year; the .mdd temperature data file name is xxxx-yyyy.mdd, which refers to the annual average temperature data from the xxxx year to the yyyy year; the vector file name is CMREC_BND .shp.

4.2 Data Products

Based on ANUSPLIN software, the multi-year average temperature distribution map of the

China–Mongolia–Russia Economic Corridor from 1982 to 2018 was obtained (Figure 2). The 37-year average temperature in the China-Mongolia–Russia Economic Corridor was 1.24 ℃. The annual average temperature in China was 4.27 ℃, and the average temperature in Mongolia was 2.55 ℃, while the average temperature in Russia was –0.37 ℃. In terms of spatial distribution, the annual average temperature difference between the north and south of the study area was about 30 ℃, which is very significant, and it showed a distribution characteristic of a decreasing trend from south to north and from the coast to the interior. The average annual temperature in the western part of Inner Mongolia in China reached more than 10 ℃, making it the region with the highest annual average temperature in the China–Mongolia–Russia International Economic Corridor, and the temperature gradually decreased toward the east and north of this area and the Liaohe Plain. The general trend of the annual average temperature distribution in Mongolia in the past 37 years followed a distribution from south to north. With the increase in latitude, the temperature gradually decreased, which conforms to the zonal law of latitude. The average annual temperature of Russia gradually decreased from the coast to the interior. The temperature distribution of the China–Mongolia–Russia Economic Corridor was not only affected by the difference in latitude and sea–land distribution but was also significantly affected by the topography. The distribution of the annual average temperature in Northeast China was significantly affected by the topography, and its distribution was related to the shape of the plain surrounded by mountains on three sides. The coldest area of the China–Mongolia–Russia Economic Corridor was located in the Russian Far East Mountains, where the temperature dropped sharply due to the higher terrain. The average temperature in the Republic of Buryatia was as low as –4.10 ℃.

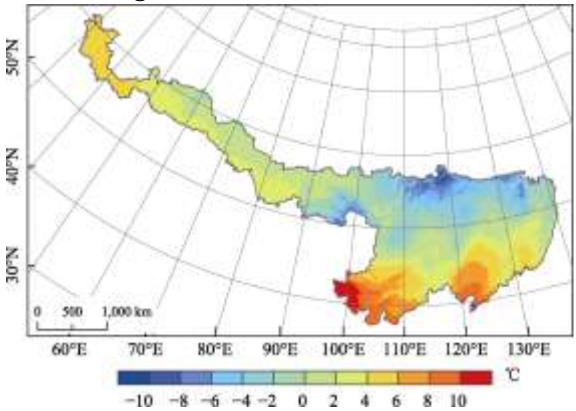

Figure 2 Distribution Map of average temperature over the years in the China–Mongolia–Russia Economic Corridor

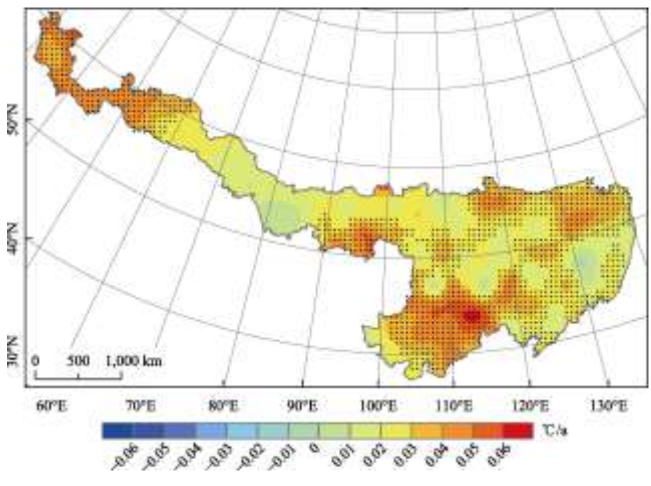

Figure 3 Spatial distribution map of the slope rate of annual mean temperature change in the China–Mongolia–Russia Economic Corridor from 1982 to 2018

The spatial distribution of the annual average temperature change in the China–Mongolia–Russia Economic Corridor from 1982 to 2018 was obtained (Figure 3). The average temperature in the China–Mongolia–Russia Economic Corridor increased significantly in the past 37 years. This increase was above 0.01 ℃/a in some areas such as the central and eastern parts of Inner Mongolia, China, while the rise rate in other areas was above 0.06 ℃/a. In addition, there was a relatively obvious temperature-drop area in the Xiaoxingan Mountains in eastern Heilongjiang, China. The temperature rise in the three eastern provinces of China ranged from 0 to 0.05 ℃/a, while the temperature rise in the Inner Mongolia Autonomous Region ranged from 0.1 to 0.06 ℃/a. There was an obvious temperature-drop area in Northeast China, mainly located in the southern part of the Xiaoxingan Mountains, while the most significant temperature-increase area was mainly located in the central part of the Inner Mongolia Autonomous Region. The temperature variation in most parts of Mongolia was between –0.01 and 0.06 ℃/a, with these areas being mainly distributed in the southeastern part of Mongolia. The areas with a temperature rise above 0.05 ℃/a were mainly concentrated in the central part of East Gobi League in southeastern Mongolia, part of the northeastern part of South Gobi League, the southeast corner of Central Gobi League and the southern part of Sukhbaatar League. The temperature variation in some parts of Russia was between 0 and 0.06 ℃/a. The temperature in the western region was relatively high and significant, roughly bounded by the Ural Mountains, while the central Tuva Republic also had a relatively significant temperature increase, with a heating rate greater than 0.05 ℃/a. There were also two warming zones in the Far East Mountains, and the warming rate in the warming zone was greater than 0.04 ℃/a. The regions with the lowest heating rate were mainly distributed in Primorsky Krai and Altai Krai, and the rate was less than 0.01 ℃/a.

4.3 Data Validation

Using the field observation data of 325 meteorological observation stations in the continental part of the China–Mongolia–Russia Economic Corridor, the interpolation results were verified, and the verification results are shown in Figure 4.

The verification results show that ANUSPLIN software could simulate the distribution of the annual average temperature in the China–Mongolia–Russia Economic Corridor with latitude and longitude as the independent variables and elevation as the covariate. The correlation coefficient (R^2) ranged from 0.980 to 0.996; the root-mean-square error (RMSE) was from 0.294 ℃ to 0.735 ℃, and the mean absolute error (MAE) was from 0.204 ℃ to 0.497 ℃. The error figures in 1996 were slightly higher than in other years. In general, the ANUSPLIN interpolation algorithm showed relatively high interpolation accuracy.

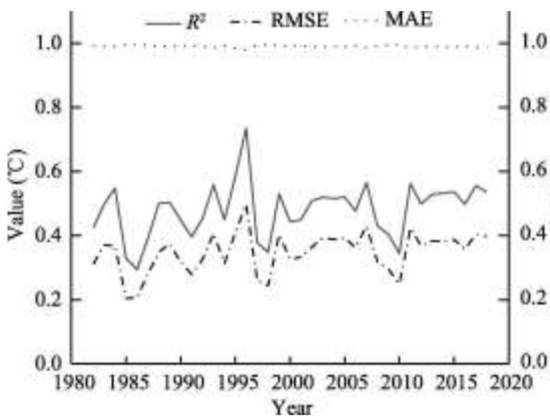

Figure 4 Average temperature from 1982 to 2018 and verification of the accuracy of the interpolation results

5 Discussion and Conclusion

Based on the data and terrain of 325 meteorological observation stations in the mainland part of the China–Mongolia–Russia Economic Corridor and using ANUSPLIN meteorological interpolation software, the Spatial–temporal Mean Temperature Dataset in the China– Mongolia–Russia Economic Corridor (1982–2018, 1-km/y) was finally obtained and verified with the observed and predicted values of meteorological stations. The results show that the annual average temperature distribution data obtained in this study can effectively reflect the temperature change trend in the China–Mongolia–Russia Economic Corridor. The annual average temperature in the China–Mongolia–Russia Economic Corridor showed a very significant difference between the north and the south, as well as a distribution characteristic of a decreasing trend from south to north and from the coast to the interior. By the temperature distribution law, the temperature dropped with the increase in altitude. The annual average temperature in most areas of the China–Mongolia–Russia Economic Corridor showed a significant warming trend, which is consistent with the global warming trend [1]. The format of this dataset is a raster, i.e., it represents the average temperature distribution in a raster, which is different from the observation values of a meteorological station. The meteorological station data were obtained from a wide range of sources, and the terrain data also included processed DEM data. All had a certain influence on the interpolation results. Therefore, there was a certain error between the final interpolation results and the actual temperature distribution. In future research, the accuracy and verification of the interpolation results could be further improved. Based on the above studies, this dataset can provide data support for exploring the characteristics of climate change in the China–Mongolia–Russia Economic Corridor.

Author Contributions

Jiao, Y. and Yu, L. X. provided the overall idea for the development of the data set and the revision and approval of the data paper; Yu, L. X., Jiao, Y., and Bao, Y. L. collected the source data of the data set. All authors co-authored the data paper.

Conflicts of Interest

The authors declare no conflicts of interest.

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