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Monthly Mean Surface Air Temperature 2°×2° Grid Dataset in China (1961–2015)

Wen, K. M.[1] Ren, G. Y.[2, 3*] Li, J.[4] Ren, Y. Y.[3] Zheng, X. L.[1] Sun, X. B.[5] Zhou, Y. Q.[6]

1. Fuzhou Meteorological Bureau, Fuzhou 350000, China;
2. Department of Atmospheric Science, School of Environmental Studies, China University of Geosciences, Wuhan 430074, China;
3. Laboratory for Climate Studies, National Climate Center, China Meteorological Administration, Beijing 100081, China;
4. Tieling Meteorological Bureau, Liaoning Province, Tieling 112000, China;
5. South China Sea Institute of Oceanology, Chinese Academy of Sciences, Guangzhou 510000, China;
6. Jinzhong Meteorological Bureau of Shanxi Province, Jinzhong 030600, China

Abstract: Based on the national surface meteorological station homogenized monthly temperature dataset provided by the National Meteorological Information Center of China Meteorological Administration, the 684 meteorological stations were selected as the target stations. First, establish a reference sequence for each target station. Then, use the difference between the target station sequence trend and the reference sequence trend as the correction value to linearly correct the temperature series of target station, using the corrected 684 target stations plus 79 rural stations for a total of 763 stations. Finally, the inverse distance weight interpolation method was used to interpolate the temperature data of 763 stations nationwide into 2°x 2° grid point data. The research results shows that taking Beijing, Wuhan, Yinchuan, and Shenzhen as representative stations of large cities in North China, Central China, Northwest China, and South China, it was found that their relative urbanization bias in the past 55 years were 67.0%, 75.4%, 32.7%, and 50.3%, respectively. This matched the results of assessing of the impact of urbanization on a single station by predecessors basically. The dataset was archived in .txt format. Each file name was titled according to the year and month. Each file consisted of a header file and 18 rows and 32 columns of average temperature (ºC) data. The first 6 rows were header files, which were the number of columns and rows, the longitude of the bottom left grid point, the latitude of the bottom left grid point, the grid size, and the missing value. The dataset consisted of 660 data files with data size of 2.75 MB (compressed into 1 file, 895 KB).

Keywords: national stations; surface air temperature; monthly mean temperature; urbanization; 1961–2015

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***Corresponding Author:** Ren, G. Y. CN-BT74Q14J, School of Environment, China University of Geosciences (Wuhan), National Climate Center, guoyoo@cma.gov.cn

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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.2019.06.08.V1.

1 Introduction

Climate change monitoring and detection require reliable long-series surface air temperature observation data as basic data. However, the impact of urbanization has become one of the most important sources of systematic errors in the surface air temperature observation data of global terrestrial regions[1–4]. After the reform and opening up, on the one hand, China has gradually loosened its original control over population mobility. Urban construction has created a large number of jobs in construction and industry. The number of migrant workers entering the city has increased year by year. With the popularization of private cars, this has promoted. The rapid development of highways, on the other hand, people's requirements for environmental quality has gradually increased, and infrastructure in rural areas and small towns has gradually improved, all of which have intensified the process of urbanization in rural areas. With the development of urbanization, the monitoring environment around the national stations has also changed a lot. The surrounding environment of many stations has gradually evolved from remote villages to towns or suburbs. Therefore, most of the basic surface air temperature data used in climate change research in China have been affected by urbanization. For example, since 1961 at the Beijing Station, the urbanization bias in the national station surface air temperature observation data has reached 71.0%[5]. In the field of climate change research in China, the basic data used generally come from the national reference climate and basic meteorological stations (referred to as the national station in this article). The regional studies have shown that the surface air temperature data sequence of this observation network was largely affected by the strengthening factors of the urban heat island effect, and exits a large system bias. Therefore, the dataset used the homogenized monthly surface air temperature data from 763 national meteorological stations and 143 villages stations as the main data source. Based on the assumption that the influence of urbanization on the average surface air temperature trend of the target station was linearly increasing, a method of iterative correction from east to west was proposed[6], which gave specific reference station (rural station) for each national station and its urbanization bias, and evaluate the distribution and changes of the urbanization bias from 1961 to 2015 of national stations in China on this basis, developed the grid dataset of monthly mean surface air temperature in China from 1961 to 2015 based on adjusting urbanization-bias.

2 Metadata of the Dataset

The metadata of the Adjusted urbanization bias monthly temperature dataset based on the records from the national meteorological stations of China (1961–2015)[7] is summarized in Table 1. It includes the dataset full name, short name, authors, year of the dataset, temporal resolution, spatial resolution, data format, data size, data files, data publisher, and data sharing policy, etc.

Table 1 Metadata summary of the Adjusted urbanization bias monthly temperature dataset based on the records from the national meteorological stations of China (1961–2015)

Item	Description
Dataset name	Adjusted urbanization bias monthly temperature dataset based on the records from the national meteorological stations of China (1961–2015)
Dataset short name	AdjustedUrbanBiasMonTemChina_1961-2015
Author information	Wen, K. M. E-8903-2019, Fuzhou Meteorological Bureau, Wenkangmin@126.com Ren, G. Y. J-9953-2012, School of Environmental Studies, China University of Geosciences, National Climate Center, Guoyoo@cma.gov.cn Li, J. Aac-5450-2021, Tieling Meteorological Bureau, Lijiaostu@163.com Zhang, A. Y. AAW-6017-2021, Beijing Meteorological Bureau, zhangay66@sohu.com Ren, Y. Y. Aac-3663-2021, National Climate Center, Renyuyu@126.com Sun, X. B. Aac-3839-2021, South China Sea Institute of Oceanology, Chinese Academy of Sciences, 165546192@qq.com Zhou, Y. Q. AAC-3645-2021, Jinzhong Meteorological Bureau, Zhouyqsx@126.Com
Geographic area	Chinese Mainland Year 1961–2015
Time resolution	Month Spatial resolution 2°×2° Data format .txt
Data volume	The data volume is 2.75MB (compressed into a file, 895KB)
Data file	Grid data of surface air temperature corrected for urbanization bias from January 1961 to December 2015
Foudations	Ministry of Science and Technology of P. R. China (2018YFA0605603); National Natural Science Foundation of China (41575003)
Data computing environment	ArcGIS
Publishing and sharing service platform	Global Change Scientific Research Data Publishing System http://www.geodoi.ac.cn
Address	No. 11, Datun Road, Chaoyang District, Beijing 100101, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences
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 dataset[8]
Communication and searchable system	DOI, DCI, CSCD, WDS/ISC, GEOSS, China GEOSS, Crossref

3 Data development Method

3.1 Introduction and Data Preprocessing

3.1.1 Basic Data from the National Meteorological Stations

The National Meteorological Information Center of the China Meteorological Administration provides the National Ground Meteorological Stations homogenized monthly temperature dataset[9], which Contains 2,419 national-level stations in China from 1951 to 2016 homogenized monthly mean temperature, mean maximum and mean minimum temperature. Due to the lack of data before 1961 and 2016, the period from 1961 to 2015 was regarded as the research period. Then, ensure that the data missing rate from 1961 to 2015 was not more than 2%, and a total of 763 national stations meet the requirements. The missing values in the national station were replaced by the average value of the five years before and after dating, and a total of 10 years. For 79 national stations among the 143 reference stations, we excluded them from the selected 763 national stations. Therefore, a total of 685 national stations were used for urbanization bias correction in this study.

3.1.2 Data of Reference Station

The network of 143 rural stations in China established by Ren *et al*. (2010) and Ren *et al*. (2015)[10–11] was selected from 2,400 long-sequence observation stations across the country. The information such as the beginning and ending years of station data and the continuity of observation, the population of the settlement, the relocation of the station, the distance between the station and the nearby town center, and the ratio of artificial buildings within a 12 km^2 area around the observation site were considered. The monthly mean surface air temperature data of rural stations also comes from the National Meteorological Information Center of the China Meteorological Administration. For the missing data in a few stations, it was also replaced by the 10-year average value of 5 years before and after the missing year.

3.2 Technical Route

3.2.1 Determination of the Corresponding Reference Station for the City Station

When constructing the reference stations of each national station, we took example from the neighbor station selection method of the spatial consistency check of climate data quality control[12–14]. Taking a station as the center and a reference station within a certain fixed radius as the reference station of the national station, the distance between the two was calculated as:

$$d\left(A_1, A_2\right) = R\cos^{-1}\left[\sin\varphi_1 \sin\varphi_2 + \cos\varphi_1 \cos\varphi_2 \cos\left(\theta_1 - \theta_2\right)\right] \quad (1)$$

where θ_1 and φ_1 were the longitude and latitude of the point A_1 (national station) respectively; θ_2 and φ_2 were the longitude and latitude of the point A_2 (country station) respectively; R represented the radius of the earth, and the average value was about 6,371 km.

First of all, ensure that the distance between the rural station and the national station was no more than 300 km. Secondly, in order to ensure appropriate rural stations could be selected for national stations in Northeast China and the central and western regions of the Qinghai-Tibet Plateau where rural stations were scarce, we used the correction method of iterating from east to west by longitude to correct the urbanization bias in the national stations. The adjusted national station could be used as a subsequent adjusting rural station.

The detrended temperature series mainly represents the variability of surface air temperature on interannual and interdecadal scales. After detrending, the correlation coefficient of the annual mean temperature of the national station and the rural station was used as a judgment index to ensure that the candidate rural station and the national station were at the same subregion of natural climate. Calculate the correlation coefficients between the detrended annual and monthly mean temperatures of each national station and its candidate rural stations. If the correlation coefficient passed the significance test with a confidence level of 0.005 ($t_{0.005}$ = 0.364), the rural station could be used as a reference station of national station.

3.2.2 Establishment of Reference Sequence of City Station

This paper stipulated that when the number of reference stations of the target station was more than 4, the 4 stations with the highest correlation would be the final reference stations according to the correlation coefficient of the detrended annual mean temperature; when the number of reference stations was less than or equal to 4, all will be retained. For each target station, the detrending correlation coefficient of the monthly mean temperature series of each reference station and the target station was used as the weight, and the weighted average of the monthly mean surface air temperature of all reference stations was calculated to obtain the reference sequence of monthly mean surface air temperature of each target station from 1961 to 2015.

3.2.3 Correction Method of Urbanization Bias

This method was based on two assumptions: (1) the linear trend of the established reference temperature series of a target station represented the large-scale background temperature change trend of the region; (2) the influence of urbanization on the average surface air temperature trend of the target station was linearly increased, namely this influence was similar in different years and decades. Taking the last year of the target station sequence (here, 2015) as the benchmark, the annual mean urbanization bias was sequentially added forwards. The correcting sequence took the current temperature of the station and the next few years as fixed values, and the new temperature data would have better scalability in the next few years (Equation (3)).

$$T_i' = T_i - \left(\Delta T_{u-r} / 10\right)\left(i - j\right) \quad (2)$$

$$T_i' = T_i + \left(\Delta T_{u-r} / 10\right)\left(k - i\right) \quad (3)$$

where T_i' was the corrected temperature, T_i was the temperature before correction, ΔT_{u-r} was the difference of the climate trend between the target station and the reference station during the entire period, namely the urbanization bias (ºC/10a), *i* represented the corrected year, *j* and *k* represened the start and end year of temperature series respectively.

4 Data Results and Verification

4.1 Dataset Composition

The grid dataset of monthly mean surface air temperature in Mainland China based on the correction of urbanization bias was a grid dataset of the corrected urbanization bias of monthly surface air temperature in Mainland China from January 1961 to December 2015, with a spatial resolution of 2°×2°, the unit was ºC, the total compressed data size was 895 KB, and there were 660 files after the data was decompressed. The file 196201 represented January 1962. This data was used in ArcGIS software.

Figure 1 showed the spatial distribution of surface air temperature corrected for urbanization bias at 2°×2° resolution in Mainland China in January 1962. There were differences in regional climate, the spatial distribution of surface air temperature was quite different. On the whole, the spatial distribution of surface air temperature (January 1962) had the characteristics of high in the south and low in the north, and their value are between –26.46 ºC and 15.84 ºC. The surface air temperature in South China was the highest, followed by the region of Southwest to North China, and the lowest surface air temperature occurs in northern Northeast China.

4.2 Data Results

The spatial distribution of the grid annual mean temperature trend in China from 1961 to 2015 is shown in Figure 2. In the past 55 years, parts of central China and parts of Southwest Chinahad grown at a rate of 0–0.1 ºC/10a, making it the weakest warming area in China; North China except Inner Mongolia, Southwest China except Tibet, and most of South China, the annual mean temperature increased at a rate of 0.1–0.2 ºC/10a;

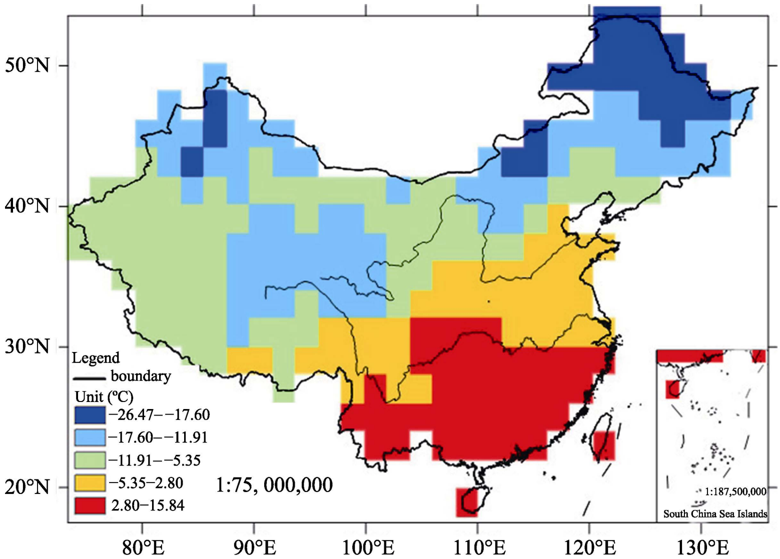

Figure 1 Spatial distribution of grid mean temperature in China in January 1962

In northern Northeast China, eastern Inner Mongolia, northwestern Liaoning, Qinghai, southern and western Xinjiang, and northern Tibet, the annual mean temperature increased at a rate of 0.3–0.4 ºC/10a. Most of the remaining areas, including most of East China, most of Northeast China, Inner Mongolia, parts of Shaanxi, most of Xinjiang, and southern Tibet, annual mean temperature increased at a rate of 0.2–0.3 ºC/10a, while parts of western Tibet showed the greatest warming trend, which was 0.4–0.51 ºC/10a.

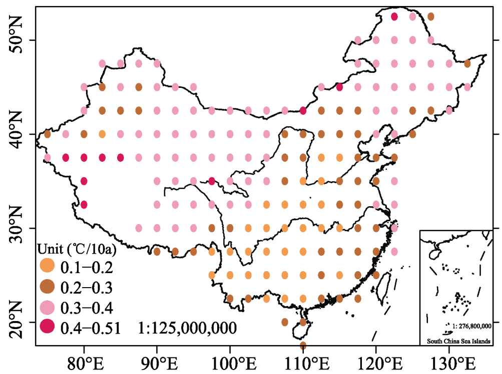

Figure 2 The spatial distribution of the grid annual mean temperature trend in China

From the perspective of seasonal changes (Figure 3), from 1961 to 2015, the spring mean temperature increased only 0–0.1 ºC/10a in parts of Southwest China. In most Southwest China except for Tibet, central China, Guangdong, Hainan, the warming rate was 0.1–0.2 ºC/10a; while in Jiangsu, Zhejiang, Inner Mongolia, central Northeast China, northern and southwestern Xinjiang, the warming rate was 0.3–0.4 ºC/10a; the largest rates were occurred in northern Northeast China, parts of eastern and western Inner Mongolia, it reached 0.4–0.5 ºC/10a; the largest warming area was western Tibet, above 0.5 ºC/10a; in the rest areas, it was between 0.2–0.3 ºC/10a.

The summer mean temperature in China had an obvious feature, that is, most of central China decreased at a rate of –0.1–0 ºC/10a. Most parts of South China, North China except Inner Mongolia and Shaanxi, parts of Southwest China, parts of east China, and parts of western Xinjiang increased at a rate of 0–0.1 ºC/10a; In Hainan, southeast coast area, Jiangsu and Zhejiang, southern Inner Mongolia, eastern and southern Northeast China, parts of Southwest China and parts of western Xinjiang, summer mean temperature increased at a rate of 0.1–0.2 ºC/10a; the regions with a warming rate above 0.3 ºC/10a included the northern part of the Northeast China, the eastern part of Inner Mongolia, Qinghai, and the northwestern part of Tibet; the remaining areas included the most Northeast China, most Northwest China and most Inner Mongolia, it increased at a rate of 0.2–0.3 ºC/10a.

The autumn mean temperature in Northeast China, most of East China, Inner Mongolia, Xinjiang, southern Tibet, Shaanxi, and Hainan increased at a rate of 0.2–0.3 ºC/10a; in northern Tibet, central Qinghai, southeastern and northwestern Xinjiang, it increased at a rate of 0.3–0.4 ºC/10a, and the weakest warming of 0–0.1 ºC/10a occurred in parts of the Southwest China extend to parts of North China; In Southwest China except Tibet, most of South China, parts of central and North China, northern Northeast China and a few areas of North China, the warming rates were 0.1–0.2 ºC/10a, and the warming trend greater than 0.3–0.4 ºC/10a appeared in Qinghai, northern Tibet, and parts of northern Xinjiang; the warming trend greater than 0.4 ºC/10a appeared in western Tibet.

The winter mean temperature increased by 0.1–0.2 ºC/10a in parts of central China, parts of South China and Southwest China, and a few areas in central and northern Xinjiang, which was the weakest warming area in winter, and in some areas it increased by 0–0.1 ºC/10a; In southeast coastal areas, parts of Jiangsu, most Northeast China, northern North China, and central Tibet, it increased by 0.3–0.4 ºC/10a; winter warming rates of 0.4–0.61 ºC/10a appeared in the central and parts of northern Northeast China, eastern and western Tibet, Qinghai and parts of Gansu, the rest included most of East China, South China, southern Northeast China, eastern Inner Mongolia, North China and parts of Southwest China, and most of Xinjiang with an increased trend of 0.2–0.3 ºC/10a.

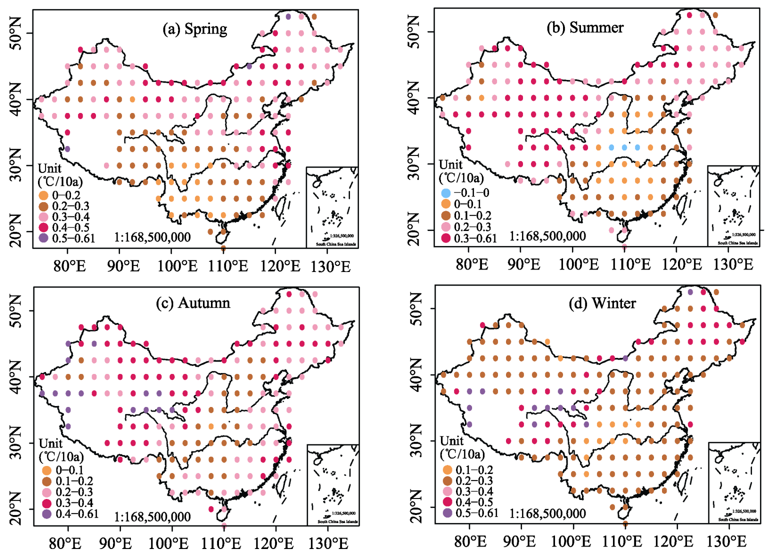

Figure 3 Spatial distribution of grid seasonal mean temperature trends in China

Figure 4 indicates the annual mean anomaly curve in China calculated using 763 national stations removed urbanization bias. The regional anomaly decreased before 1969. The temperature anomaly from 1969 to 1987 did not change much, and it was a stable period. After 1987, there was a period of rapid increase, and larger temperature anomalies appeared during this period. The late 1980s was a period of interdecadal transition when the regional average anomaly changed from negative to positive.

From the perspective of the interdecadal variation of the seasonal mean anomaly (Figure 5), it was not difficult to find that the average anomaly curve of each season showed a relatively obvious downward trend before the mid to late 1970s; it gradually entered a relatively warm period in the mid to late 1990s, the seasonal anomaly values were greater than 0 in the majority. Spring temperature anomaly basically fluctuated around the zero value line before the mid to late 1990s. From the end of the 1990s, the spring mean temperature anomaly was above the zero value line, and the anomaly values fluctuated within a large positive range. Summer mean anomaly had similar evolution characteristics to that in spring. Before the mid-1990s, most of the regional anomalies were close to 0, and then until 2015, the regional anomalies were all greater than 0, and their values were larger. Before the mid-1970s, the summer temperature anomaly showed a slight downward trend. From the mid-to-late 1970s to the mid-1990s, the summer temperature anomaly fluctuated very little. Autumn temperature anomalies were mostly less than 0 before the mid-1990s. After the mid-1990s, autumn temperature anomalies were mostly greater than 0, and the anomalies were relatively large. Most winter temperature anomalies were less than 0 before the end of the 1980s, and the values were relatively small, and after the end of the 1980s, most of the temperature anomalies were greater than 0.

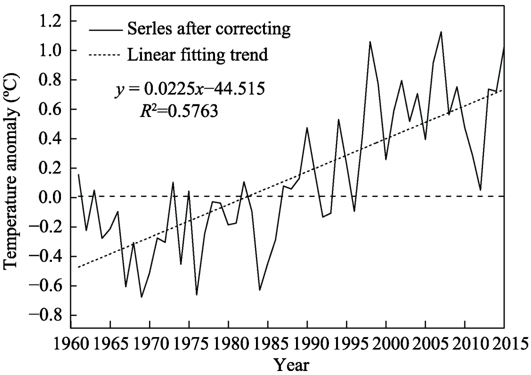

Figure 4 Annual anomaly sequence curve removed urbanization bias in China

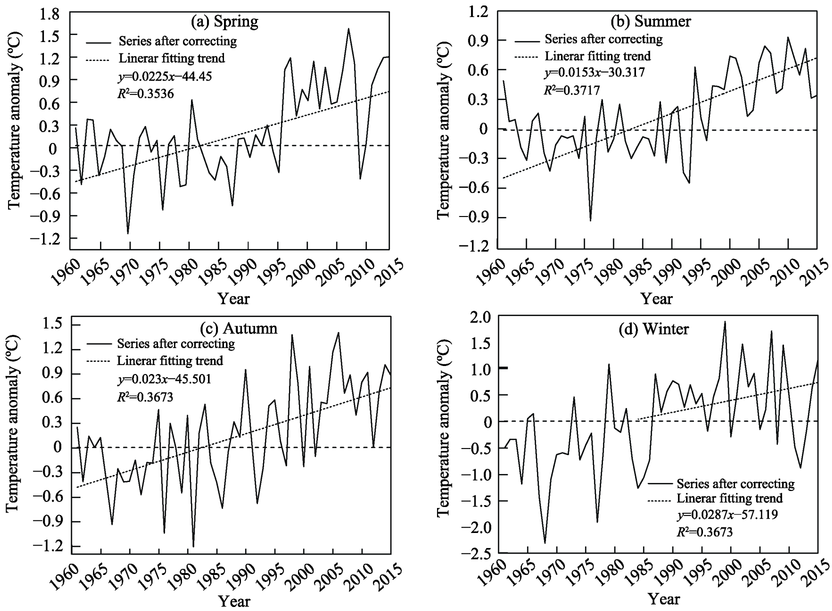

Figure 5 The seasonal anomalies sequence curve removed urbanization bias in China

4.3 Data Validation

By comparing with the methods of evaluating the urbanization bias in single station developed by previous scholars, it verified the rationality of the method of correcting urbanization bias and the results obtained in this article. Considering the availability of data and the uniformity of station distribution, Beijing, Wuhan, Yinchuan and Shenzhen were selected as representative metropolitan stations in North China, Central China, Northwest China, and South China to test the corrected results.

The analysis results of this paper were very consistent with those of Chu *et al.*[15] corrected 1961–2000 and Yan *et al*.[16] estimated that the urbanization bias from 1977 to 2006 in Beijing Station;and compared with the results of Ren *et al*. and Chen *et al*.[17–18] corrected Wuhan Station, Li *et al*.[19] corrected Yinchuan station, and Chen *et al*., Zhang *et al*., and Si *et al*.[20–22] corrected Shenzhen station. Due to the difference of reference stations, the method of selecting reference stations, the length of reference sequence, and the study time range, it was found that the corrected conclusions obtained in this paper were consistent with those obtained by predecessors.

5 Discussion and Summary

Based on the assumption that the influence of urbanization on the trend of surface air temperature of national stations was linearly increasing, by using the dataset of " Adjusted urbanization bias monthly temperature dataset based on the records from the national meteorological stations of China (1961–2015)" provided by the National Meteorological Information Center of the China Meteorological Administration, and the 143 rural stations developed by the research group, using the method of comparing cities and villages, and correction from east to west by longitude, corrected the urbanization bias in the temperature series for more than half a century in China, and obtained some benefits discoveries. The results showed that, compared with the scattered distribution of surface air temperature changes in China before the correction of urbanization bias, the temperature evolution trend was relatively concentrated after the correction, showing a belt shape, which was more consistent with the actual climate change and the distribution of climate zones in China. In addition, the warming trend in China had been widely and significantly reduced after correcting urbanization bias, indicating that the surface air temperature records of national stations in China contained obvious urbanization bias. Larger bias were distributed in North China, Central China, northern Northeast China, parts of Southwest China, Xinjiang and parts of Tibet, with the values of 0.1–0.3 ºC/10a; by using the grid area weighting method[23], the relative urbanization bias in surface air temperature series in China was estimated to be 19.6%.

This dataset was to correct the urbanization bias in the surface air temperature of the national stations on the basis of the station, and basically eliminate the impact of the urbanization bias. Analysis of modern climate change based on this dataset, the temporal and spatial change trends characteristics of the countrywide and regional surface air temperature obtained were relatively realistic. Therefore, on the one hand, this dataset had significant significance for climate change monitoring, detection and simulation research. On the other hand, it also had important value for climate change impact assessment. The informations of regional background climate change required for climate change impact assessment in the field of water resources and agriculture, this dataset could meet the requirements.

Author Contributions

Ren, G. Y. made an overall design for the development of the dataset. Li, J. and Zhou, Y. Q. designed the algorithms of dataset. Wen, K. M. contributed to the data processing and analysis. Ren, Y. Y. did the data verification. Wen, K. M., Zheng, X. L. and Sun, X. B. wrote the data paper.

Conflicts of Interest

The authors declare no conflicts of interest.

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