Study on Temperature based on China in the Context of Global Warming

Song Li
Xi'an Gaoxin No.1 High School, Class 2AP1, Xi'an, Shaanxi, 710075, China

Abstract: In this paper, the monthly data set of ground meteorological elements in China provided by the China Meteorological Administration is used to model and analyze the temperature data of China in 1951-2019. The trend of temperature change in china over the past 70 years is studied by scatter plots and linear regressions and the spatiotemporal characteristics of meteorological factors are analyzed by Empirical Orthogonal Function models, and the temperature change in china over the next 25 years is predicted by Grey Prediction and Time Series Model. The results show that under the background of global warming, the temperature in China is on the rise in many latitudes, and will rise about 0.6-0.8 degrees Celsius in 25 years.

Keywords: Empirical orthogonal function model(EOF); Linear regression; Grey prediction model; Time series model

1. Introduction

According to IPCC Fourth Assessment Report, for the past 100 years, average global surface temperature has increased 0.74°C and the sea level has increased by 0.17 m. The Report further illustrates that by the end of the 21st century, global surface temperature will continue to rise 1.1-6.4°C and sea levels would rise 0.18-0.59m, and the frequencies of high temperatures, heat waves, and strong precipitation may greatly increase. The world's average temperature climbed about 0.6 degrees Celsius in the 20th century. In the Northern Hemisphere, ice and snow thawed nine days earlier than 150 years ago, while autumn frost began about 10 days later.

Moreover, global warming has an important impact on climate disasters and ecosystems, such as changes in extreme weathers or climate events: from a point of view of extreme temperatures, the extremes of high and low temperatures on most of the world's continents since 1950 have increased significantly, i.e., the decrease in extreme cold events and the increase in extreme warm events; from a point of view of strong precipitations, although changes in land-based heavy precipitation events have been regionally inconsistent, there has generally been an increase in heavy precipitations since 1950, and during El Niño, there has also been an increase in extreme heavy precipitation events in the tropical oceans. For ecosystems, the habitat range, seasonal activities, migration routes, species abundance and interlinking effects of many terrestrial, freshwater, and marine species have changed with climate change, and the increase in tree mortality observed in many parts of the world has been attributed to climate change.

In the context of such global warming, what is the trend of temperature change in China over the past few decades? What are the spatiotemporal characteristics of meteorological factors? What is the forecast trend of temperature in the next few years? This paper will start from these problems, analyze and predict China's temperature data through mathematical methods and mathematical models. It is hoped that both professional and non-professional people can intuitively understand the changing trend of China's temperature in the past few decades, so as to enhance the awareness of non-professional people on climate change issues and urge decision makers to formulate policies to deal with climate change quickly.

2. Method

1. China Historical Temperature Analysis

The temperature data of China in the past 10 years are visualized and the trend of temperature change in different regions is analyzed intuitively.

2. Temporal and Spatial Characteristics of Temperature in China

By using the Empirical Orthogonal Function Model, the temperature data of China in recent 70 years are analyzed and summarized from two latitudes of time and space.

3. Analysis of Temperature Trend in China

Using linear regression to process the temperature data of many cities, the function expression of maximum temperature and time is obtained and analyzed.

4. Future Trends in China's Temperatures

Using Grey Prediction Model and Time Series Model, the temperature data of 5 cities in China are fitted and predicted from two different insights, and the corresponding broken line statistic charts of temperature change are drawn.

3. Visual Analysis of Temperature in China

in the Last 10 Years

The maximum temperature data of the first quarter in 824 meteorological observation stations in China in the past 10 years were selected to draw the scattered points, and the scattered points were colored according to the temperature range, and finally figure 1 was obtained. Compared with the national January maximum temperature data scatter plot from 2010 to 2017, we can intuitively see that the number of dark blue scattered spots in the whole country is decreasing, and it is obvious that the red and orange scattered spots in the northeast region and the southern region are also increasing. Compared with the scatter charts of the highest temperature data from March 2010 to 2017, it can be seen that the orange scattered points in central China gradually geographically replace the green and yellow scattered points, and the orange and red scattered points in the southern region increase and the density becomes larger.

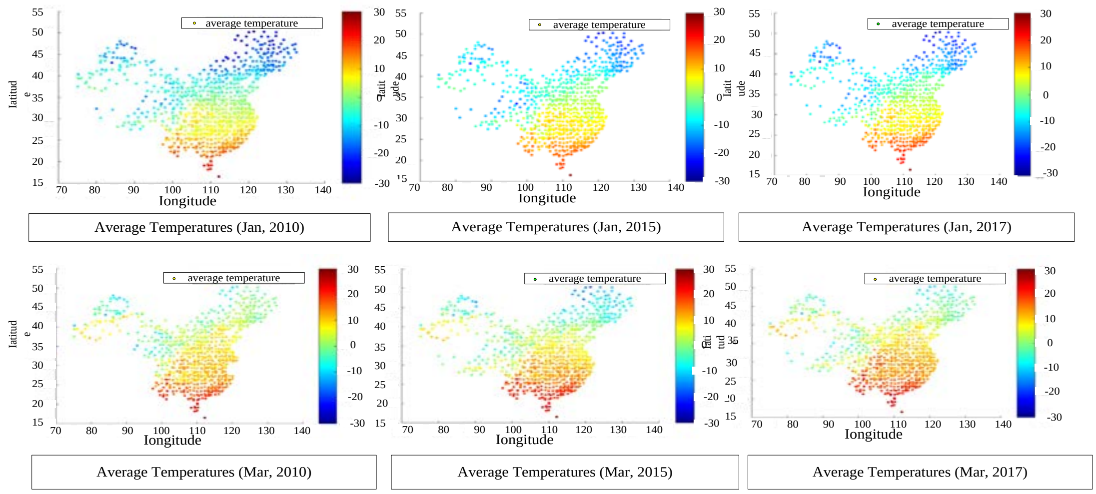

Figure 1. 2010~2017 China temperature scatter plot

4. Analysis of Temporal and Spatial Characteristics of Chinese Historical Temperatures-Empirical Orthogonal Function (EOF) Model

By EOF, the data can be viewed as time functions, invariable time coefficient with the changes in spaces, and space functions, invariable eigenvectors with the changes in time, for the purpose of dimensionality reduction of data.

The Temperature Variation Fields in China from 1957 to 2019 was decomposed by EOF models and applied by the North Significance Test. The variation rate distribution structure of the Temperature Variation Field in China was characterized to the maximum extent by the first eigenvectors of the Significance Test. The spatial distribution they represent is a typical distribution structure of Temperature Variation Fields. If each component of the eigenvector is the number of the same symbol, then the eigenvector reflects the characteristic that the change trend of the region variable is basically the same, and the larger numerical absolute value is the center. If certain eigenvector is in the alternating distribution form of positive and negative phases, it represents two distribution types.

Table 1 shows that the cumulative contribution rate of the first four eigenvectors' eigenvalues is 94.83%, but only the error ranges of the first three eigenvectors do not overlap and pass the North Significance Test. Therefore, the first three characteristic roots can well characterize the three main spatial distribution modes of temperature in China in the past 62 years.

The variance contribution rate of modal 1 eigenvector is 48.5929%, which is much higher than that of other modes, and is the main spatial distribution form of temperature field in China. The negative value center of characteristic value of modal 1 site is mainly in southwest China, and it shows that the temperature in southwest China has increased obviously in the data of nearly 60 years.

The variance contribution rate of modal 2 eigenvector is 21.2403%, which is also a typical spatial distribution form of temperature. The negative distribution pattern is mainly distributed in northeast China. It shows that the temperature in Northeast China has a certain upward trend in the past 60 years.

The variance contribution rate of modal 3 eigenvector is 14.6317%, which is an atypical spatial distribution form of temperature. The negative value of this distribution pattern mainly appears in the northwest region of China, indicating that the temperature in the northwest region has increased slightly in the past 60 years.

Table 1. Contribution rate of five eigenvectors before decomposition of annual temperature EOF in China

Mode	Characteristic Root	Variance Contribution	Cumulative Variance Contribution	Error Range of Characteristic Roots (upper limit)	Error Range of Characteristic Roots (lower limit)
1	-0.1023	48.5929%	48.5929%	18.2931	4.1186
2	-0.0353	21.2403%	69.8332%	3.9960	1.8002
3	0.9042	14.6317%	84.4703%	3.5082	1.2401
4	0.1928	10.3624%	94.8327	3.9010	0.8783
5	-0.3654	5.1724%	100%	1.94719	0.4384

Table 2. Time coefficient for modes

Mode 1	Mode 2	Mode 3	Mode 4	Mode 5
-0.1023	-0.0353	0.9042	0.1928	-0.3654
0.2452	-0.0700	0.4204	-0.3177	0.8107
-0.9307	0.2014	0.0300	-0.2369	0.1904
-0.2269	-0.4787	-0.0623	0.7656	0.3596
0.1085	0.8510	0.0299	0.4686	0.2088

5. Analysis of Spatial Distribution Characteristics in Time

The time coefficients represent the time variation characteristics of the corresponding eigenvectors in spatial distribution modes, and the coefficients' symbols determine the directions of a mode: the positive sign is the same direction as the mode, and the negative sign is opposite, and the larger the absolute value of the coefficient is, which means that the mode is more typical. The three types of air temperature spatial modal distributions in 62 years are statistically analyzed, and the eigenvectors corresponding to the maximum absolute values of the annual time coefficients are taken as the spatial distribution modes of the current year. It can be seen that the distribution mode of temperature field in 62 years is mainly Mode 1, which has nearly 35 years, accounting for 56.45% of the total annual number, and the trend slope of time coefficient is less than zero, which to some extent indicates that the temperature in China has increased in these 35 years.

6. Analysis of the Trend of Temperature Change in China —— A Linear Regression Analysis

$y(i=1\sim n)$; $x(i=1\sim n)$

Denoting as the highest temperature sequence in January and as the years.

The highest temperatures in January in Shanghai can be simulated by the Least Squares Method according to the year:

Beijing (1957~2019): $y=0.02291x-44.42$

Gansu (1958~2019): $y=0.021501x-46.659$

Shanghai (1959~2019): $y=0.013845x+12.003$

Sichuan (1961~2019): $y=0.028157x-58.615$

Guangdong (1957~2019): $y=0.011367x-8.3491$

From the five locations of North China, Northwest, East China, Southwest and South China, all the temperature growth rates are positive, which means that Chinese mainland have different degrees of temperature increases year by year in each region.

7. Study on Temperature Prediction in China for the Next 25 Years - Grey Prediction Model

The original sequence values and the prediction sequence values of temperatures are obtained by Grey prediction Model:

Table 3. Prediction results

Sequence (Years)	Original Temperature values(°C)	Prediction Temperature Values(°C)	Sequence (Years)	Original Temperature values(°C)	Prediction Temperature Values(°C)
1	18.2000	15.1350	31	13.2000	15.5328
2	17.3000	15.1368	32	15.0000	15.5467
3	14.3000	15.1503	33	11.4000	15.5605
4	13.8000	15.1638	34	19.2000	15.5744
5	13.4000	15.1773	35	13.6000	15.5883
6	18.4000	15.1909	36	14.7000	15.6021
7	14.0000	15.2044	37	15.7000	15.6160

8	16.0000	15.2179	38	17.6000	15.6300
9	17.6000	15.2315	39	14.9000	15.6439
10	16.5000	15.2451	40	16.7000	15.6578
11	19.2000	15.2586	41	14.9000	15.6718
12	14.4000	15.2722	42	17.9000	15.6857
13	15.5000	15.2858	43	14.6000	15.6997
14	20.0000	15.2995	44	22.1000	15.7137
15	12.1000	15.3131	45	16.5000	15.7277
16	12.0000	15.3267	46	12.7000	15.7417
17	12.5000	15.3404	47	10.5000	15.7557
18	13.9000	15.3541	48	18.3000	15.7698
19	10.9000	15.3677	49	12.5000	15.7838
20	15.8000	15.3814	50	15.80000	15.7979
21	16.8000	15.3951	51	13.90000	15.8119
22	12.8000	15.4088	52	20.70000	15.8260
23	14.9000	15.4226	53	7.300000	15.8401
24	19.7000	15.4363	54	10.80000	15.8542
25	21.5000	15.4501	55	18.00000	15.8684
26	15.1000	15.4638	56	20.20000	15.8825
27	14.8000	15.4776	57	19.70000	15.8967
28	12.4000	15.4914	58	17.30000	15.9108
29	15.6000	15.5052	59	22.10000	15.9250
30	15.4000	15.5190	60	14.20000	15.9392

Statistical Charts obtained by MATLAB programming:

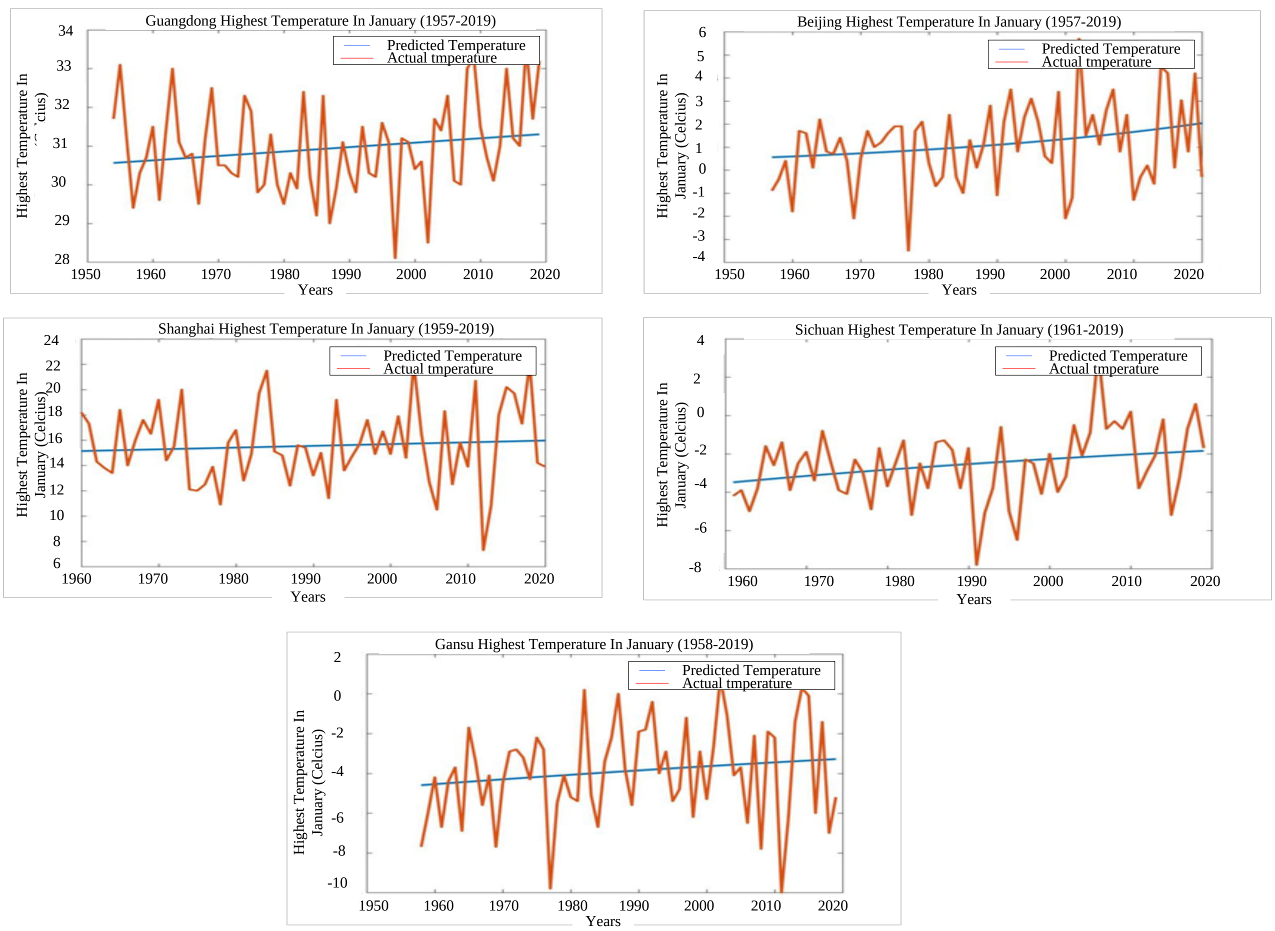

Figure 1. Statistical Charts obtained by MATLAB programming

In order to predict the trends of temperature changes in the next 25 years, 5 samples were evenly selected according to the geographical locations of cities (Shanghai, Beijing, Guangdong, Gansu, Sichuan). Thus, the model fits historical statistics of temperatures well. In general, the national temperature based on these five cities' current circumstances will rise 0.6~0.8 degrees Celsius in the next 25 years.

8. Analysis of the Trend of Historical Temperature in China —— Time Series Model

The prediction objects are arranged in chronological order to form a time series, which uses the changing patterns in the past of a group of time series to conjecture the possibilities of future changes, the changing trends, and the future changing pattern.

Time Series Model is also a kind of regression model, which is based on the principle that, on the one hand, we can infer the developmental trends of objects by recognizing the continuity of the developments and using the data of past time series, and on the other hand, we can fully consider the randomness of a certain occurrence generated by some unexpected factors and effectively eliminate the unanticipated data fluctuations.

Because of the certain correlation of the annual temperatures in Shanghai, the Time Series Model can be used to establish a prediction model for the changes in highest temperatures in January from 1959 to 2019, and the original time series data can be recorded.

The predicted values are obtained:

Table 4. Data sheet for january maximum temperature forecast in Shanghai

Year	Predicted Temperature(°C)	Year	Predicted Temperature(°C)
1959	18.2000	1989	15.2021
1960	17.3000	1990	13.9542
1961	17.3852	1991	13.8989
1962	15.3978	1992	12.8255
1963	13.7688	1993	15.2878
1964	13.3307	1994	15.8950
1965	15.7778	1995	13.9233
1966	15.7410	1996	14.9500
1967	14.7890	1997	16.4045
1968	16.5412	1998	15.8500
1969	16.6913	1999	15.5670
1970	17.6102	2000	15.4401
1971	16.3156	2001	16.1980
1972	14.7082	2002	15.8288
1973	17.5755	2003	18.2700
1974	15.4704	2004	18.7406
1975	11.8204	2005	14.1922
1976	12.0378	2006	11.3048
1977	13.0017	2007	14.4046
1978	12.0616	2008	14.9067
1979	13.2722	2009	14.0008
1980	16.0294	2010	14.5044
1981	14.3814	2011	17.2150
1982	13.6641	2012	13.2652
1983	17.1445	2013	9.0035
1984	20.2769	2014	14.3835
1985	17.7311	2015	18.8191
1986	14.6589	2016	19.5581
1987	13.2603	2017	18.0683
1988	13.8501	2018	19.4995

Based on the same method, the prediction models of five selected urban time series in China are as followed:

Beijing: $y_1 = 0.2157 y_{t-1} + 0.1592 y_{t-2} + \varepsilon_t$

Shanghai: $y_1 = 0.5259 y_{t-1} + 0.4554 y_{t-2} + \varepsilon_t$

Gansu: $y_t = 0.4861 y_{t-1} + 0.3368 y_{t-2} + \varepsilon_t$

Guangdong: $y_t = 0.6290 y_{t-1} + 0.3701 y_{t-2} + \varepsilon_t$

Sichuan: $y_t = 0.4797 y_{t-1} + 0.3503 y_{t-2} + \varepsilon_t$

Conclusions: The coefficients in the selected five urban prediction equations are greater than zero, indicating that the temperatures in these areas will increase further with time in the future.

9. Policies Suggestions and Related Recommendations

Based on the results of this study, we have the following policy recommendations, taking into account the serious consequences of further temperature rise in the future:

First, the government should play its leading role, such as deposits, financial subsidies and other ways to formulate regional energy conservation and emission reduction measures. According to the different characteristics of the region and each industry, the corresponding administrative and economic means are adopted to ensure the effectiveness and sustainability of policy implementation.
Second, China should improve the existing energy consumption structure. Vigorously develop renewable energy, improve the effective utilization of existing energy, further reduce the use of coal in China's resources, thereby reducing CO2 emissions.
Third, we must adhere to the road of green development, set up green water Qingshan is Jinshan Silver Mountain development concept. Strengthen ecological protection, respect nature, conform to nature, and solve the problem of harmonious symbiosis between good people and nature. To explore the system construction of "landscape, forest, lake, and grass" life community and to popularize the sustainable ecological compensation mechanism, and to establish a good ecological civilization system.
Fourth, it is necessary to give full play to the role of scientific and technological innovation in promoting the construction of ecological civilization. It is necessary to improve cadres and the masses at all levels' understanding of the importance of scientific and technological innovation, increase scientific and technological investment in the construction of ecological civilization, establish multiple monitoring standards for the quality assessment of ecological civilization, and improve the policy system of scientific and technological innovation of the ecological civilization system. This paper studies and popularizes the key technology of ecological construction, trains the complex talents of discipline, and provides strong scientific and technological support and talent guarantee for the construction of ecological civilization.
Fifth, we should vigorously strengthen the people's understanding and cognition of climate change, strengthen the people's awareness of adaptation to climate change and their sense of crisis, and make them realize the scientific fact of rising temperature and its possible serious consequences. Each community should carry out corresponding propaganda and education and public opinion education, appeal to the public to carry out climate change adaptation actions, strengthen propaganda and education, raise citizens' environmental awareness, and create a good atmosphere for protecting the environment in the whole society.

References

[1] Wang Chenghai, Li Jian, Xu Xiaoguang. The ubiquitous patterns of weather changes in china for 50 years and the possible trend of temperature. Weathers of Plateau. 2012, 31(01), 126-136.
[2] Gong Ying. American situations under the conditions of global warming.Jilin University. 2010.
[3] Zhao Jiayang. The spatiotemporal characteristics, abrupt changes, and analyses of future trend of climates in China (1960-2013). 2017.
[4] Guanjun T. The structure method application of background value in grey system GM(1,1) Model (II).Systems Engineering-Theory & Practice. 2000, 20(5), 125-127.
[5] Xie N.M., Liu S.F. Discrete GM (1,1) and mechanism of grey forecasting model. Xitong Gongcheng Lilun yu Shijian/ System Engineering Theory and Practice. 2005, 25(1), 93-99.
[6] Si Shoukui, Sun Zhaoliang. Mathematical modeling algorithms and applications(2nd version). Beijing: National Defense Industry Press. 2017, 4.
[7] Zhou Wenkui. Influences of climate change on crop productions in China and agricultural strategies. Nanjing Agricultural University. 2012.