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Research on Temperature Changing Rules of Some Major Cities (Shanghai, Guangzhou and Beijing) in China from 2015 to 2020

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Abstract. Nowadays, China is experiencing extreme heat wave weather this year. Currently, domestic citizens are suffering from the excessive hot weather and have no idea how to protect themselves efficiently from getting illness or having heat stroke. Therefore, we have a research on temperature change rules in some major cities (Shanghai, Guangzhou and Beijing) in China from 2015 to 2020. We collect and obverse several temperature data of Beijing, Shanghai and Guangzhou to see if there are upward or downward trends in temperature. We attempt to understand how temperatures have changed over time in these cities in China and how these trends can help forecast future temperatures. This research can help people know the probable temperature changing trends in the three cities in the next few years and take some precautions in advance.

Keywords: Temperature changing trend, Beijing, Shanghai, Guangzhou, from 2015 to 2020, linear regression model, linear fitting, OSL table.

1. Introduction

1.1. Background and Brief Introduction

China has experienced extreme heat wave weather this year. On August 12th, China Meteorological Administration issued this year's first red alert for high temperature (Red alert criteria: in the past 48 hours, 4 or more provinces and regions have seen the highest temperature of 40°C or above continuously and it is expected to continue in the future). In Chinese extreme hot in 2013 and 2017, the national meteorological center just sent high temperature orange alert, as you can see the orange early warning is the highest level under normal circumstances. This time bring out of the closet “red alert”, which fully explain the high temperature has been the breakthrough in the intensity, scope and duration of three indicators. They are moving in the history of the most. From late July to now, the middle and lower reaches of the Yangtze River and southwest China have experienced a wide range of hot weather with strong degree. China have a sustainable development of the high temperature and meteorological drought, from the Sichuan Basin to the middle and lower reaches of the Yangtze River region has been heavier drought, seriously affected people's daily life at ordinary time. There is a surge in demand for air conditioning and a trouble in COVID-19 epidemic prevention work. Epidemic prevention workers wearing protective clothing are hard to resist heat wave and many outdoor grassroots workers suffer from heat stroke. There have been hundreds of overheating deaths in the country since July to mid-August.

On August 13th, Shanghai has kept 40 days of high temperatures above 35°C this year with the highest extreme temperature being 42°C. Since July this year, the average number of high temperature days above 35°C in Zhejiang province has been 31 days and the average number of high temperature days above 38°C in Zhejiang Province has been 16 days. It is the highest in the same period in history. Chongqing has experienced two rounds of high temperature weather, the average number of high temperature days in the city reached 30 days, which is the second most since 1951. The local usual temperature is up to 43°C~44°C and the highest temperature in some districts may exceed the historical extreme value. In spring and winter, the temperature gradually rose and the southern region generally stayed about 20°C or even 30°C. Water levels in the main stream of the Yangtze River, Dongting and Poyang lakes were the lowest on record for the same period, according to the reports on August 13th from China's Ministry of Water Resources. The drought has affected 9.67 million mu of arable land in Anhui, Jiangxi, Hubei, Hunan, Chongqing and Sichuan Province, which also affected water supplies for 830,000 people. The extreme high temperature in China since July is undoubtedly related to the abnormal subtropical high. It has interrupted the southwest monsoon and crushed almost all typhoons. From typhoon Ali (No. 4) to Mirey (No. 8) were all supported by extremely high ocean heat, but without exception, they all had difficulties in developing. They suffered a comprehensive defeat in the confrontation with subtropical high. Mirei, the newly generated No. 8 typhoon, made a difficult landfall in Japan, passing over Tokyo and ending with a squiggle. It posed no threat and certainly no relief to the high temperature in China. The regional heat wave is forecast to last longer than 62 days in 2013, making it the longest since 1961. Above all, the extreme high temperature in China has seriously destroyed the ecological environment and exerted a detrimental effect on our society severely.

The Sixth Assessment report of IPCC (United Nations Intergovernmental Panel on Climate Change) pointed out that under the background of global warming and greenhouse effect, many extreme weather and climate events had been observed since the middle of the 20th century, among which the frequent occurrence of high temperature and heat wave was a very significant feature. High temperature and heat wave events will become a new normal. It is expected the similar condition will occur more frequently in the future. The characteristic of long duration of high temperature may become more and more obvious.

Above all, we have a research on temperature change rules in some major cities (Shanghai, Guangzhou and Beijing) in China from 2015 to 2020. We collect and obverse several temperature data of Beijing, Shanghai and Guangzhou to see if there are upward trends in temperature. We attempt to understand how temperatures have changed over time in these cities in China and how these trends can help forecast future temperatures. Initially, the study can make people pay more attention to climate warming. Simultaneously, they can know the temperature basic change rules and ready to prevent the extreme high temperature weather in time. Besides, it may also play a crucial role in reducing the number of people suffering from heat stroke. Additionally, it reminds the national government to make relevant control policy of high temperature weather system and everyone to take action to protect our planet more actively.

1.2. Literature Review

Xue WU from weather bureau of XinYang wrote a paper about the effect of urbanization in the weather of four different city in China [1]. She used analysis of meteorological data, urban and suburban comparison method and correlation coefficient weight analysis to compare and summarize from groups

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of data between 1980 and 2009, including the annual average temperature, diurnal mean annual temperature, the highest temperature and the lowest temperature in each year. Urbanization has obvious warming effect on the city. In the decadal comparison, urbanization in the 1990s had the most significant effect on temperature.

Min WANG, Yuhua LIANG and Gang ZHI from Jilin Normal University wrote a paper about the annual average temperature of 9 different main drainage basin in China over the 15-year period after 2001, including southeastern rivers, the Haihe River, the Huaihe River, the Yellow River, continental river, the SongLiao river, the Yangtze River, the Pearl River and southwest rivers [2].

XiaoDi GAO, Zhihong JIANG and Jinhu YANG from Nanjing University of Information Science and Technology wrote a paper about the annual mean temperature in three different time period (1961-1990, 2021-2050 and 2071-2097) in the case of global warming [3]. They collected and summerized the main temperature change from 1961 to 1990 and they also estimated the temperature in the future.

Yangming JIANG, Weihong CUI, Qianlin DONG and Guangxiong PENG from Institute of Remote Sensing Applications, Chinese Academy of Science and China University of Mining and Technology wrote a paper by using MODIS data to reflect the temperature and its spatial distribution characteristics in China in the past 10 years are retrieved [4]. Basing on the meteorological data, the time series of winter temperature anomalies in urban, suburban, rural areas and around meteorological stations in China in the past 60 years are reconstructed.

Ke LIU, Yinlong XU, Shengcai TAO, Jie PAN and Honglong YANG Institute of Agricultural Environment and Sustainable Development, Chinese Academy of Agricultural Sciences; Key Laboratory of Agricultural Environment and Climate Change, Ministry of Agriculture; College of Atmospheric Sciences, Lanzhou University wrote a paper by using simulation effect of model unequal weight set, model equal weight set andmulti-model set on China temperature and forecast of China temperature change in the next 30 years [5].

Quansheng GE, Shunbing WANG and Jingyun ZHENG from Institute of Geographic Sciences and Resources Research, Chineese Academy of Science wrote a paper about the sequence reconstruction of temperature changes in China over the past 5000 years by using an ensemble method which was used to reconstruct the past air temperature series of China within past 5000 years [6].

Cuihua HAN, Zhixin HAO, Jingyun ZHENG from Institute of Geographic Sciences and Resources Research, Chinese Academy of Science wrote a paper about average temerature changes in China and characteristics of temperature change in difference regions of China between 1951 and 2010 [7]. They disscussed the characteristics of temperature changes in four periods of 1951-1980, 1961-1990, 1971-2000 and 1981-2010, which were divided into different regions as of annual winter and summer, 8 regions with different annual winter and summer temperature variations and 7 regions with different winter temperature variations. The seasonal and decadal differences of the results were discussed.

Jinsong WANG, Fahu CHEN, Qiang ZHANG, Liya JIN, Jing Li, Ming JIN and Jianhui CHEN from China meteorological administration, Lanzhou Institute of Arid Meteorology, Key Laboratory of Arid Climate Change and Disaster Reduction of Gansu Province, Key Open Laboratory of Arid Climate Change and Disaster Reduction of China Meteorological Administration, Sino-German Research Center for Arid Environment of Western China Key Laboratory of Environment and Ministry of Education in Lanzhoup wrote a paper about the temperature changes in different regions in Asia in recent 100 years, including arid area and semi-arid area of central Asia, by using an EOF interpolation method [8].

Mingli ZHANG, Zhaomei ZENG and Jinjun JI from Institute of Atmospheric Physics, Chinese Academy of Science wrote a paper about the characteristcs of regional climate in eastern Asia during the 100-year period [9].

Weihong QIAN and Bo LU from Department of Atmospheric Science, Peking University wrote a paper decomposing the trend of temperature change in different time periods and the multi-time scale periodic changes in the whole time domain, discussing the causes of temperature periodic changes [10]. It based on the newly reconstructed millennium global temperature series, solar radiation series and North Pacific SST index series in the last 400 years.

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James Hansen, Makiko Sato, Reto Ruedy, Ken Lo, David W. Lea and Martin Medina-Elizade from National Aeronautics and Space Administration Goddard Institute for Space Studies, Columbia University Earth Institute and University of California wrote a paper about the temperature change all over the world [11].

Ye LI, Eric J. Johnson and Lisa Zaval from the Center for Decision Sciences and Psychology Department, Columbia University wrote an article about the temperature change everyday in the case of global warming [12].

M. James C. Crabbe from Luton Institute for Research in the Applied Natural Sciences wrote a paper about the climate change in case of global warming (analysis of coral reefs) by considering the modelling the effects of temperature [13].

2. Data Sorting and Analysis

2.1. Dataset and Materials

The data of the research are derived from *CEIdata* and *Kaggle* which are official website so that we can achieve reliable results and attain feasible graphs. The data embodies overall 6573 figures. All the data were gained through professional experiment procedures.

2.2. Data Processing and Method

The program for this research was written and afterwards displayed in the *Microsoft Excel* software as well as *Anaconda Jupyter Notebook – Python programming* software. In the latter program, it gives out the results: OLS Regressive Table, the scattering diagram including the linear fitting charts, the F-statistic, the R^2 value (coefficient of determination) and so on. Besides, linear regression model is mainly used as a method to accomplish the research. Through these details which are analyzed and roughly shown in following figures, obtain some conclusions of the research can be gained obviously.

2.3. Data Recordings and Analysis

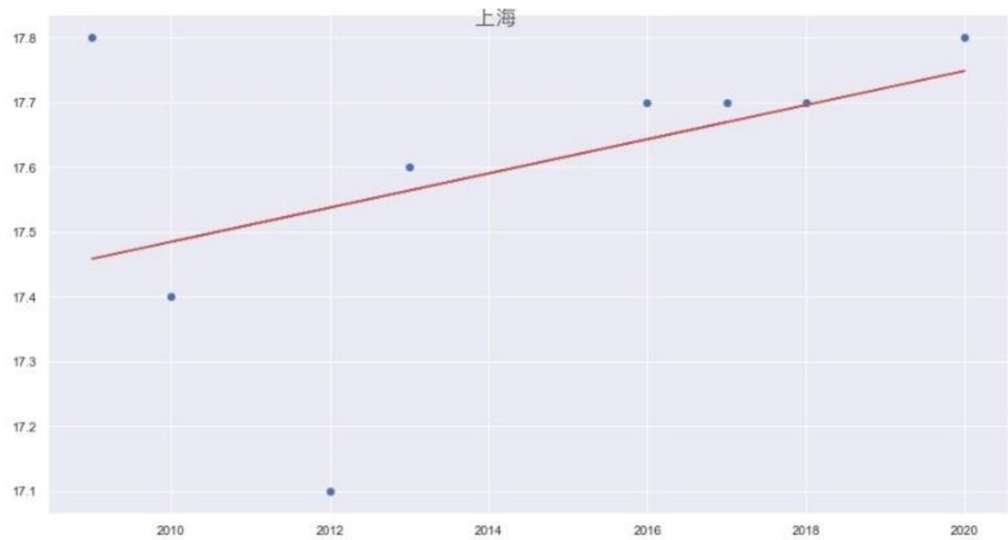

Figure 1. Linear fittings of partial annual average temperature of Shanghai in China respectively.

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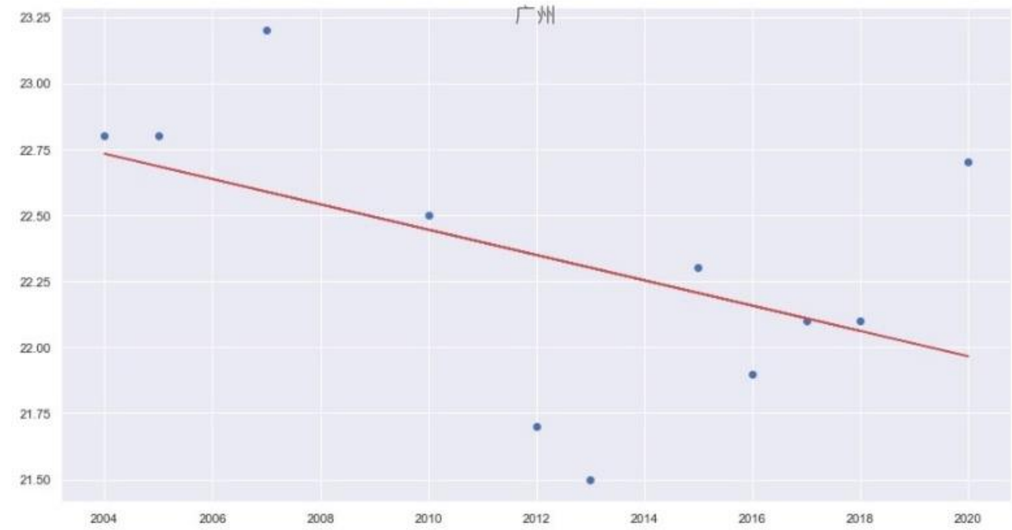

Figure 2. Linear fittings of partial annual average temperature of Guangzhou in China respectively.

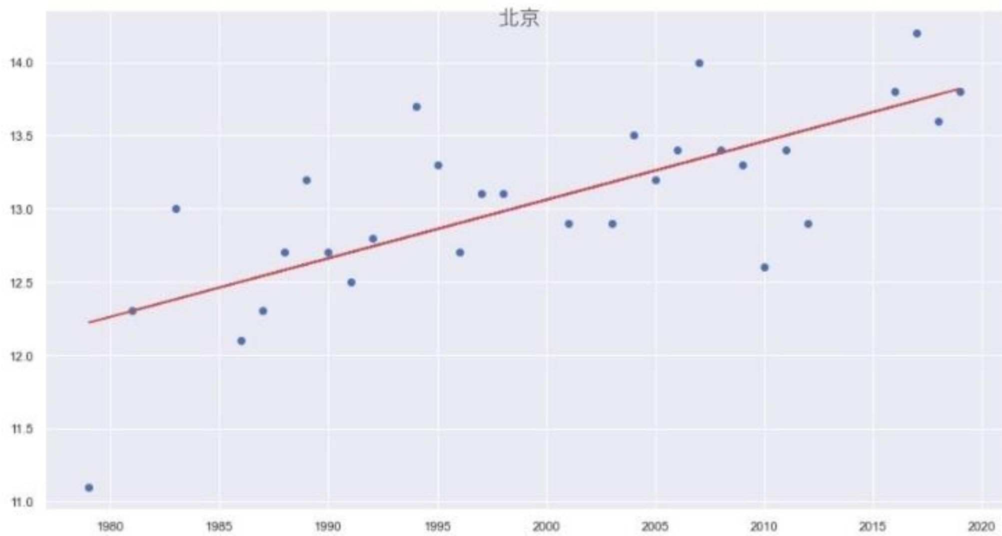

Figure 3. Linear fittings of partial annual average temperature of Beijing in China respectively.

For the tendency of Beijing's and Shanghai's temperature, they both show positive correlation to years, while Guangzhou relatively witnesses a downward trend these years. However, the three graphs do not completely prove the future conditions. They are just prospective predictions of these cities' temperature strike for the next few years and can forecast surrounding districts' probable temperature change trends as references. Maybe, in 2050 or 2100, Beijing's temperature would decrease or Guangzhou's temperature would increase.

After attaining the diagram of temperature trends shown as Figure 1 ~ 3, we found the standard deviations of temperature, for Shanghai, Guangzhou and Beijing metropolises, shown in Figure 4.

Standard deviation, calculated as the arithmetic square root of what is called the *variance* and denoted as *SD* or σ (sigma), is a measure used to quantify the amount of dispersion degree of a set of data values.

According to the broken line chart, it is obvious for us to observe the *standard deviation*, or what is called *SD*. The *SD* of Guangzhou is the least, whereas the *SD* of Beijing is the highest. Besides, Shanghai stays at the middle. The higher the standard deviation, the higher dispersion degree will be; also, the temperature will become more unstable and its span may be larger. Take Guangzhou as an example,

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since the *SD* fluctuated between approximately 5 and 7, its dispersion degree is the lowest; and hence the temperature span narrows – in other words, the temperature difference in a year in Guangzhou is little. Likewise, the temperature difference in a year in Shanghai is in the middle and the difference in Beijing is the largest. It can be found that the temperature difference in a year in the northern cities is less than the southern cities.

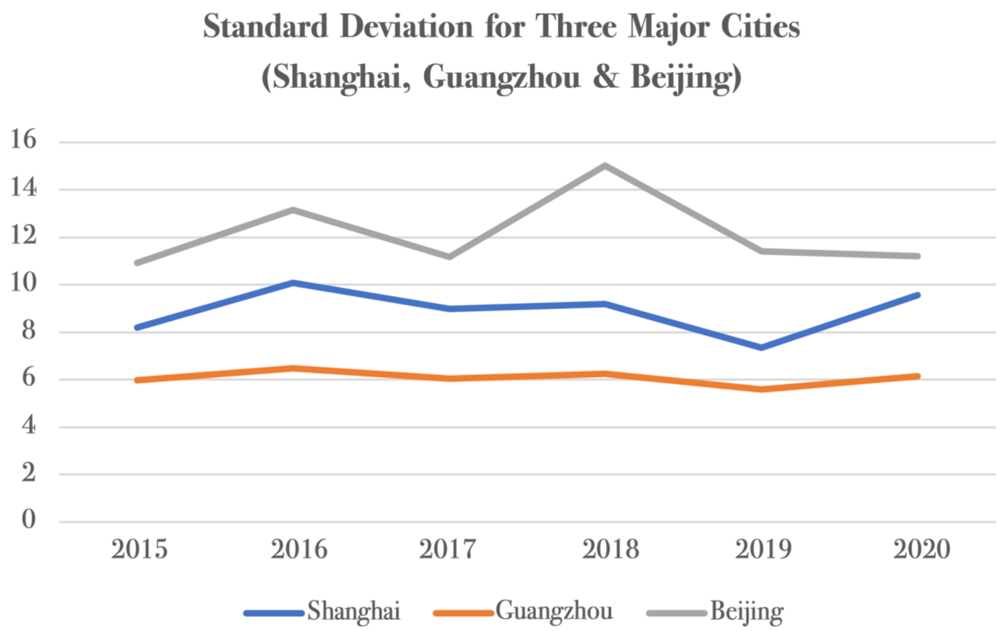

Figure 4. The change of standard deviation of yearly average temperature in Shanghai, Guangzhou and Beijing through the 6-year period (2015-2020).

```
In [244]:
data = pd.read_csv("[redacted].csv")
x = data['Year']
y = data['Temp']
from sklearn.model_selection import train_test_split
x_train, x_test, y_train, y_test = train_test_split(x, y, train_size = 0.7, test_size = 0.3, random_state = 100)

In [247]:
import statsmodels.api as sm
x_train_sm = sm.add_constant(x_train)
lr = sm.OLS(y_train, x_train_sm).fit()
lr.params

Out[247]: const   -66.891162
          Year      0.039976
          dtype: float64

In [248]:
print(lr.summary())
```

Figure 5. The Python sample codes (from *Jupyter Notebook*) and the functions used to generate an *OLS Regression Results* table.

Getting the idea of the altering patterns, tables called the *OLS Regression Results* are reformed. By means of importing the **.csv* file to the *Anaconda Jupyter Notebook* and utilizing caller function as shown in Figure 5, *y* is corresponded as dependent variable and *x* is called as independent variable, and use code known as `lr.params` to obtain a table sample, as shown in Figure 6.

According to Figure 5, one of the codes, `lr.summary()` is used to print out the tables. Between the second rectangular block and the third rectangular block, the quantities "const" and "Year" actually matches with the linear equation $y = mx + c$. In the equation. "const" matches with the y-intercept, 'c', and "Year" matches with the gradient, 'm'. So through Figure 5, we can know the linear regression equation is $y = 0.039976x - 66.89$.We can recognize the line must be in an upward trend through the number 0.039976 influencing the independent variable due to the fact that it is more than 0.

```
                            OLS Regression Results
==============================================================================
Dep. Variable:                   Temp   R-squared:                       0.539
Model:                            OLS   Adj. R-squared:                  0.522
Method:                 Least Squares   F-statistic:                     32.72
Date:                Wed, 24 Aug 2022   Prob (F-statistic):           3.90e-06
Time:                        22:37:25   Log-Likelihood:                -16.776
No. Observations:                  30   AIC:                             37.55
Df Residuals:                      28   BIC:                             40.35
Df Model:                           1
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const        -66.8912     13.976     -4.786      0.000     -95.520     -38.262
Year           0.0400      0.007      5.720      0.000       0.026       0.054
==============================================================================
Omnibus:                        2.347   Durbin-Watson:                   2.247
Prob(Omnibus):                  0.309   Jarque-Bera (JB):                1.128
Skew:                          -0.365   Prob(JB):                        0.569
Kurtosis:                       3.607   Cond. No.                     3.49e+05
==============================================================================
```

Figure 6. The OLS table of Beijing's yearly temperature on average, 2015-2020, generated by Python, showing the statistical details like R-squared (R2), number of observation, F-statistic and so forth.

According to Figure 6, it shows the statistical results of the relationship between the dependent and independent variables. *R-squared* (R^2, scientific name: *coefficient of determination*), defined as a statistical measure indicating the extent of variation in a dependent variable owing to an independent variable, is used to judge whether a group of data can fit linearly or not. If it is greater than 0.5 or very close to 1, then the data are proved to be suitable to fit; else if it is much less than 0.5 or pretty close to 0, then the dataset is unable to be fit linearly. Taking an instance of the average yearly temperature of three major cities, as shown in Figure 7 ~ 9, the data for them can used to achieve *Linear Fitting*, for the reason that their R-squared values are greater than 0.5. Additionally, in terms of the *Prob(F-statistic)*, if it is very close to 0, then its model will be very appropriate – all the *F-statistics* fundamentally meet the condition.These data fully explain our model analyses are reasonable, feasible and scientific.

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```
                            OLS Regression Results
==============================================================================
Dep. Variable:                   Temp   R-squared:                       0.191
Model:                            OLS   Adj. R-squared:                  0.057
Method:                 Least Squares   F-statistic:                     1.420
Date:                Wed, 24 Aug 2022   Prob (F-statistic):              0.278
Time:                        10:50:47   Log-Likelihood:                 1.4810
No. Observations:                   8   AIC:                             1.038
Df Residuals:                       6   BIC:                             1.197
Df Model:                           1
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const        -35.5667     44.620     -0.797      0.456    -144.747      73.613
Year           0.0264      0.022      1.192      0.278      -0.028       0.081
==============================================================================
Omnibus:                        4.583   Durbin-Watson:                   2.294
Prob(Omnibus):                  0.101   Jarque-Bera (JB):                0.846
Skew:                          -0.675   Prob(JB):                        0.655
Kurtosis:                       3.846   Cond. No.                     1.09e+06
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.
[2] The condition number is large, 1.09e+06. This might indicate that there are
strong multicollinearity or other numerical problems.
```

Figure 7. Examples of *OLS Regression Table* generated by using yearly average temperature of Shanghai respectively, with all types of statistical outcomes, like *R-squared, F-statistic*, etc.

```
                            OLS Regression Results
==============================================================================
Dep. Variable:                   Temp   R-squared:                       0.244
Model:                            OLS   Adj. R-squared:                  0.160
Method:                 Least Squares   F-statistic:                     2.899
Date:                Wed, 24 Aug 2022   Prob (F-statistic):              0.123
Time:                        11:16:29   Log-Likelihood:                -6.4314
No. Observations:                  11   AIC:                             16.86
Df Residuals:                       9   BIC:                             17.66
Df Model:                           1
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const        118.7967     56.656      2.097      0.065      -9.367     246.961
Year          -0.0479      0.028     -1.703      0.123      -0.112       0.016
==============================================================================
Omnibus:                        0.268   Durbin-Watson:                   1.835
Prob(Omnibus):                  0.874   Jarque-Bera (JB):                0.137
Skew:                          -0.197   Prob(JB):                        0.934
Kurtosis:                       2.621   Cond. No.                     7.88e+05
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.
[2] The condition number is large, 7.88e+05. This might indicate that there are
strong multicollinearity or other numerical problems.
```

Figure 8. Examples of *OLS Regression Table* generated by using yearly average temperature of Beijing respectively, with all types of statistical outcomes, like *R-squared, F-statistic*, etc.

```
                            OLS Regression Results
==============================================================================
Dep. Variable:                   Temp   R-squared:                       0.539
Model:                            OLS   Adj. R-squared:                  0.522
Method:                 Least Squares   F-statistic:                     32.72
Date:                Wed, 24 Aug 2022   Prob (F-statistic):           3.90e-06
Time:                        10:35:52   Log-Likelihood:                -16.776
No. Observations:                  30   AIC:                             37.55
Df Residuals:                      28   BIC:                             40.35
Df Model:                           1
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const        -66.8912     13.976     -4.786      0.000     -95.520     -38.262
Year           0.0400      0.007      5.720      0.000       0.026       0.054
==============================================================================
Omnibus:                        2.347   Durbin-Watson:                   2.247
Prob(Omnibus):                  0.309   Jarque-Bera (JB):                1.128
Skew:                          -0.365   Prob(JB):                        0.569
Kurtosis:                       3.607   Cond. No.                     3.49e+05
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.
[2] The condition number is large, 3.49e+05. This might indicate that there are
strong multicollinearity or other numerical problems.
```

Figure 9. Examples of *OLS Regression Table* generated by using yearly average temperature of Guangzhou respectively, with all types of statistical outcomes, like *R-squared, F-statistic*, etc.

Since Beijing is the best city whose dataset can be used to achieve linear fitting, we analyzed some of the months with only the temperature of 15th day and make OLS tables and line charts. May and July from Beijing's data from 2015 to 2020 are chosen because their qualities of linear fitting are relatively good(Standard deviations are more than 0.5), and the outcomes are witnessed in Figure 10, 11, 12 and 13.

```
                            OLS Regression Results
==============================================================================
Dep. Variable:      AvgTemperature(C)   R-squared:                       0.772
Model:                            OLS   Adj. R-squared:                  0.658
Method:                 Least Squares   F-statistic:                     6.760
Date:                Wed, 24 Aug 2022   Prob (F-statistic):              0.122
Time:                        23:49:24   Log-Likelihood:                -6.5221
No. Observations:                   4   AIC:                             17.04
Df Residuals:                       2   BIC:                             15.82
Df Model:                           1
Covariance Type:            nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const      -2426.6786    942.457     -2.575      0.124   -6481.742    1628.385
Year           1.2143      0.467      2.600      0.122      -0.795       3.224
==============================================================================
Omnibus:                          nan   Durbin-Watson:                   1.863
Prob(Omnibus):                    nan   Jarque-Bera (JB):                0.500
Skew:                          -0.672   Prob(JB):                        0.779
Kurtosis:                       1.907   Cond. No.                     2.18e+06
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.
[2] The condition number is large, 2.18e+06. This might indicate that there are
strong multicollinearity or other numerical problems.
```

Figure 10. Outcomes of *OLS Regression Table* generated through the data of May in Beijing (2015~2020).

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```
                            OLS Regression Results
==============================================================================
Dep. Variable:     AvgTemperature(C)   R-squared:                       0.791
Model:                           OLS   Adj. R-squared:                  0.687
Method:                Least Squares   F-statistic:                     7.579
Date:               Wed, 24 Aug 2022   Prob (F-statistic):              0.111
Time:                       23:56:54   Log-Likelihood:                -4.9002
No. Observations:                  4   AIC:                             13.80
Df Residuals:                      2   BIC:                             12.57
Df Model:                          1
Covariance Type:           nonrobust
==============================================================================
                 coef    std err          t      P>|t|      [0.025      0.975]
------------------------------------------------------------------------------
const      -1700.2143    628.304     -2.706      0.114   -4403.590    1003.161
Year           0.8571      0.311      2.753      0.111      -0.482       2.197
==============================================================================
Omnibus:                         nan   Durbin-Watson:                   1.489
Prob(Omnibus):                   nan   Jarque-Bera (JB):                0.616
Skew:                         -0.845   Prob(JB):                        0.735
Kurtosis:                      2.083   Cond. No.                     2.18e+06
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specified.
[2] The condition number is large, 2.18e+06. This might indicate that there are
strong multicollinearity or other numerical problems.
```

Figure 11. Outcomes of *OLS Regression Table* generated through the data of July in Beijing (2015~2020).

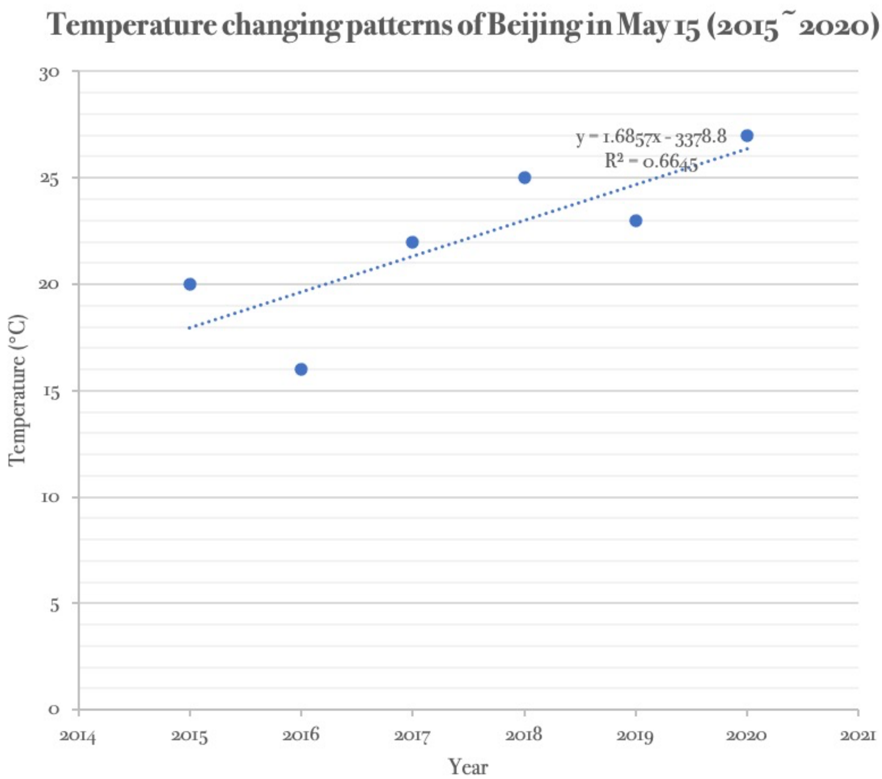

Figure 12. The changing trend of Beijing's temperature in May (2015~2020).

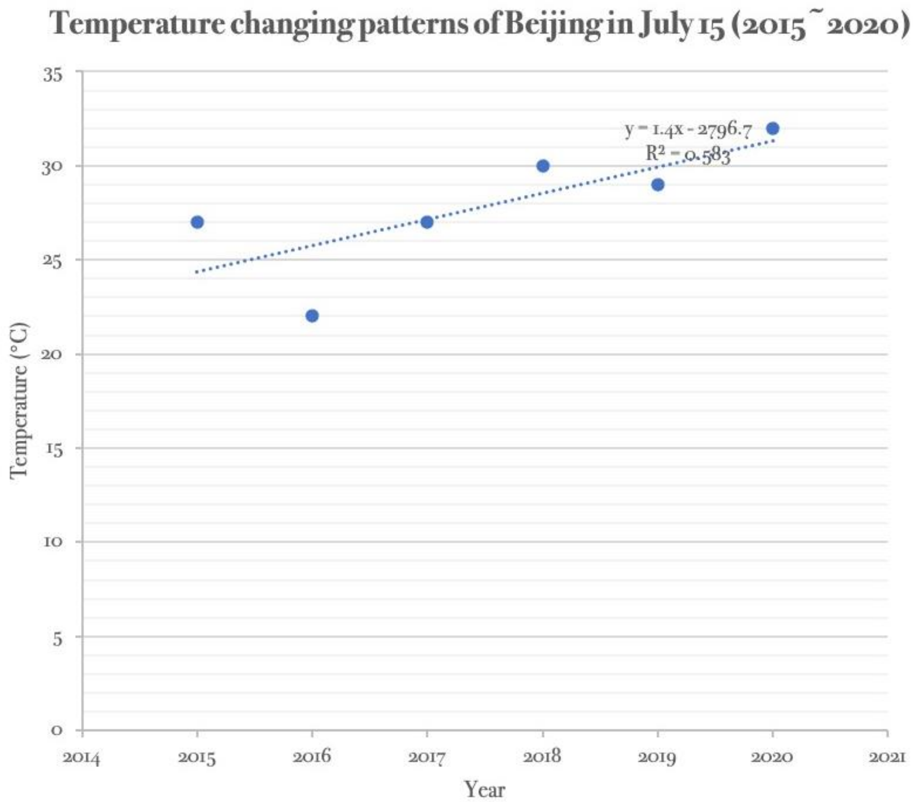

Figure 13. The changing trend of Beijing's temperature in July (2015~2020).

3. Conclusion

According to these diagrams and linear equation, the gradient of Guangzhou's annual temperature changing is less than 0, it shows a downward trend; and the gradients of Shanghai and Beijing are more than 0, the lines witness upward tendency. Therefore, in conclusion, Beijing and Shanghai's temperatures are rising while Guangzhou's temperature is falling gradually in recent years. Simultaneously, Beijing and Shanghai's temperatures are extrapolated to grow in the next few years. However, Guangzhou's temperature is projected to drop.

Nevertheless, our data of Guangzhou's and Shanghai's temperature are too few and incomplete to make more accurate conclusions. Briefly, they includes some subjective assumes which make the conclusions of Guangzhou's and Shanghai's temperature more unbelievable and unscientific. Moreover, the method and model used in the research are single and a little unreasonable. In the future research, more relevant data will be dug and related methods will be used like time-series approach as well as multiple curve regression. It is believed that the research would be much better.

References

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