Analysis on the Characteristics of Temperature Change in Zhengzhou from 1990 to 2017

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Abstract. In order to find out the changing trend of temperature and extreme weather in Zhengzhou under the background of rising global temperature. This study analyzes the changing trend of annual mean temperature and seasonal average temperature in Zhengzhou from 1990 to 2017 based on meteorological data. The extreme temperature index for 28 years was extracted. The results show that from 1990 to 2017, the air temperature in Zhengzhou shows a significant upward trend, and its rising rate is higher than that of the global warming rate. There are differences in the four seasons in Zhengzhou, with the largest change rate in spring, followed by summer and autumn, and the weakest warming trend in winter. The extreme temperature index in Zhengzhou has certain regularity, the extreme index FD0 decreases significantly, the change of ID0 is not obvious, and SU25, TR20 and HTD35 increase significantly. Except for the change of ID0 is not obvious, other indexes can better reflect the warming trend of temperature in Zhengzhou, indicating that the extreme temperature index has an obvious response to the change of temperature and can be used as an index to study the change of urban temperature.

1. Introduction
In the fifth assessment report of the United Nations Intergovernmental Panel on Climate Change (IPCC) in 2013, pointed out that the global climate system is warming at an accelerated pace, and almost all regions of the world have experienced a warming process. Warming is reflected in the rise of the earth's surface temperature and ocean temperature, the rise of sea level, the melting of the Arctic and Antarctic ice sheets and the retreating of glaciers, and the increase in the frequency of extreme weather events [1, 2]. Due to the rapid rise of global temperature, great changes have taken place in the global climate, and the living environment of animals and plants has been seriously threatened. For a long time, human activities and natural factors jointly affect global climate change, but for the changes observed since the 1950s, human activities are likely to be significant and major factors [3].

The temperature in China is synchronized with the change of global temperature. In recent years, with the rapid development of the domestic economy, the domestic weather has become more difficult
to predict, agriculture and forestry have been seriously threatened, the years of favorable weather have
decreased sharply, and the frequency and intensity of extreme temperature events have increased
sharply, which has had a serious negative impact on the living environment of domestic animals and
plants, social and economic systems, and human activities [4, 5]. Climate and eco-environmental
issues have become key areas of concern in China. Among them, under the influence of the rapid
development of urbanization, urban climate and extreme weather events change most obviously, and
disasters such as high temperature, rainstorm and hail have become the main sources of people's
economic losses. Therefore, it is an urgent requirement for China to study the extreme characteristics
of urban weather and climate elements in response to climate change and the construction of
ecological civilization. Taking Zhengzhou as an example, this study studies the temperature changes
in the process of rapid urban development in recent years, starting with extreme weather and seasonal
temperature changes, analyzes the characteristics of temperature changes in Zhengzhou, and makes
clear the trend of temperature changes in the four seasons in Zhengzhou. Analyze the number of
extreme weather events and explore the factors that affect the temperature change, so as to provide a
basis for the sustainable development of the city and the construction of a suitable living environment.

2. Data sources and research methods

2.1. Data sources
Zhengzhou, as the capital of Henan Province, is the hub of north-south transportation in China, located
in the hinterland of the Central Plains, and is an important inland open city and famous historical and
cultural city in China. Due to the importance of geographical location and the guidance of national
policies, the urbanization of Zhengzhou has developed rapidly in recent years, the urban population is
growing and the urban area is expanding. With the rapid development of the city, the urban climate
effect of Zhengzhou is becoming more and more obvious [6]. In the context of global warming, the
temperature in Zhengzhou is rising, and the hot weather in summer is becoming more and more
intense, which has a negative impact on people's health and social and economic development.

This study takes the temperature in Zhengzhou as the research object, and obtains the
meteorological data of Zhengzhou Station (53083) from 1990 to 2017 from China Meteorological data
Network (https://data.cma.cn). The data includes eight kinds of meteorological data, such as air
temperature, relative humidity, evapotranspiration, rainfall and wind speed. And the time scale is daily,
in which the air temperature data include daily mean temperature, daily maximum temperature and
daily minimum temperature.

2.2. Research methods
In this study, the trend line analysis method was used to study the variation trend of air temperature in
Zhengzhou from 1990 to 2017, and the trend line slope [7] of annual mean temperature, seasonal mean
temperature and time series was calculated. If the slope is regular, the temperature shows an upward
trend, while a negative slope indicates a downward trend with time, and the greater the absolute value
of the slope, the more obvious the temperature change. The calculation formula is as follows:

\[ \text{Slope} = \frac{n \times \sum_{i=1}^{n} i \times \text{TEM}_i - \sum_{i=1}^{n} i \times \sum_{i=1}^{n} \text{TEM}_i}{n \times \sum_{i=1}^{n} i^2 - (\sum_{i=1}^{n} i)^2} \]

In the formula: The Slope represents the slope of temperature change; n is the number of years in
the monitoring period, and the value is 28. The TEMi in this study represents the average temperature.
When Slope>0, the temperature is on the rise, and Slope<0 indicates that the temperature is on a
downward trend.
3. Results and Analysis

3.1. Interannual variation trend of temperature

Figure 1. The change trend Chart of Annual mean temperature in Zhengzhou.

| Time period   | 1990-1999 | 1999-2008 | 2008-2017 | 1990-2017 |
|---------------|-----------|-----------|-----------|-----------|
| Change rate (°C / 10a) | 1.95      | 0.65      | 1.32      | 0.82      |

Figure 1 shows the trend curve of annual mean temperature in Zhengzhou. The multi-year average temperature in Zhengzhou from 1990 to 2017 is 15.25°C. Among them, the average temperature was the lowest in 1991, with an annual average of 13.87°C, and the annual average temperature in 2017 was the highest, which was 16.74°C. Among the 28 years, there are 13 years in which the temperature is lower than the average, and 15 years in which the temperature is higher than the average, and most of the above-average years are after 2000. The above data show that the temperature in Zhengzhou has shown an upward trend since 1990. In order to further explain the trend of temperature change in Zhengzhou, the average annual temperature change rates of 1990-1999, 1999-2008, 2008-2017 and 1990-2017 were calculated by trend line analysis (Tab. 1). As can be seen from Table 1, the annual average temperature in Zhengzhou increased significantly at a rate of 0.82°C / (10a) from 1990 to 2017. Among them, the rising speed from 1990 to 1999 is 1.95°C / (10a), the rising rate from 1999 to 2008 is 0.65°C / (10a), and from 2008 to 2017 is 1.32°C / (10a). The rising speed of each period is obviously different, but it shows a warming trend, which is consistent with the conclusion of that 1998-2012 belongs to the intermittent period of global temperature increase [8].
3.2. Seasonal variation trend of temperature

Fig. 2. Variation trend of mean temperature in four seasons.

Fig. 2 (a), (b), (c) and (d) show the change trend of average temperature in Zhengzhou in four seasons respectively. The trend line analysis method is used to calculate the slope of temperature change in the four seasons. As can be seen from the chart, there is a difference in the temperature change law of Zhengzhou in the four seasons during 2000-2017, and the change rate is the highest in spring, rising at the rate of 1.33℃ / (10a), followed by 0.70℃ / (10a) in summer and 0.66℃ / (10a) in autumn, and the warming trend in winter is the weakest, by 0.49℃ / (10a). The seasonal temperature change in Zhengzhou is different from the global warming law. The reason is that after the rapid expansion of the city, the impact of human activities on air temperature is greater than that of the natural environment.

3.3. Extreme weather changes

The definition of extreme index used in this study was determined by the expert Group on Climate change Detection, Monitoring and indicators established jointly by the (WMO) Climate Committee of the World Meteorological Organization (WMO) and the CLIVAR Program (Tab. 2) [9]. The absolute index is selected to study the law of temperature change in Zhengzhou from 2000 to 2017.
Table 2. The definitions of extreme air temperature indices.

| Extreme indices       | Symbol (d) | Definition                                                                 |
|-----------------------|------------|-----------------------------------------------------------------------------|
| Frost days            | FD0        | The number of days in which the daily minimum temperature is less than 0℃ in a year |
| Freezing days         | ID0        | The number of days in which the daily maximum temperature of the year is less than 0℃ |
| Summer days           | SU25       | The number of days in which the daily maximum temperature of the year is greater than 25℃ |
| Hot night days        | TR20       | The number of days in which the daily minimum temperature is greater than 20℃ in a year |
| High temperature days | HTD35      | The number of days in which the daily maximum temperature of the year is greater than 35℃ |

Fig. 3 shows the trend curve of five extreme temperature indexes: frost days, freezing days, summer days, hot night days and high temperature days. As can be seen from the chart, the change of extreme temperature index in Zhengzhou from 1990 to 2017 has certain regularity. The extreme index FD0 decreases significantly at the rate of -11.67d / (10a), while the change of ID0 is not obvious. SU25, TR20 and HTD35 increase significantly at the rate of 5.47d / (10a), 10.94d / (10a) and 5.96d / (10a), respectively. From 2000 to 2017, the temperature in Zhengzhou showed an obvious warming trend. In the extreme temperature index, the extreme temperature warming index (SU25, TR20, HTD35) increased significantly, while the extreme temperature cold index FD0 decreased significantly.

![Figure 3. Variation trend of extreme temperature index.](image)

4. Conclusion
(1) Zhengzhou shows a warming trend from 1990 to 2017, which is consistent with the change of global temperature, but it increases significantly at the rate of 0.82℃ / (10a), which is obviously faster
than the temperature change under the background, which is mainly affected by human activities and urban heat island effect.

(2) There are differences in the law of temperature change in four seasons in Zhengzhou. The change rate is the highest in spring, rising at the rate of 1.33°C / (10a), followed by 0.70°C / (10a) in summer and 0.66°C / (10a) in autumn. The warming trend in winter is the weakest, which is different from that of the global temperature.

(3) The change of extreme temperature index in Zhengzhou from 1990 to 2017 has certain regularity. The extreme index FD0 decreases significantly at the rate of -11.67d / (10a), while the change of ID0 is not obvious. SU25, TR20 and HTD35 increase significantly at the rate of 5.47d / (10a), 10.94d / (10a) and 5.96d / (10a), respectively. Except for the change of ID0, all the other indexes reflect the warming trend of temperature in Zhengzhou, indicating that the extreme temperature index has an obvious response to the change of temperature and can be used as an index to study the change of urban temperature.

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