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Analysis of the Long-Term Trend and Anomalies of Urumqi's Temperature under Global Warming.

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Abstract:

Global warming has become an indisputable scientific fact, and understanding its regional characteristics is a core issue in current climate research. Urumqi, a typical large inland city in the arid region of Central Asia, exhibits strong and sensitive climate change signals, making it a key indicator of regional responses under global warming. This paper aims to systematically review the long-term trends, seasonal variations, and anomaly characteristics of temperature changes in Urumqi. Additionally, the primary focus of this article is the temperature in Urumqi in the context of global warming. Based on 58 years of observational data, this study employed distributed lag non-linear models, linear trend estimation, cumulative anomaly analysis, and the Mann-Kendall test to analyze temperature trends. These data mainly used a distributed lag non-linear model, Linear trend estimation, cumulative anomaly, and the M-K test. Results indicate that over the past 58 years, the annual average temperature in Urumqi has risen slowly, with the most intense warming in winter, followed by autumn and spring, and the weakest in summer. Extreme warm events are significantly more frequent than extreme cold events.. This temperature change pattern poses severe challenges to the stability of the Tianshan glaciers, regional water security, the urban ecological environment, and socio-economic development, urgently necessitating scientific adaptation and mitigation strategies.

Keywords: global warming, glacier shrinkage, distributed lag non-linear model, Linear tendency estimation, cumulative anomaly

1. Introduction

Against the background of temperature, global warming has become an indisputable fact. Global warming has brought about a series of complex and far-reaching impacts, such as glacier melting, sea-level rise,

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and frequent extreme climate events, which seriously threaten the human living environment and the sustainable development of the social economy.

In 2015, the annual average, maximum, and minimum temperatures of urban and suburban stations in Urumqi showed an upward trend, and the minimum temperature of suburban stations increased the fastest [1]. From the IPCC report, the global average temperature increased by 0.85°C from 1880 to 2012, and this warming trend is still ongoing. It can be confirmed that the annual average temperature in the urban area of Urumqi experienced a sudden increase in 2000. The UF curve after 2000 exceeded the critical value and continued to rise, indicating that the temperature in Urumqi significantly increased after 2000 [2].

According to the author Huanhuan Ge, the temperature in Urumqi changed little in 10 years, with an increase of 0.7 °C [3]. However, the total annual precipitation increased slowly year by year, and the 10-year increase was less than 5 mm. Long and Wang used the Linear trend estimation, cumulative anomaly, and M-K test to test the temperature during the 58 years [3, 4]. The temperature also has an impact on respiratory diseases [5].

Therefore, an in-depth exploration of the intrinsic link between Urumqi's temperature and global warming, coupled with a systematic analysis of its evolutionary characteristics, core influencing factors, and potential development trends against the backdrop of climate change, not only enriches the research system in the field of climate change but also provides a solid foundation for formulating scientifically sound response strategies for the regional ecological environment in Urumqi.

Furthermore, this article aims to analyze the temperature trend and abnormal conditions in Urumqi.

2. Abnormal Trends and Manifestations of Temperature

There are the characteristics of Long-Term Temperature Trends in Urumqi. The temperature in Urumqi has shown a significant upward trend. The linear warming rate of the annual average temperature is 0.50°C per decade. The warmest year was in 1997, and the ten warmest years since 1976 all occurred after the end of the 20th century. The warming trend of the annual average minimum temperature is the most obvious, with a linear warming rate of 0.77°C per decade, which is about 2.5 times that of the annual average maximum temperature. The increase in temperature has led to a significant advance in the start dates of spring and summer, and a delay in the start dates of autumn and winter, resulting in a significant extension of summer. The linear extension rate is 5.9 days per decade, with a total increase of 25 days in the past 42 years. Other seasons have shortened to varying degrees, with winter shortening the most significantly, at a linear shortening rate of -3.6 days per decade, with a total shortening of 15 days in the past 42 years [6]. This continuous warming trend has a profound impact on the local ecosystem, agricultural production, and human living environment.

2.1 Decadal Variation Characteristics The warming

As Fig.1, the X-axis represents a particular year (year), Y-axis represents the number of days with an air temperature exceeding 28°C (days)

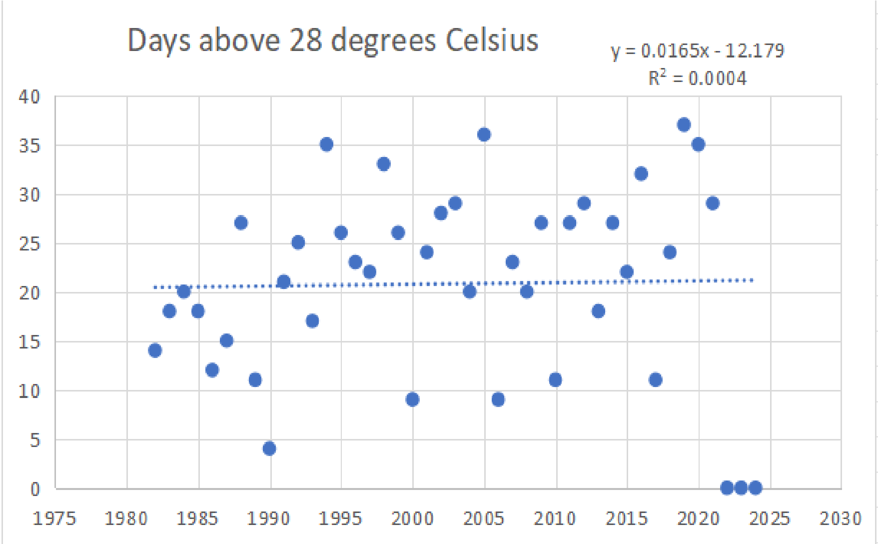

Fig. 1 The number of days with temperature exceeding 28℃ from 1982 to 2024 (Photo/Picture credit: Original).

As Fig.1 shows, days above 28 degrees Celsius overall show an increasing trend. In detail, the process is not a simple linear increase but shows obvious phased or decadal fluctuations. It can be roughly divided into two stages:

Firstly Mid-1980s to the late–1990s, in most years, negative anomalies occurred, with the stage average temperature being 7.13 °C [3]. The temperature trend showed both decreases and increases, and the overall change trend was not obvious.

Secondly, since the 21st Century, warming has entered an accelerated channel, with the temperature baseline jumping to a new, higher level [3]. Warm years (years with positive temperature anomalies) occur frequently, and records are constantly being broken [6]. Extreme Heat Events, like warm years, characterized by positive temperature anomalies, are becoming more common, and records are continually being shattered. The frequency of high-temperature days (daily maximum temperature ≥ 28 °C), the length of heatwaves, and the records for extreme maximum temperatures in summer are all on the rise. Heatwaves have become more frequent and intense, posing threats to urban energy supply (power load), public health (heat-related illnesses), and agricultural production [7].

2.2 Sharp Rise in Annual Mean Temperature Multiple studies

Using daily temperature data from the Urumqi National Reference Climate Station since 1961, employing methods such as linear trend analysis and Mann-Kendall tests, has revealed a clear warming trend. The results show that the rate of increase in the annual average temperature in Urumqi generally ranges between 0.30°C/decade and 0.45°C/decade, far exceeding the global average rate for the same period (about 0.15°C/decade) [8, 9]. This means that over the past 60 years, the cumulative increase in the annual average temperature in Urumqi has reached 1.8°C to 2.7°C, indicating an extremely strong warming signal. This rapid warming is consistent with the overall „warming and wetting“ transition trend observed in the arid Northwest region of China.

3. The Abnormal Performance of the Temperature in Urumqi City.

3.1 Glacier Retreat

As global warming leads to the persistent shrinkage of glaciers, the water supply and ecological networks in Central Asia's vast arid regions have been significantly affected — a phenomenon that has aroused broad public concern. According to study results, total runoff in the source region of the Urumqi River shows an upward trend in two distinct periods: the baseline phase (1997-2016) and the mid-century phase (2040-2059), the study findings reveal that there has been an increase in total runoff in the Urumqi River source region during both the baseline period (1997-2016) and the mid-century period (2040-2059), which includes contributions from rainfall, glacier meltwater, and snowmelt [10]. Analysis of satellite remote sensing data, in conjunction with ground observations, indicates a 37.5% reduction in the glaciated area of No.1 Glacier—the source of the Urumqi River basin in the Tian Shan mountains of China—from 1989 to 2014 [9]. Specifically, the glacier area decreased from 31.55 km² on August 18, 1989, to 28.66 km² on August 24, 1994, and further to 19.74 km² by August 31, 2014 [11].

3.2 Human Activities

First of all, urbanization. Huge-scale urban construction changes the urban underlying surface of Urumqi. As the area of impermeable surface, including building land and road land, increases, the surface evaporation capacity and the heat dissipation capacity decrease, and the urban heat island effect is finally formed. Over the past 15 years, rapid urbanization has led to changes in the nature of the underlying surface. At the same time, human activities have significantly increased the emission of large amounts of artificial heat and pollutants into the atmosphere, all of which will have certain impacts on the climate of the city [3].

Secondly, the emission. Industrial activities in Urumqi emit a large amount of greenhouse gases and pollutants, which intensify the local warming trend. For example, carbon dioxide emitted by industrial boilers and heat released during industrial production will both have an impact on the local temperature. However, until now, there are many factories around Urumqi that discharge polluting gases.

3.3 Health Impacts

At low temperature, with the increase of lag days, the risk of respiratory disease first aid gradually decreased, and then increased; high temperature has a certain protective effect on the risk of first aid for respiratory diseases. Based on the experimental data from the Urumqi Center for Disease Control and Prevention, as well as the analysis of the distributed lag nonlinear model[4], the impact of low temperatures on the risk of emergency treatment for respiratory diseases in men was slightly higher than that in women; people under 65 years old were more affected

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by low temperatures. Low temperatures may increase the risk of emergency treatment for respiratory diseases, while high temperatures may have a certain protective effect on the risk of emergency treatment for respiratory diseases. Different ages and genders have different sensitivities to cold and heat effects[4].

3.4 Response Measures

The first response is the mitigation. Vigorously develop low-carbon energy, promote urban green transformation, and control greenhouse gas emissions at the source. Advocating Green Travel, such as travelling by bike or tram.

Then adaptation. Strengthen climate monitoring and early warning, strengthen urban infrastructure (e.g., sponge cities, flood and heat prevention facilities) to cope with extreme weather. Nowadays, the heat island effect within cities can harm the health of urban residents and damage the ecological environment. Moreover, greenhouse gases exacerbate the urban heat island effect. In 2015, the "Guiding Opinions on Promoting Sponge City Construction" issued by the General Office of the State Council pointed out that sponge cities can achieve "no water accumulation during light rain, no waterlogging during heavy rain, no black or malodorous water bodies, and mitigation of the heat island effect"[12].

Last Planning and Research is incorporating climate risk assessment into long-term urban development planning; continue to deepen research on regional climate simulation and impacts to enhance the ability to prevent disasters from coming(e.g., extremely high temperature weather)

4. Conclusion

This study systematically analyzes the phased characteristics of temperature changes in Urumqi over 58 years for the first time, revealing the coupled relationship between urbanization and rising temperatures. It provides scientific basis for formulating region-specific climate adaptation strategies.

In addition, to construct a targeted and refined climate change response system, it is necessary to conduct in-depth research on the evolutionary characteristics of future meteorological elements in Urumqi (with a primary focus on temperature change trends), so as to provide scientific support for the formulation of practical solutions. Specifically, regional climate resilience can be enhanced through key pathways such as strengthening the construction of urban green space systems to mitigate the urban heat island effect, dynamically optimizing the crop planting structure based on the spatiotemporal evolution laws of temperature, and improving the multi-source monitoring and precise early warning system for extreme temperature events. Only by establishing a systematic, comprehensive, scientific, and efficient response framework can solid protection be provided for Urumqi to resist the compound risks induced by climate change.

At the level of technological empowerment and source control, it is recommended to adopt High-Resolution Climate Models for numerical simulation and multi-scenario prediction of the refined scenarios of future temperature changes in the city, so as to improve the spatiotemporal accuracy and reliability of climate predictions. Meanwhile, it is imperative to strengthen the collaborative control of industrial pollution sources around Urumqi, reduce the total emission of atmospheric pollutants through measures such as strictly enforcing emission standards and promoting clean production technologies, and mitigate the disturbance of human activities on the regional climate system. Furthermore, interdisciplinary coupled assessments of climate risks should be carried out across key fields including water resources, energy security, and public health. Based on the results of interdisciplinary analysis, a hierarchical and differentiated climate adaptation strategy system should be constructed to consolidate the climate security barrier for regional sustainable development and facilitate the coordinated advancement of ecological protection and economic and social development.

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