

Precipitation Trend Change in Lanzhou and the Yellow River Basin Under Global Warming

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Abstract:

Global warming is reshaping precipitation patterns worldwide, with arid regions showing particularly striking changes. Lanzhou, a dry and rain-scarce area in northwest China, has experienced increasing precipitation and atmospheric moisture levels amid global warming. Research indicates this “warm and humid” phenomenon represents an improvement in arid regions ‘moisture conditions without altering their fundamental arid characteristics. The precipitation patterns and properties in Lanzhou differ fundamentally from those in eastern China, demonstrating that agricultural ecological challenges in arid areas cannot be resolved merely by increasing water availability. “However, despite the increase in precipitation, arid regions cannot rely solely on the increase of water resources to address agroecological challenges; the uneven temporal and spatial distribution of rainfall must also be taken into account.”

Keywords: global warming, climate change, Lanzhou region, Yellow River basin, precipitation

1. Introduction

Under the backdrop of global climate change, the global average surface temperature has increased by approximately 0.85 °C over the past 100 years (IPCC,013). In the Northern Hemisphere, 1983–2012 was the hottest 30-year period in the last 1,400 years [1]. Extreme weather events, such as heavy rain and heat waves, also exhibited increasing trends over the past 50 years, and are expected to occur more frequently in the future. According to the Clausius–Clapeyron equation, the water-holding capacity of the atmosphere increases by about 7% for a 1 K increase

in temperature. This will significantly alter spatial and temporal patterns of global precipitation, thereby enhancing regional differences in climate change [2]. Daily precipitation in the global and China regions has generally become more extreme in recent decades, with an increasing trend of flood disasters and increasingly severe public property losses. Short-term heavy precipitation events are the main cause of flood disasters. A systematic analysis of the climatology and long-term variation characteristics of short-term heavy precipitation events in China is of great reference value for formulating disaster prevention and mitigation strategies and climate change adapta-

tion measures.

In the past, studies on climate and climate change of extreme precipitation in China mostly used daily precipitation data to analyze indicators such as the number of precipitation days, daily precipitation intensity, heavy rainfall precipitation, and the number of heavy rainfall days. These studies found that precipitation indicators such as China's annual average daily precipitation intensity, hourly precipitation intensity, and extreme precipitation all increased from the northwest inland to the southeast coast. Since the mid-20th century, the number of precipitation days has significantly decreased, while extreme precipitation has tended to increase in most regions of China. At the hourly scale, research has found that the frequency, intensity, and duration of heavy precipitation in summer have all shown an increasing trend in northeastern and southeastern China, while the hourly precipitation frequency in North China has greatly decreased. It was discovered that the increase in daily precipitation in the middle and lower reaches of the Yangtze River is attributed to the increase in the number of hourly precipitation days, while the hourly precipitation intensity has actually decreased. With the advancement of technology, the demand for refined precipitation data has been growing steadily. Currently, heavy rainfall is defined as daily precipitation of 50 mm or more [1]. However, the distribution of daily precipitation may be uneven. When short-duration heavy rainfall occurs within an hour or even just a few to ten minutes, the likelihood of disasters increases significantly compared to scenarios with more evenly distributed precipitation over one day or several hours. In the past, due to the scarcity of minute-level precipitation data, the temporal-spatial distribution and long-term trends of hourly short-duration heavy rainfall remained unclear. The increase in precipitation in Lanzhou and the Yellow River Basin (YRB) has triggered widespread flooding across the surrounding areas, causing significant damage to public infrastructure.

Based on this, this study conducted a quantitative analysis of the long-term precipitation trends in Lanzhou and the YRB based on historical climate data, aiming to clarify the mechanism of precipitation changes under the background of global warming and provide adaptive strategy support for water resources management and regional sustainable development.

2. Geographical and Climatic Characteristics of Lanzhou

Lanzhou, the capital of Gansu Province, is located in the northwest of China and situated in the upper reaches of

the Yellow River, serving as a key node city along the Silk Road Economic Belt. Its geographical coordinates are roughly between 35°34' and 36°34' north latitude, and 102°37' and 104°34' east longitude [3]. The city stretches 127 kilometers from east to west and varies in width from 20 to 80 kilometers from north to south, covering a total area of 13,085.6 square kilometers. Lanzhou has a temperate semi-arid continental climate with distinct seasons. Spring is dry and windy, summer is hot but short, autumn is cool, and winter is cold and dry. The average annual temperature is about 9.3°C, with the hottest month (July) averaging around 22.4°C and the coldest month (January) averaging about -6.9°C [4]. Annual precipitation is relatively low, around 300 millimeters, mainly concentrated in summer. Due to topographical influences, Lanzhou's climate also exhibits vertical variation characteristics, with significant temperature differences between mountainous areas and river valleys. Additionally, Lanzhou's unique natural landscapes and ecological environment are shaped by its location in the transitional zone between the Loess Plateau and the Qinghai-Tibet Plateau, combined with the Yellow River flowing through the city. From 1968 to 2024, Lanzhou's precipitation has continued to increase, particularly in July and August, with annual rainfall rising year by year. This year, flood disasters occurred in Yuzhong County, Lanzhou, causing 10 deaths and 33 people missing. Xinhua News Agency, Beijing, August 8-Since August 7, continuous heavy rainfall in Yuzhong County and other areas of Lanzhou has triggered mountain floods. As of 15:30 on August 8, the disaster has resulted in 10 deaths and 33 people missing. According to the data, Yuzhong County in Lanzhou City, Gansu Province and other areas were hit by continuous heavy rainfall, triggering mountain floods that caused significant casualties and severe property losses to residents. Therefore, vigilance and prevention are necessary for the future. Rainfall-induced floods are among the most closely related climate phenomena to human activities.

3. Basic Characteristics of Precipitation in Lanzhou

According to the definition of extreme precipitation events, the average threshold for extreme precipitation in Lanzhou is 7.03 mm h⁻¹. Therefore, the short-term heavy precipitation threshold of 20 mm h⁻¹ in the „Implementation Rules for Short-term and Near-term Forecasting Business in Gansu Province“ released by the Gansu Provincial Meteorological Bureau in 2018 is significantly high and does not match the actual precipitation situation. Hence, the standard of 10 mm h⁻¹ is preferable.

Since 2010, the annual average of short-time heavy precipitation events in Lanzhou has been 1.37 times, which occurred from late July to August, and the main occurrence period was from 16:00 to 02:00 in the afternoon. Among them, the high occurrence period was from 21:00 to 22:00, and the maximum hourly rainfall reached 63.2mm.

The spatial distribution of short-term heavy precipitation in the Lanzhou region shows uneven patterns, generally exhibiting a south-abundant and north-scarce distribution pattern. There is no significant east-west variation, with multiple high-value centers scattered across the area. These precipitation events primarily occur in “Chengguan District” in the central-northern part of Yong deng County, Township in the southern part of Yong den County, Zhonghe Township in the southern part of County, Zhong lianchuan and southern Mapo Township, Xinying Township, Ding yuan Town, Lian da Township, Xia guan Ying Town, Xinglong Mountain in the northeastern part of Yu zhong County, as well as Hei kou Town in the western part of Xi gu District, Xincheng Town in the main urban area, and the eastern part of Anning District, Qilihe District, and Chengguan District. Although there are significant differences in the frequency of short-term heavy precipitation across stations, no obvious dispersion occurs, conforming to a normal distribution. The spatial distribution shows significant correlation with latitude and windward slope factors.

Influenced by altitude, wind direction, mountain, valley, and other topographic factors, the short-term heavy precipitation high incidence areas in Lanzhou can be divided into 4 types: valley trumpet-shaped terrain influence type, southwind windward slope terrain influence type, urban heat island effect influence type, and high cold mountain terrain influence type.

4. Data and Methods

Data Source: NASA POWER 3.2 Meteorological Data Coverage Period: 1982-2024 Parameters 3.3 Daily Precipitation Analysis Methods: Trend analysis, correlation analysis According to the data analysis charts and relevant literature, the study indicates that from 1982 to 1994, Lanzhou’s precipitation was predominantly concentrated between January and July, with an average annual rainfall of less than 0.2% [5]. From 1994 to 2014, precipitation showed a yearly increase, with July and August being the rainiest months, making flood disasters more likely [6]. Currently, due to special geographical location and the unpredictable factors of global warming leading to increased precipitation, as well as limited data availability causing biases in data sources, the precipitation patterns and distri-

bution models around the world are changing with global warming. The changes in precipitation are particularly significant in arid regions. Against the background of global warming, both atmospheric moisture content and precipitation in the northwest of China have increased. However, this „warm and humid“ trend only improves the moisture level in arid areas and does not alter the basic climatic characteristics of aridity and drought. The precipitation patterns in the northwest region are fundamentally different from those in the eastern region, with the increase mainly reflected in more extreme precipitation and short-term convective precipitation. Additionally, the increase in precipitation primarily occurs in inland river basins, where arid areas cannot rely solely on abundant water resources to address ecological issues. It is essential to clarify the differences in arid characteristics between the northwest arid region and the semi-arid region of the YRB. The water resources in the northwest of the Hexi Corridor mainly come from mountain precipitation and snow and ice resources, requiring in-depth exploration of the relationship between precipitation in the northwest region and the snow and ice resources of the Qilian Mountains and Tianshan Mountains. A scientific and rational understanding of the phenomenon of increased precipitation in the northwest is a prerequisite for the rational allocation and utilization of water resources in the northwest and the scientific development of ecological civilization. In particular, the Lanzhou region should make good use of rainfall to address certain arid issues while also preventing flood disasters from causing damage to public property, and take preventive measures in advance [7].

5. Suggestion

Lanzhou, with its vast territory, diverse vegetation, varied land surfaces, arid climate, and abundant resources, faces a complex challenge in balancing ecological conservation and high-quality development. Addressing this issue requires scientific approaches to mitigate the impacts of rising rainfall, which directly affects the region’s sustainable economic growth. Key priorities include: (1) The increased precipitation in the Lanzhou region has created favorable conditions for ecological civilization development, while also providing optimal climatic environments for highland summer vegetable cultivation. This period presents a golden opportunity to advance ecological civilization construction in the northwest region. However, achieving maximum benefits requires rigorous scientific evaluation to identify key areas and the most suitable regions for prioritizing ecological civilization initiatives [8]. (2) The increase in precipitation in the Lanzhou region has created a broader space for artificial weather modifi-

cation. It is necessary to fully study how to make full use of favorable conditions, strengthen the overall planning of artificial weather modification operations, and rationally develop and utilize the cloud water resources in the air [9]. (3) Scientifically and systematically utilize and allocate precipitation and water resources in the Northwest region. Clarify the differences in drought characteristics between the arid zones of the inland river basins in the Northwest and the semi-arid areas of the YRB in Longdong. For the arid regions within inland river basins, given the significant negative impacts of current climate warming in the long term, proactive measures must be taken. This includes early planning, resolute implementation of central government decisions on ecological civilization construction, and execution of environmental protection, scientific governance, and mountain flood prevention. Research should be conducted to balance the preservation of ice and snow resources with the scientific and orderly utilization of water and drought resources, while leveraging this opportunity to drive the development and application of new technologies and materials. For the semi-arid regions of the YRB, it is crucial to understand the water conservation patterns of the YRB. This requires rational arrangement, development, and allocation of water resources, scientific and orderly large-scale human activities, and rational approaches to ecological environment development, governance, and civilization construction. In response to the increasing urban domestic water demand amid rising living standards, it is essential to promote scientific water use and conservation measures with measured effectiveness [10]. (4) Investigate the patterns of climate resource changes in Lanzhou under climate change, clarify their advantages and disadvantages, and plan. Strengthen research on the impact of wind and solar power development as primary new energy sources in the climate change context; enhance studies on how increased precipitation affects crop characteristics in sandy and arid regions; increase investment in foundational research on early water conservancy infrastructure maintenance, and the influence of mountain flood patterns on production and daily activities in the Hexi region. (5) Strengthen the protection of cultural relics and culture in arid areas. Purpose: To help everyone understand the precipitation trend in Lanzhou, China [11].

6. Conclusion

In recent years, under the backdrop of global warming, the climate characteristics and precipitation patterns in Lanzhou have undergone significant changes. Research results show that precipitation in Lanzhou has generally increased, with a particular concentration between July and

August. Extreme precipitation events have also increased in frequency, and localized rainstorms are prone to triggering flash floods and geological disasters, posing severe challenges to urban safety and the ecological environment. While increased precipitation has improved humidity conditions in arid regions to some extent, providing new opportunities for ecological civilization construction and agricultural development, the fundamental characteristics of the arid climate remain unchanged. The complex topography and landforms of Lanzhou (such as valleys, wind vents, and river valleys) significantly influence the spatial distribution and intensity of precipitation, resulting in a distribution pattern of more precipitation in the south and less in the north. Faced with the dual pressures of increasing precipitation and frequent extreme weather events, we should strengthen research on the changing patterns of climate resources, scientifically utilize precipitation resources, optimize water resource allocation, improve flood control and disaster reduction systems, and promote the coordinated development of artificial rainmaking and ecological governance. Through comprehensive management and forward-looking planning, Lanzhou and the YRB can achieve the dual goals of ecological and environmental improvement and regional sustainable development while ensuring safety.

References

- [1] Shi Y F, Shen Y P, Hu R J. Preliminary study on signal, impact and foreground of climatic shift from warm-dry to warm-humid in Northwest China. *Journal of Glaciology and Geocryology*, 2002, 24 (3): 219-226.
- [2] Zhao D, Gao X, Wu S. Non-uniform changes in precipitation and temperature in China during 1960-2015. *International Journal of Climatology*. 2020;1-12.
- [3] Chen Y N, Xu Z X. Plausible impact of global climate change on water resources in the Tarim River basin. *Science in China (Series D: Earth Sciences)*, 2005, 48 (1): 65-73.
- [4] Yang X D, Zhai P M. Changes in precipitation intensity, frequency and total in Northwest China. *Science & Technology Review*, 2005, 23 (6): 24-26.
- [5] Li D L, Wei L, Cai Y, et al. The present facts and the future tendency of the climate change in Northwest China. *Journal of Glaciology and Geocryology*, 2003, 25 (2): 135-142.
- [6] Li B F, Chen Y N, Xun S, et al. Temperature and precipitation changes in different environments in the arid region of Northwest China. *Theoretical & Applied Climatology*, 2013, 112 (3-4): 589-596.
- [7] Chen D D, Dai Y J. Characteristics of Northwest China rainfall intensity in recent 50 year. *Chinese Journal of Atmospheric Sciences*, 2009, 33 (5): 923-935.
- [8] Wang H J, Chen Y N, Chen Z S. Spatial distribution and

temporal trends of mean precipitation and extremes in the arid region, northwest of China, during 1960-2010. *Hydrological Processes*, 2013, 27 (12): 1807-1818.

[9] Deng H J, Chen Y N, Xun S, et al. Dynamics of temperature and precipitation extremes and their spatial variation in the arid region of Northwest China. *Atmospheric Research*, 2014 (138): 346-355.

[10] Zhao L, Jiang Y, Zhong H, et al., 2025. 2024 China climate characteristics and major weather and climate events. *Meteorology*, 51(3):349-357.

[11] Sun X, Wang X, Zhao Y, et al. Research on two downscaling models for precipitation and temperature based on CMIP6—A case study of the Yellow River above Lanzhou. *Journal of Hydraulic and Hydrographic Engineering*, 2025(4):33-44.