Climate Change in China: An Analysis of Temperature and Precipitation Variations Across 2367 Meteorological Stations (1981-2020)

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Abstract. This study aims to examine the changes in climate across China from 1981 to 2020, focusing on both spatial and temporal variations. The analysis utilizes data collected from 2367 meteorological stations throughout the country. The findings of this research indicate an overall warming trend across China, with more significant temperature increases observed in the northern regions. However, the changes in precipitation patterns were more complex. While southern areas experienced greater rises in precipitation, some inland regions witnessed decreases. Further investigation into seasonal and monthly variations revealed substantial variability in both warming and precipitation patterns across different regions and timeframes. Surprisingly, the study found that the relationship between geographical factors such as latitude and altitude and the extent of climate change was relatively weak, except in arid Xinjiang. Although this research provides a comprehensive overview of climate change in China, it also emphasizes the necessity for more localized studies. These localized studies would help in understanding the multifaceted factors that drive the observed changes. By conducting more focused research, people can gain a deeper understanding of the specific influences and impacts of climate change in different regions of China.

Keywords: Climate change, China, temperature, precipitation, spatial variation.

1. Introduction

Climate change, a critical issue fueled by global warming, has emerged as one of the most pressing challenges confronting humanity in the 21st century. It's a multifaceted problem that presents a considerable threat to sustainable development worldwide. The Intergovernmental Panel on Climate Change (IPCC), in its comprehensive and authoritative reports, provides unequivocal evidence of a consistent rise in global average surface temperatures since the pre-industrial era. Their data manifests that in the Northern Hemisphere, the period extending from 1983 to 2012 is likely the warmest 30-year span in the last 1400 years.

These escalating temperatures, primarily instigated by anthropogenic greenhouse gas emissions, have resulted in a broad spectrum of climatic abnormalities and extreme weather events worldwide. It's a pervasive issue, the impacts of which are felt across every corner of the globe. However, the degree of severity varies significantly depending on geographical location, socio-economic factors, and local climate characteristics. These variances in experienced impacts necessitate a localized focus in addition to a global perspective to effectively address the climate crisis.

China, standing as the world's most populous country and the most significant emitter of greenhouse gases, is no exception to these environmental changes [1]. Given China's diverse geographical landscapes and climates, understanding the heterogeneity of climate change within the country is crucial. This understanding is paramount for the development of appropriate mitigation and adaptation strategies that can effectively combat the adverse effects of climate change in each unique region.

The primary objective of this research is to investigate the extent and spatial variability of climate change in China. The study will pay particular attention to temperature and precipitation changes across an extensive network of 2400 meteorological stations from 1981 to 2020. This forty-year study period will be divided into two segments: 1981-2010 and 1991-2020, allowing for an in-depth examination of the temporal dynamics of climate change. The collected data will be meticulously

analyzed to identify key characteristics and explore the relationship between climate change and various factors, including regional disparities, altitudinal variations within the same region, and monthly climatic differences.

While previous studies have examined regional climate change in China [2, 3], the scope of this research is more extensive. It represents a comprehensive analysis that leverages a vast dataset from 2400 meteorological stat ions, a scale that is unprecedented in previous research. Moreover, this study delves into the variations of climate change within the same region at different altitudes. Although the impact of altitude on climate change is well-documented [4, 5], limited research has specifically focused on its effects within the same geographical region. This novel approach promises to shed light on new insights into the climatic changes at different altitude levels within the same region.

In addition to the above, the analysis takes into account monthly climatic differences. Seasonal patterns in climate change are significant as they have been linked to changes in ecosystems and human behavior [6, 7]. By examining monthly variations in climate, a more nuanced understanding of China's climate change patterns can be obtained, providing a more detailed timeline of changes throughout the year.

To analyze the data collected from the meteorological stations, robust statistical methods will be employed. Mean temperature and precipitation changes will be calculated for each station and aggregated to provide a national overview. This data will then be disaggregated to explore regional, altitudinal, and monthly variations. This in-depth analysis will provide a comprehensive understanding of the spatial and temporal variations in climate change across China.

In conclusion, this study aims to provide an in-depth analysis of climate change in China over a 40-year period. By investigating regional, altitudinal, and monthly variations, this research will contribute to a better understanding of the heterogeneity of climate change within the country. The findings will be invaluable for policymakers, environmentalists, and scientists in formulating effective climate change mitigation and adaptation strategies that are tailored to local conditions [8].

While climate change is indeed a global problem, the solutions must be implemented at the local level. Understanding the specific characteristics of climate change in China will not only benefit the country itself but also contribute to the global efforts to combat this existential crisis [9]. This research, by providing an in-depth and localized understanding of climate change in China, will significantly contribute to these efforts and pave the way for more effective climate action.

2. Methodology

2.1. Data sources and description

The data utilized in this research is derived from the China Meteorological Data Service Center (https://data.cma.cn/). The dataset comprises information from 2367 national-level meteorological stations in China, encompassing average precipitation and temperature data (including monthly and annual data) from two distinct 30-year periods: 1981-2010 and 1991-2020 [10].

2.2. Selection of indicators

The dependent variables in this study are the differences in average temperature, precipitation volume, and precipitation change percentage between the two 30-year periods (1991-2020 average versus 1981-2010 average). These metrics are fundamental to reflect climate change in a given area.

The independent variables include the latitude of the station, elevation, geographical partition, the province in which the station is located, and the type of climate. These variables were chosen to explore the relationship between the degree of climate change and the basic geographical elements of a region. The geographic location and altitude data for each station are included in the dataset.

2.3. Methodological approaches

The methodology for this research can be divided into several key steps:

The collected meteorological station data will be structured into a dataset that includes temperature, precipitation, station latitude, elevation, geographical partition, and province. The dataset will be examined to ensure there are no missing or anomalous values. Necessary data cleaning and processing will be performed.

Pearson's correlation analysis will be employed to assess the relationship between temperature and precipitation with the other factors. Correlation coefficients between each factor will be calculated and statistical significance testing will be performed to identify the strength and significance of the relationships.

Multiple linear regression analysis will be used to establish mathematical models of the relationships between temperature and precipitation with the station latitude, elevation, geographical partition, and province. Through the regression model, the degree of influence of each factor on temperature and precipitation can be determined, and statistical significance testing will be performed. Geographical Information System (GIS) tools (ArcGIS Online) will be used to visually analyze the relationship between factors like station latitude, elevation, geographical partition, and the temperature and precipitation.

Statistical significance tests will be conducted during the correlation and regression analyses to ensure the reliability of the observed relationships and results. Appropriate statistical methods, including hypothesis testing and confidence intervals, will be used to evaluate the results and determine their level of significance. By employing this comprehensive methodology, the study aims to provide an in-depth understanding of the spatial and temporal variations of climate change in China and the relationships these have with geographical elements. The findings will contribute significantly to the existing body of knowledge and can serve as a guide for future climate change mitigation and adaptation strategies.

3. Results and discussion

China, with its vast territory and diverse climate zones, serves as a critical study area for global climate change research. This paper aims to analyze the changes in temperature and precipitation across different regions of China and identify the possible contributing factors. In this study, China will be divided into the following nine regions for research purposes: Northeast China, North China, East China, Central China, South China, Southwest China, Qinghai-Tibet Plateau, Eastern part of Northwest China, and Western part of Northwest China. These regions will be sequentially labeled as Region A to Region I.

3.1. Temperature trends

China has experienced a general warming trend. From 1991-2020, the nation's average temperature rose by 0.319°C compared to the 1981-2010 period. Out of the 2367 stations with complete data, 2261 recorded a rise in temperature. However, this increase was not uniform across the country. The average temperature rise in each region is in Table 1.

Table 1. Difference between the average temperatures in China during 1991-2020 and the period 1981-2010

Region	Temperature Rise (in °C)
A	0.239
B	0.355
C	0.384
D	0.325
E	0.202
F	0.263
G	0.482
H	0.379
I	0.330

These figures indicate that the northern regions of China have seen higher rates of warming than the south. Notably, the regions of Qinghai-Tibet Plateau, Eastern Northwest, and North China (Regions F, G, and B) experienced significant warming, exceeding 0.35°C. In contrast, South China and Southwest China saw relatively smaller increases (Figure 1). The only southern region with a higher warming rate was the Yangtze River Delta, potentially due to the urban heat island effect [10].

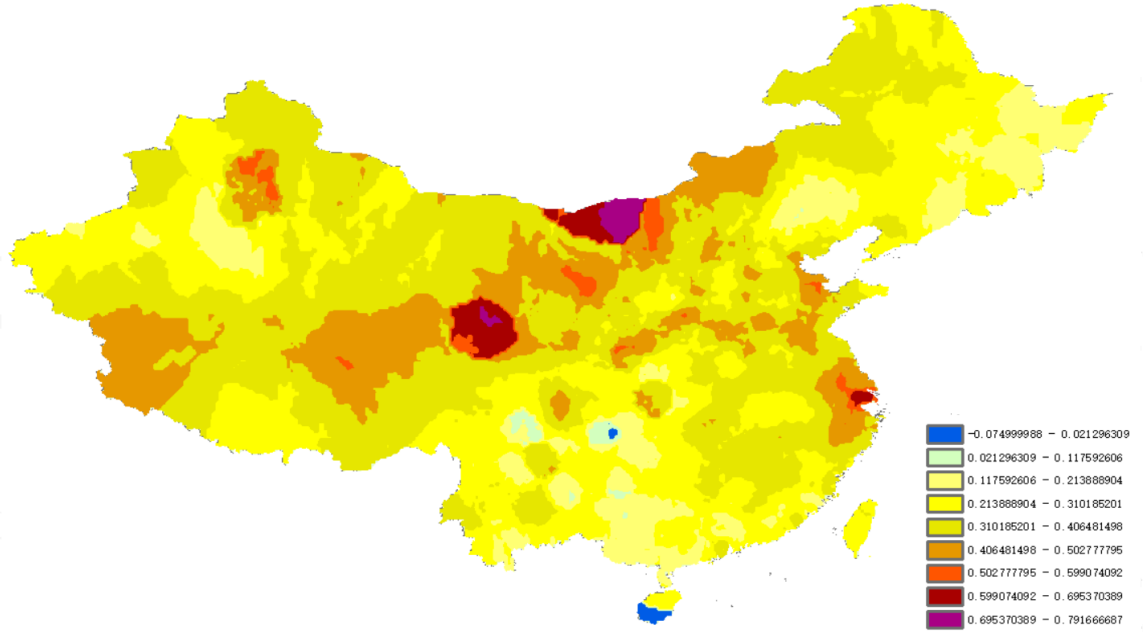

Figure 1. Changes in mean annual temperatures in China between the periods 1981-2010 and 1991-2020

3.2. Seasonal overview

The average monthly temperature increases (in °C) across the country from January to December were 0.21, 0.46, 0.67, 0.43, 0.3, 0.26, 0.26, 0.26, 0.27, 0.2, 0.34, and 0.15, respectively. It's clear that spring witnessed the largest warming trend, with March being the month with the highest rate of increase. The Northwestern inland regions saw the most significant warming in spring, with some areas experiencing increases above 1°C, which is shown in Figure 2.

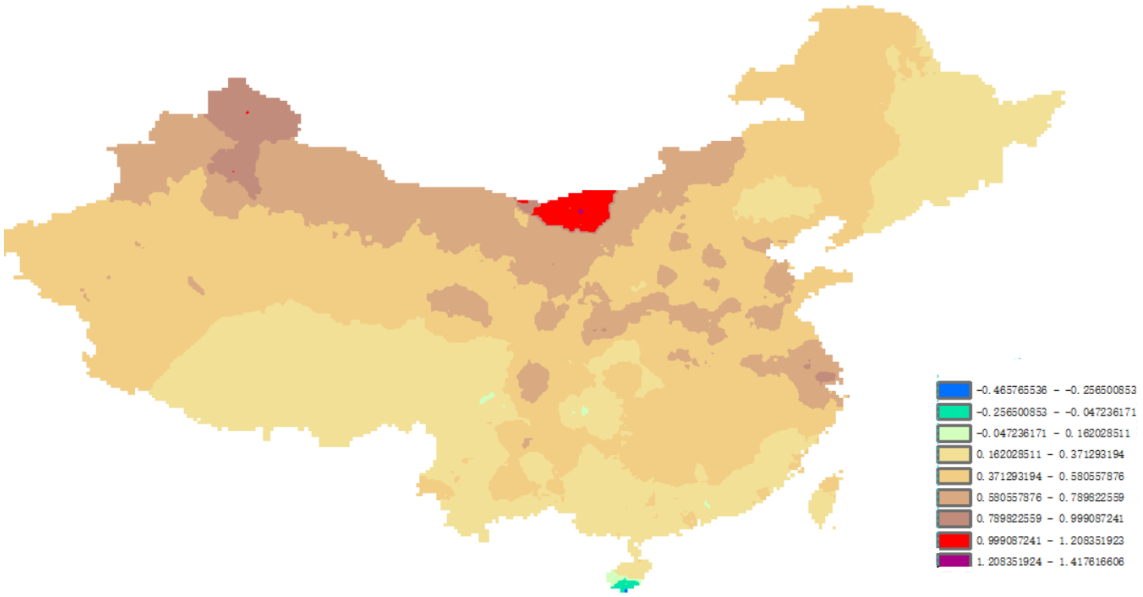

Figure 2. Changes in mean air temperature in spring in the periods 1981-2010 and 1991-2020 in China

But in the summer, the situation has changed, although the northern region is still warming up a lot, but the southern region is warming up less, in general in the summer in southern China warming up significantly lower than in the north, and the localities in southern China even appeared in the situation of the temperature drop, which is shown in Figure 3.

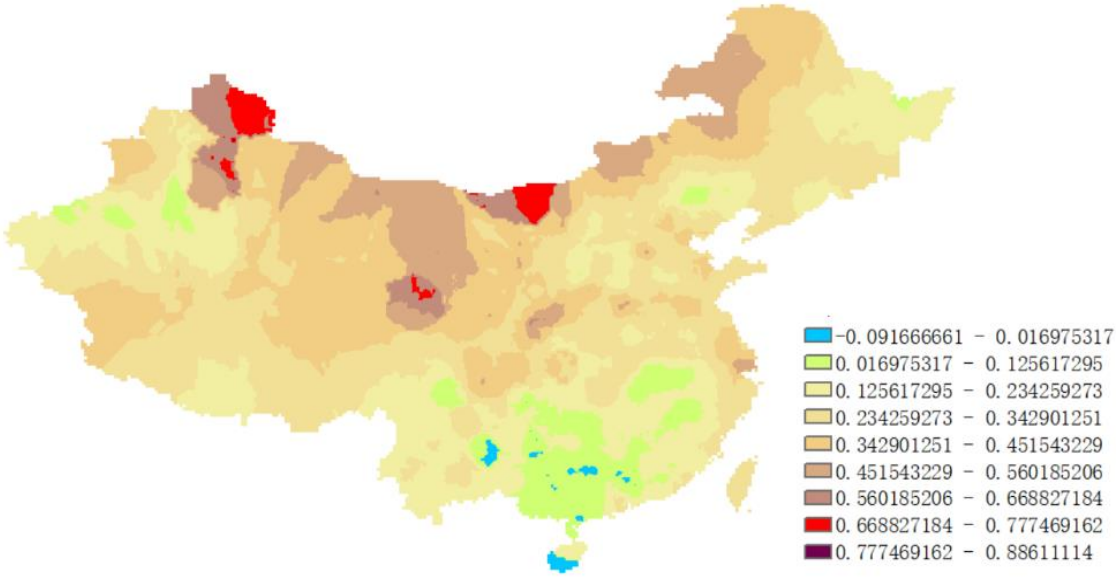

Figure 3. Changes in mean air temperature in summer in the periods 1981-2010 and 1991-2020 in China

During the autumn season, the center of the region with the greatest temperature increase in China has shifted to the Qinghai-Tibet Plateau. At this time, the western regions have experienced a significantly higher warming trend compared to the eastern regions. However, the Sichuan Basin and its surrounding areas have not experienced a noticeable temperature increase. In fact, in some areas such as northern Hebei and Beijing, temperatures have even decreased, which is shown in Figure 4.

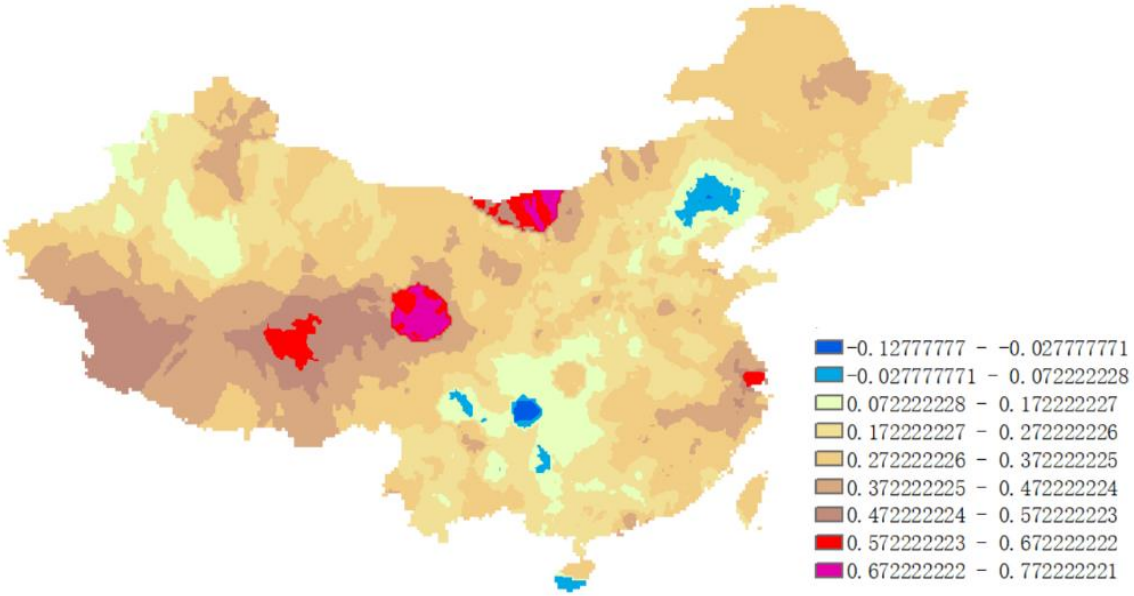

Figure 4. Changes in mean air temperature in autumn in the periods 1981-2010 and 1991-2020 in China

During the winter season, apart from the northeastern part of Xinjiang, there has been a widespread temperature increase in other regions. The Qinghai-Tibet Plateau remains the focal point of this warming trend. And it is shown in Figure 5.

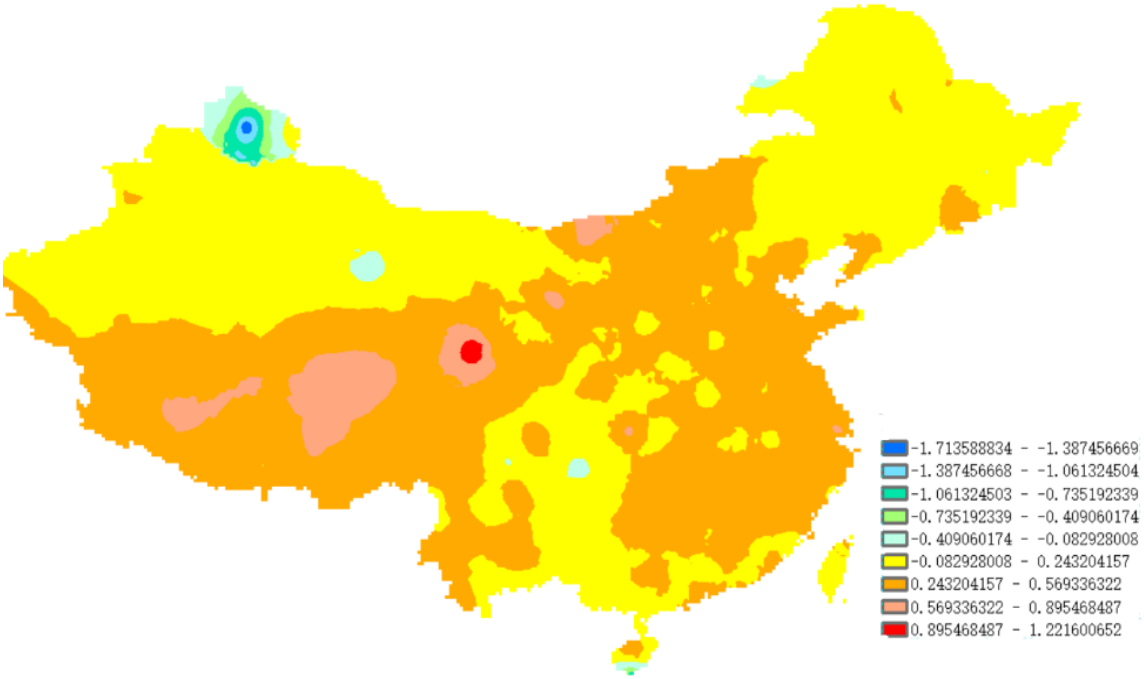

Figure 5. Changes in mean air temperature in winter during the periods 1981-2010 and 1991-2020 in China

3.3.Precipitation trends

3.3.1 Annual overview

Overall, China has seen a slight increase in precipitation. Among the 2367 meteorological stations included in this study, 1525 recorded a rise in precipitation. The precipitation increase rates in each region are in Table 2.

Table 2. Rate of increase in precipitation in different regions of China

Region	Precipitation Increase Rate
A	0.022
B	0.022
C	0.028
D	0.008
E	0.026
F	0.0006
G	0.031
H	0.021
I	0.0403

The changes were not evenly distributed. Southern regions saw higher increases in precipitation, with some areas even exceeding 100mm. However, regions from Yunnan/Sichuan to Henan and Shaanxi saw a reduction in precipitation, with Yunnan witnessing the most significant decrease, exceeding 4% in the southern part of the province.

The climate change trends and spatial distribution in China are complex and influenced by multiple factors. Further research is needed to understand the underlying mechanisms and develop effective strategies to mitigate and adapt to these changes (Figure 6).

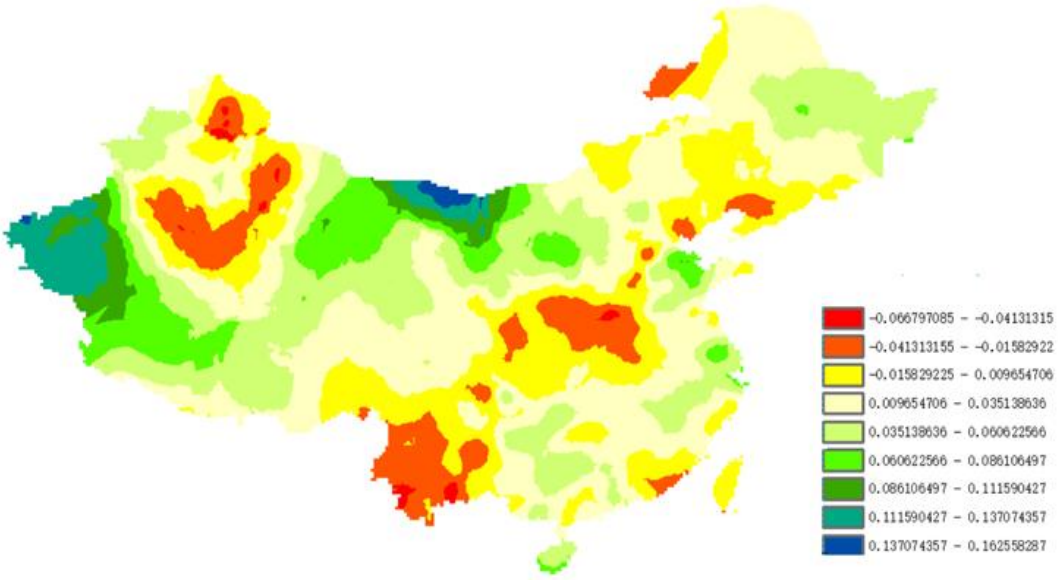

Figure 6. Increase rate of average precipitation between 1981-2010 and 1991-2020 in China

3.3.2 Changes in precipitation concentration

Due to China being heavily influenced by the summer monsoon, the proportion of summer precipitation to the annual total can reflect the concentration of rainfall to some extent. As shown in Figure 7, the regions where the proportion of summer precipitation has decreased are mainly the northeast and the northern part of Xinjiang. In contrast, most other regions across the country have experienced a greater concentration of rainfall during the summer season.

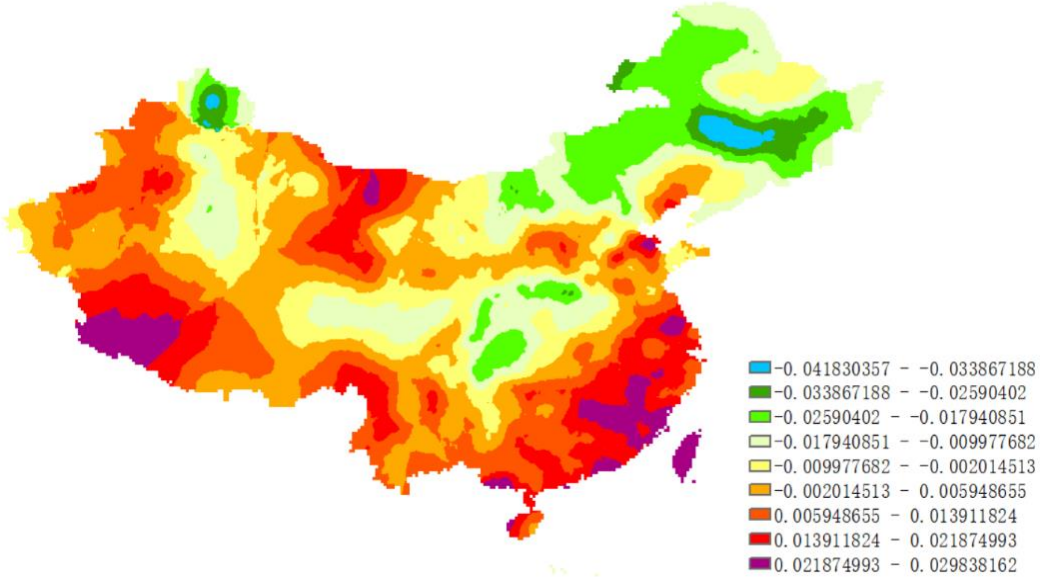

Figure 7. Difference in average summer precipitation as a proportion of the year between 1991-2020 and 1981-2010 in China

3.4.Temperature variations and relationship with latitude and altitude

The table 3 below presents the correlation coefficients between latitude and temperature change, between the altitude of the meteorological station and changes in temperature, precipitation, and the rate of precipitation change across the nine regions.

Table 3. Correlation coefficients between latitude and altitude and the temperature/ precipitation change in China

Regions	Latitude - Temperature Change	Altitude - Temperature Change	Altitude - Precipitation Change	Altitude – Rate of Precipitation Change
A	-0.01268	-0.05453	0.105689	0.085389
B	-0.22094	-0.10876	0.066847	0.158344
C	0.305284	-0.21313	-0.05799	-0.15682
D	0.130778	-0.14691	0.031158	-0.0328
E	0.147192	-0.11905	-0.07725	-0.05659
F	0.069346	0.044413	-0.05717	-0.02155
G	0.156624	-0.01854	0.216233	0.134482
H	0.014404	0.049003	0.378852	0.210723
I	0.072263	0.063084	0.498712	0.382988

Except for Xinjiang (Region I), the climate changes in other regions seem to have little correlation with their latitude and altitude (absolute value of correlation coefficient is not above 0.3). Only Xinjiang sees a weak positive correlation between altitude changes and increased precipitation. This phenomenon could be attributed to Xinjiang's location in an arid zone with high mountains. The orographic effect is prominent, resulting in a significant maximum rainfall height.

4. Conclusion

The intricate climatic changes across different regions in China underline the impact of complex geographical features and climatic systems on the regional climate. The monthly variations in precipitation across different regions highlight the influence of monsoonal patterns, with regions experiencing distinct wet and dry periods. Interestingly, the correlation between climatic changes and geographical features such as latitude and altitude are relatively weak in most regions, except Xinjiang. This weak correlation suggests that other factors might be at play, influencing the region's climate. For instance, anthropogenic activities, landscape changes, and atmospheric dynamics could play a role in shaping the climate of these regions.

In Xinjiang, the positive correlation between altitude and increased precipitation is likely due to its unique geographical situation, with arid plains and high mountains. The phenomenon of orographic rainfall, where air masses are forced to ascend the mountains and precipitate, might explain the increased precipitation with altitude. These observations, while providing a comprehensive overview of climatic changes across China, point towards the need for more localized and detailed studies. Factors influencing the climate are multifaceted and complex, and therefore, a more in-depth understanding of local climatic systems is crucial for climate change mitigation and adaptation strategies.

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