Assessment of Drought Risk and Resilience

Drought Analysis Project Report

By

Noor Ahmad Yaqubi

30.12.2023

Introduction

A prolonged and severe shortage of rainfall, or drought, has long been recognized as an influential natural phenomenon that impacts a considerable portion of the world's landmass. Drought is a major threat to the environment and human well-being because of its unrelenting impact on water resources, agriculture, ecosystems, and communities. The world has recently seen increasing instances of drought, underscoring the critical need for preventative actions to lessen its effects and promote environmental resilience. A lengthy period of unusually dry weather that significantly disrupts the hydrologic equilibrium in the affected area is referred to as a drought, according to the National Weather Service of the USA (National weather services, 2023).

To put it simply, it's an extended duration of unusually dry conditions that has detrimental effects on crops and water supplies, among other things (National Weather Services, 2023). The degree of the moisture shortage, the length of the dry spell, and the geographic area affected all influence how severe a drought is (National weather services, 2023). There are four different definitions for drought: Definition of meteorology: This calculates the precipitation's divergence from the average. Still, given that different places have different climates, what is deemed a drought in one area might not be in another (National weather services, 2023).

There are four different definitions for drought: Meteorological Definition: These gauges how far precipitation deviates from the average precipitation. Still, given that different places have different climates, what is deemed a drought in one area might not be in another (National weather services, 2023). The definition of agricultural drought focuses on the insufficiency of soil moisture to meet the unique requirements of a given crop (National Weather Services, 2023). It denotes a condition in which the soil's available water supply is insufficient to support crop growth. When both surface and groundwater sources fell below their typical levels, this is known as a hydrological drought definition. It includes groundwater depletion as well as the loss of water in lakes, reservoirs, and rivers (National weather services, 2023 Socioeconomic Definition: As defined by the National Weather Services (2023), is the time at which people's lives are negatively affected by the physical scarcity of water. It brings focus to the negative effects of water scarcity on a range of socioeconomic factors, such as communities, businesses, and means of subsistence.

Beginning in 1995, Afghanistan saw unusually long periods of dry weather, which sparked an extended period of lengthy droughts that lasted until the winter of 2002–2003, when significant snowfall resulted in a brief relief. But this break was short-lived, as drought conditions returned in the years that follow. Notably, recorded sources like the Asia-Pacific Network for Global Change Research (APN, 2015) comprehensive report, the Mayan results (Miyan, 2015), aggress and concur on the occurrence of consecutive droughts from 1998 to 2001. The consequences of insufficient rainfall, and snowfall between 2008 and 2010 have also been particularly devastating, leading to substantial crop damages and failures across six provinces reported by the various news agencies across the country such as Herat, Jawzjan, Balkh, Badghis, Faryab, and Sar-e-Pul (ABC News, 2012). Thus, the ability to accurately assess and monitor drought conditions is crucial for effective water resource management and mitigation strategies.

Site Description

The study focuses on Herat province, the third-largest province in Afghanistan, covering an expansive area of 55,868 km^2. Chosen due to its relevance to the author's location and its pronounced susceptibility to severe drought conditions, particularly in Herat city, the provincial capital spanning an area of 182 km^2. The significance of Herat extends to neighbouring provinces like Badghis and Farah, which share analogous climatic conditions and are equally vulnerable to drought. The research objectives centre on assessing hydrological drought, scrutinizing climate change models using historical and future CORDEX data and analysing drought patterns specific to the region. By delving into historical meteorological data, the study seeks to identify drought periods and quantify their severity. The anticipated outcomes aim to deepen our comprehension of drought dynamics, fostering improved anticipation and management strategies. The study's broader regional implications intend to extend its applicability to multiple areas confronting similar challenges.

The research leverages CORDEX (Coordinated Regional Climate Downscaling Experiment) as a pivotal tool in understanding climate change impacts. CORDEX, a global collaboration of researchers employing regional climate models (RCMs), generates regional-scale climate projections for both impact assessment and adaptation studies. Engaging in activities such as the CORDEX-CMIP6 archiving specifications, Med-CORDEX-CMIP6 baseline run protocol, and the EURO-CORDEX project, CORDEX aims to enhance climate modelling capabilities. The study further incorporates the Regional Climate Model Evaluation System (RCMES) to evaluate regional models over a 20-year hindcast period, providing essential tools and resources for assessing regional climate change. This collaborative effort signifies a comprehensive approach to understanding and addressing the intricate interplay of regional climate dynamics, fostering advancements in climate change adaptation and mitigation strategies.

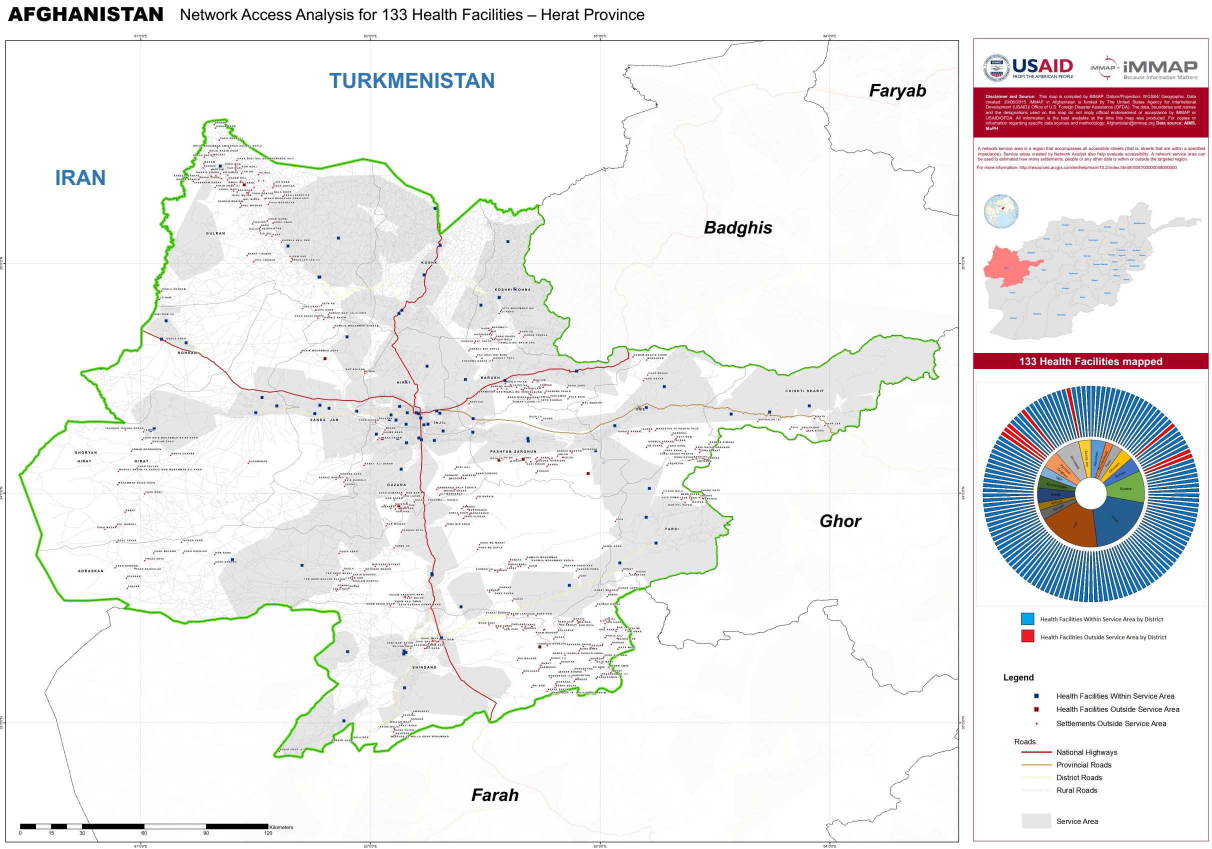

Figure 1 Herat Province

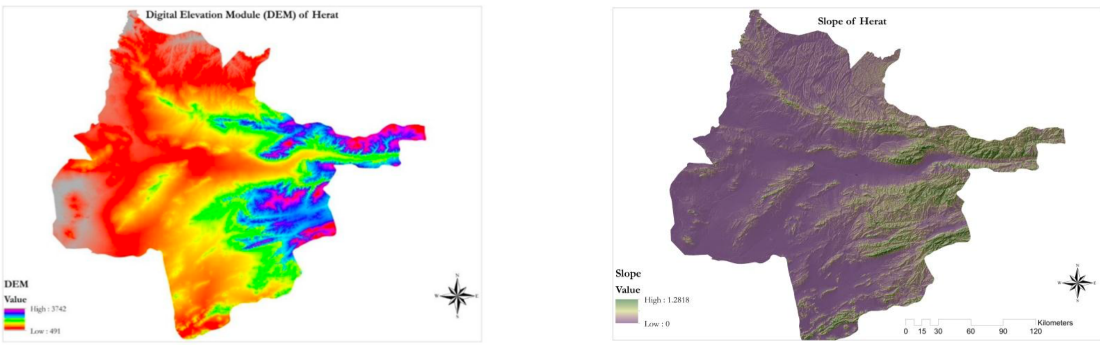

Figure 2 Herat Province DEM and Slope Maps

Data Collection

In this study the historical and future projection data are obtained from WCRP CORDEX website accessible through; https://esgf-data.dkrz.de/search/cordex-dkrz/

Domain = WAS-44 for South Asia
Variables = Precipitation and Temperature
Data Frequency = Daily
Experiment = Historical and RCP85 Projection
Ensemble = r12i1p1
RCM Model = RCA4
Downscaling Realization = v2
Herat City in Afghanistan
Latitude = 34.343044
Longitude = 62.199074

For this assessment two types of meteorological data of precipitation and temperature was considered to perform drought analysis.

Precipitation

In the first part of the analysis the NetCDF data related to the historical and rcp85 future projection of the climate scenarios are adapted in Figure 3.

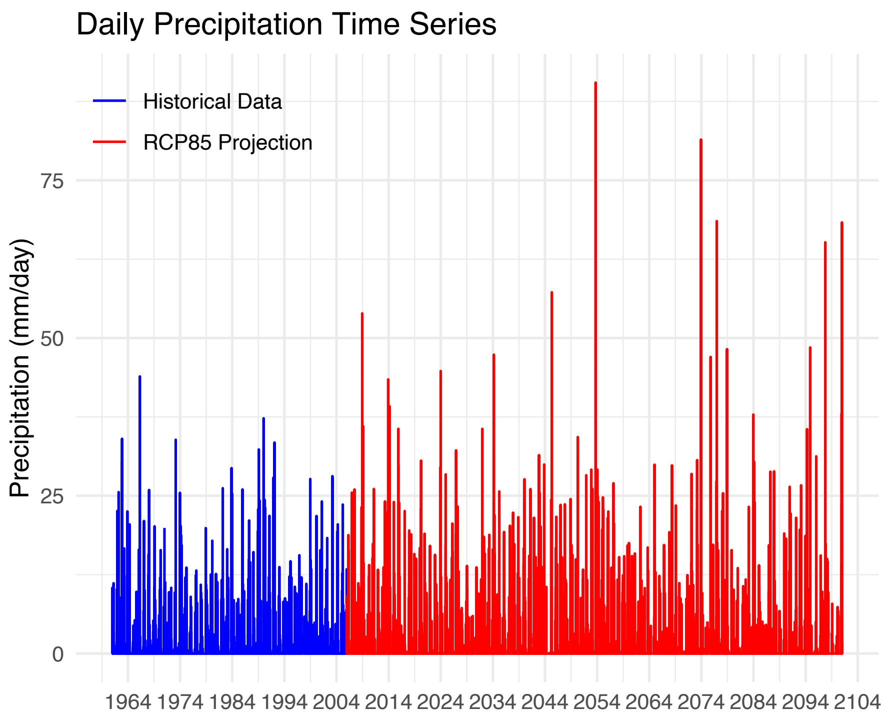

Figure 3 Daily Precipitation Time Series

The plot below represents the daily variation of the precipitation from 1961 to 2100. In this plot the data are split into historical from 1961 to 2006 in blue and from 2006 to 2100 for future projection shown red. Annual summary of the data is shown is Figure 4, and Figure 5. These plots indicate a clear reduction in the mean annual precipitation amount of the projected rainfall. Meanwhile there are indications of increase in the occurrence of the maximum precipitation through the year.

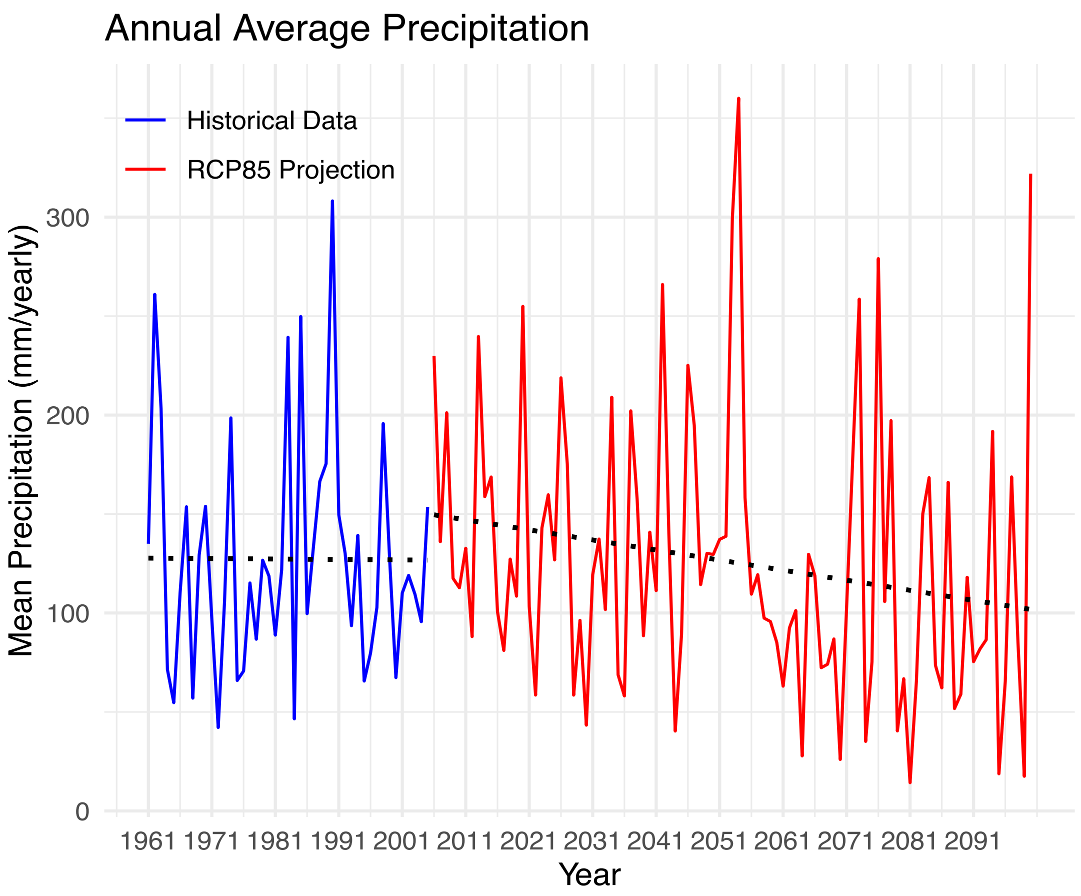

Figure 4 Annual Mean Precipitation Trends

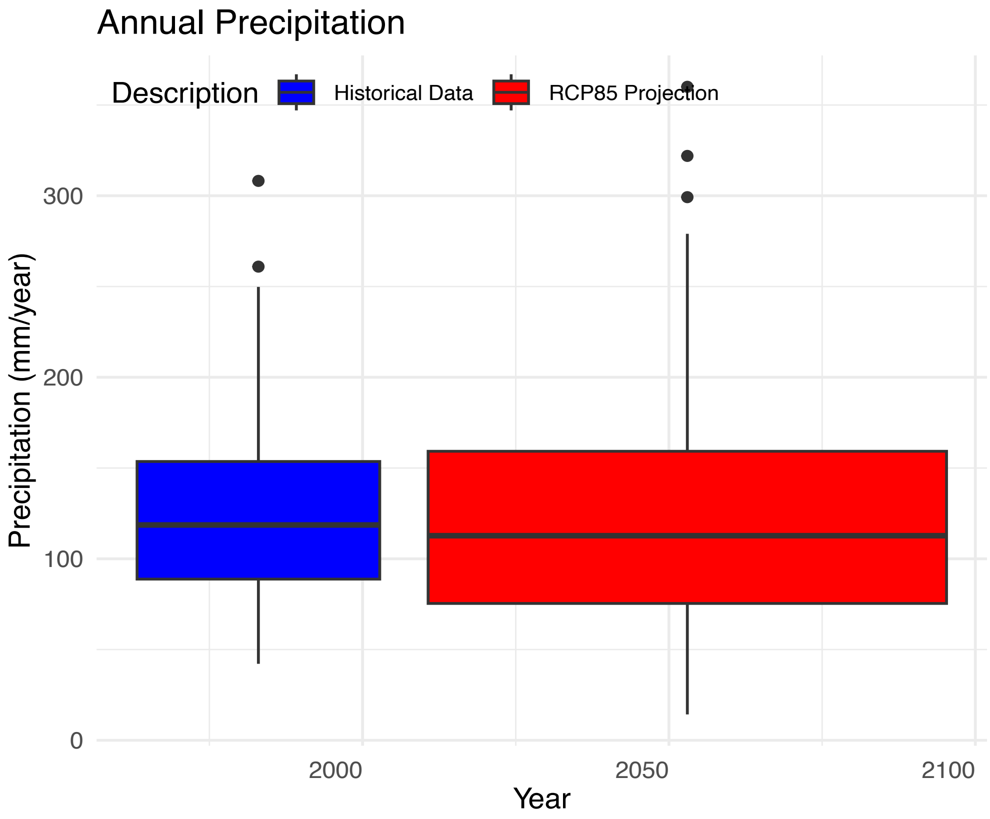

Figure 5 Comparison of Historical Vs Projected Precipitation

Seasonal Mean Precipitation

Seasonal mean precipitation variation for each season for historical and rcp85 projection are shown in Figure 6, and Figure 7 below.

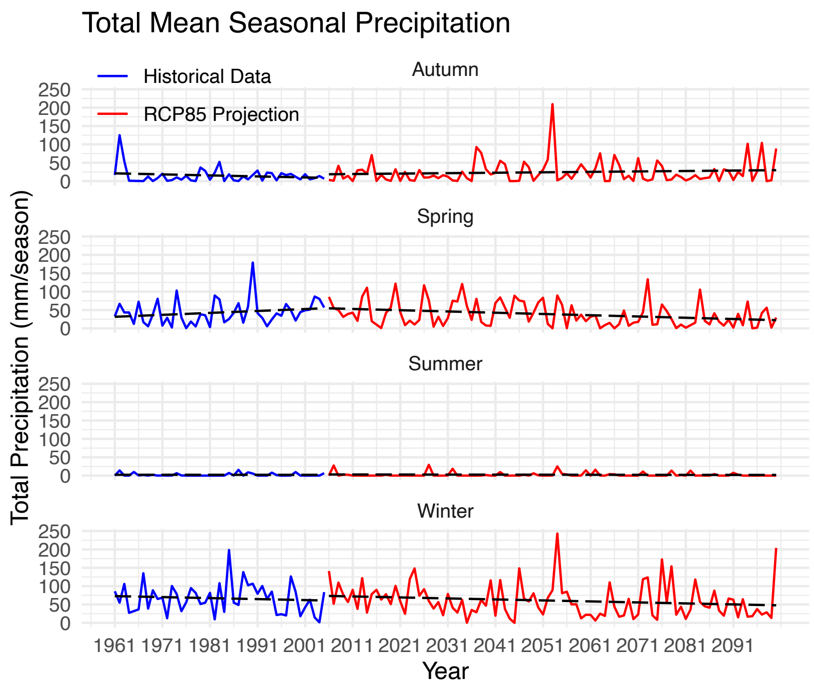

Figure 6 Total Mean Seasonal Precipitation

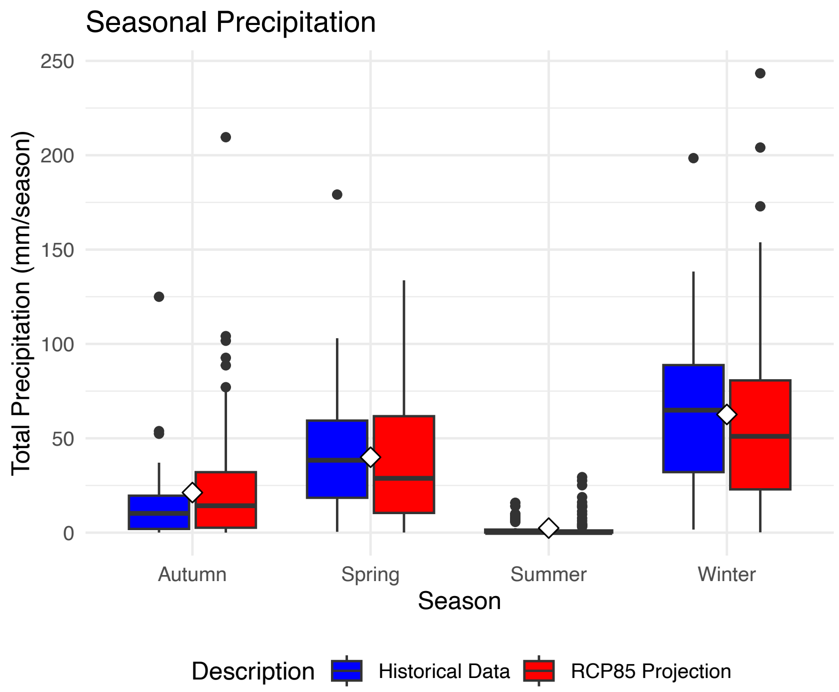

Figure 7 Comparison Seasonal Precipitation

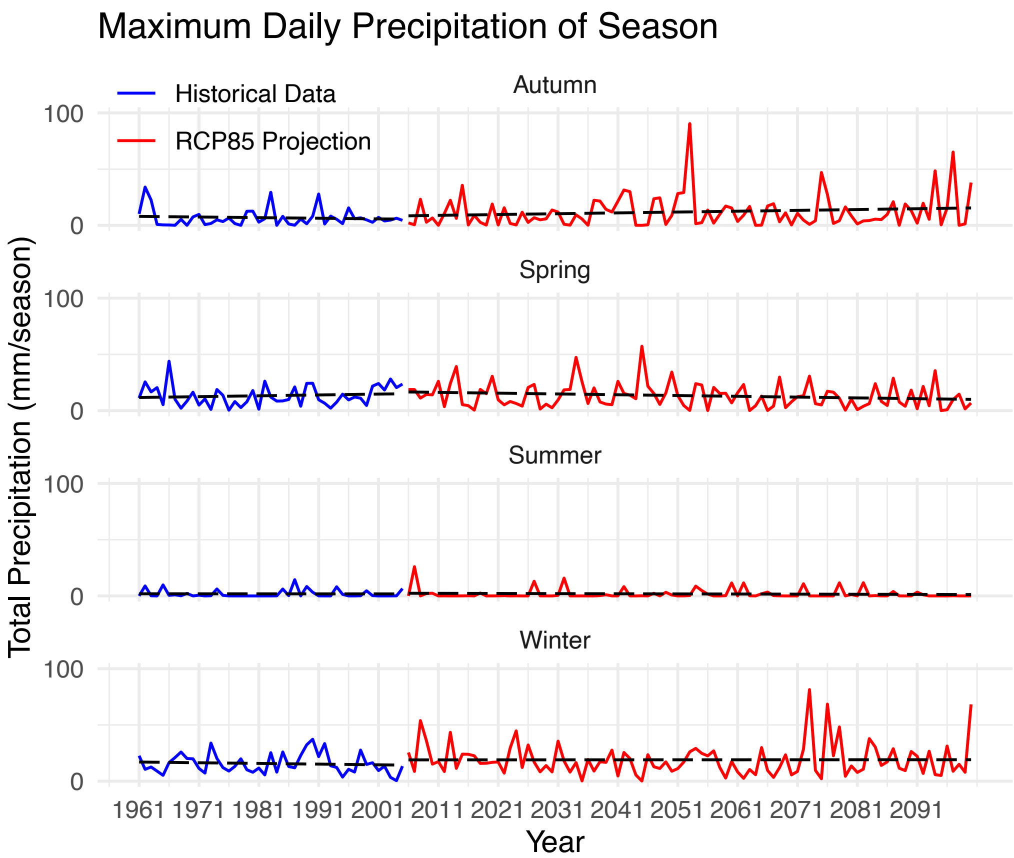

Figure 8 Maximum Daily Precipitation of Season

This plot indicates that both in spring and winter the mean seasonal precipitation is decreasing, however there is not many changes happening in the summer. In the autumn season mean seasonal precipitation is expected to rise slightly.

The Extreme analysis of the seasonal precipitation shown in the Figure 8. It can be seen that the maximum daily precipitation can be expected at the autumn and winter. In the spring the precipitation is more moderate.

Monthly Precipitation Variation

Looking deeper into the monthly mean precipitation analysis presented in **Error! Reference source not found.** a discernible decrease in monthly precipitation is evident across most months, with the exception of November. This trend is observable in both the maximum and mean precipitation values for both historical data and the rcp8.5 future projection. The detailed examination of individual months provides additional insights into the evolving precipitation patterns, thereby contributing to a comprehensive understanding of the anticipated climatic shifts.

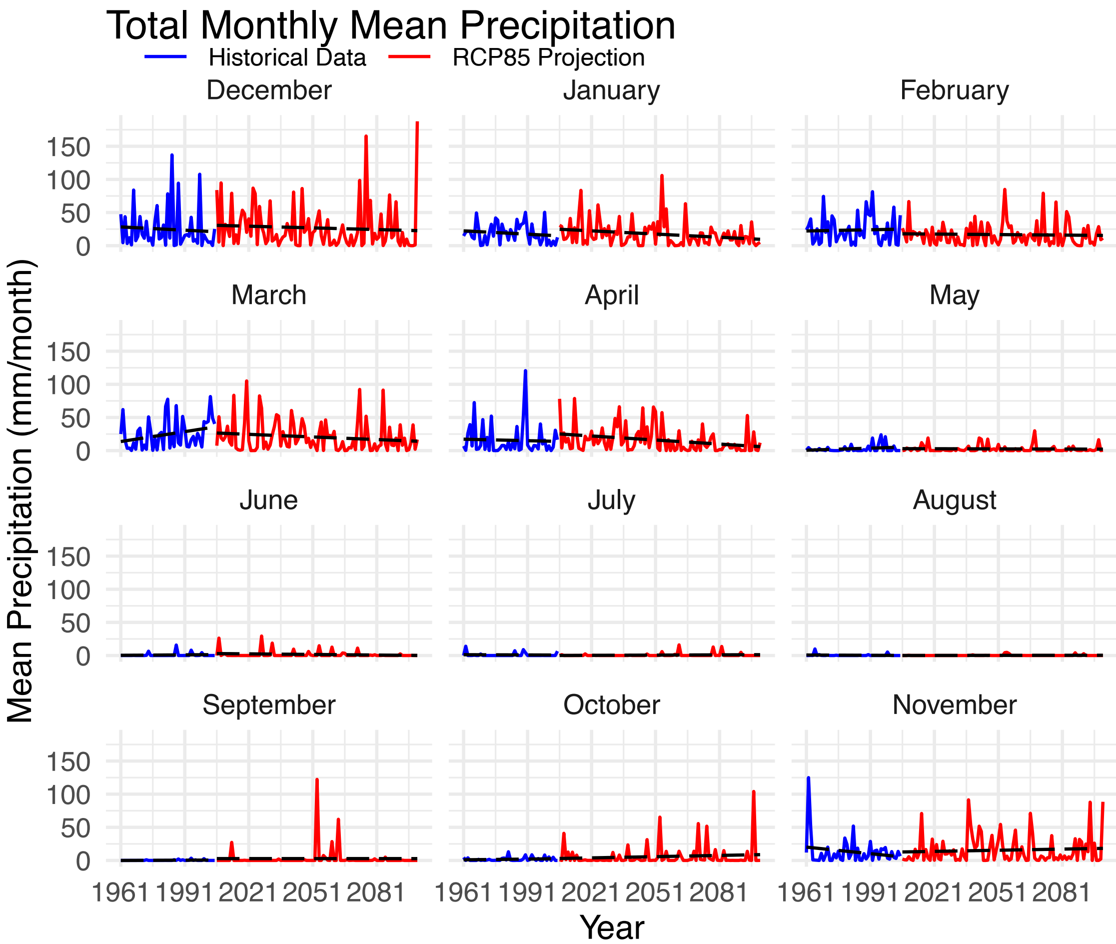

Figure 9 Monthly Precipitation Statistics

Each graphical representation in the dataset indicates a marginal reduction in spring precipitation during the spring seasons, a factor of considerable significance for agricultural productivity and the local economy. In normal climatic conditions, the occurrence of precipitation is relatively minimal during the summer months. Contrarily, in the autumn, while the projections do not reveal a substantial declining trend, there is an expectation that extreme precipitation events will become more prevalent, as evidenced by the clustering of black dots in the plot. Furthermore, for the winter season, traditionally characterized by elevated precipitation levels, a distinct and observable decreasing trend in precipitation is apparent. Nevertheless, occasional extreme weather events are anticipated in this season as well.

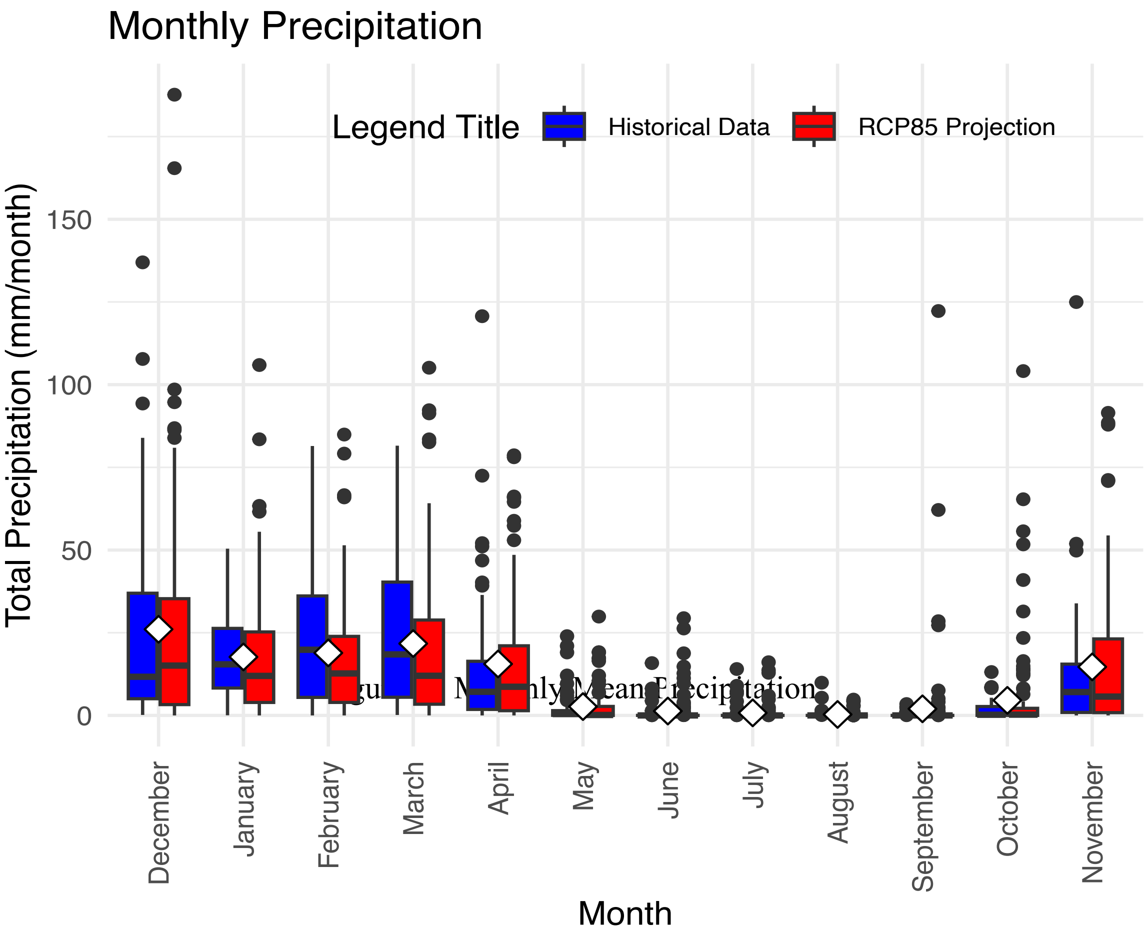

Figure 11 Comparison of The Seasonal Mean Precipitation

Temperature

The temperature variation depictions presented in Figure 12 andFigure 13 unequivocally illustrate a noteworthy surge in the mean annual temperature anticipated by the end of this century, as per the rcp8.5 climate scenario projection. As evident from the visual representations, the mean annual temperature is projected to increases significantly such that it will rise from approximately 15.5 ℃ to 18.1 ℃. This signifies a substantial elevation of more than 2.5 ℃ in the mean annual temperature, underscoring the impactful and potentially far-reaching implications of the climatic changes on the overall temperature trends over the course of the century. The increasing trajectory portrayed in these figures offers valuable insights into the evolving climate patterns and serves as a critical resource for informed decision-making in the field of climate science and climate adaptation policy formulation.

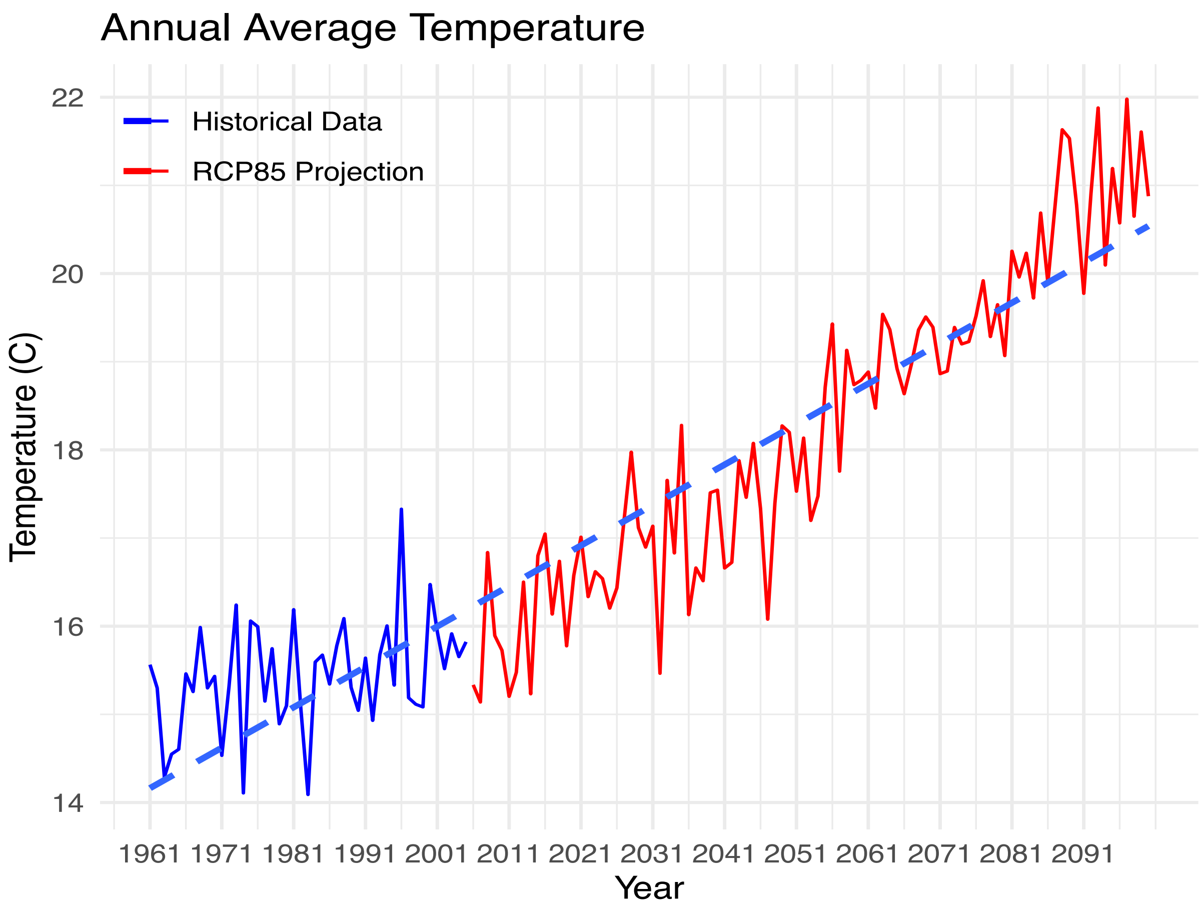

Figure 12 Mean Annual Temperature Variation

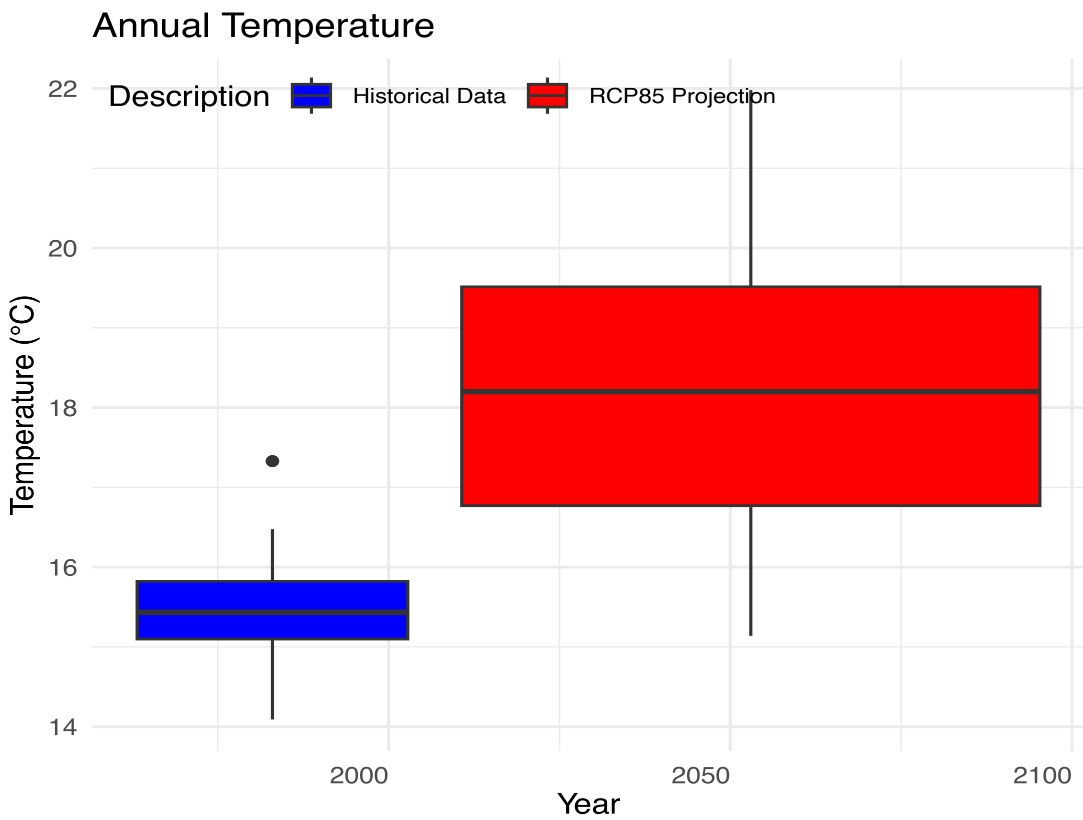

Figure 13 Comparison of Mean Annual Temperature

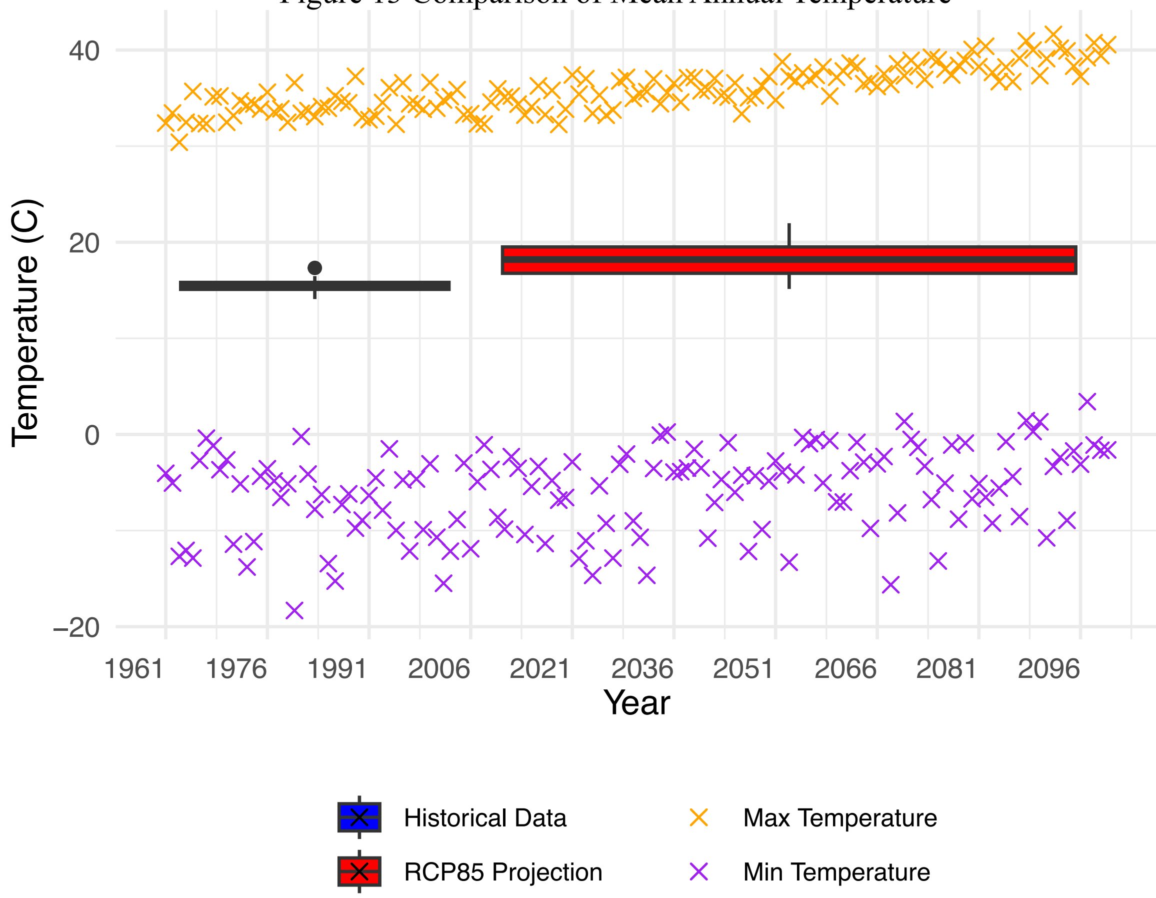

Figure 14 Annual Temperature Summary

Seasonal Temperature Variation

In examining the trends of seasonal mean temperatures shown in Figure 15 and Figure 18, it becomes evident that the historical mean temperature patterns reveal a consistent value of approximately 15 °C during both the autumn and spring seasons. However, a notable divergence is anticipated under the RCP8.5 scenario, where climate projections suggest a discernible increase in mean temperatures for these two seasons, reaching an estimated 17 °C. This projected temperature shift implies a substantial alteration in the thermal conditions experienced during autumn and spring.

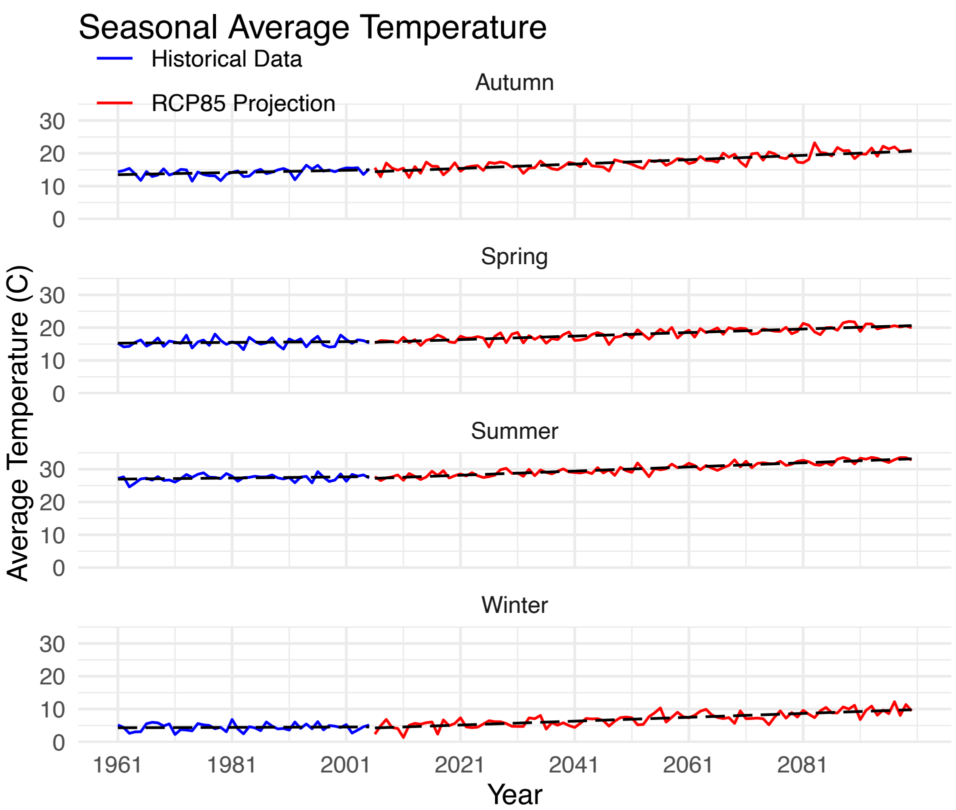

Figure 15 Mean Seasonal Temperature

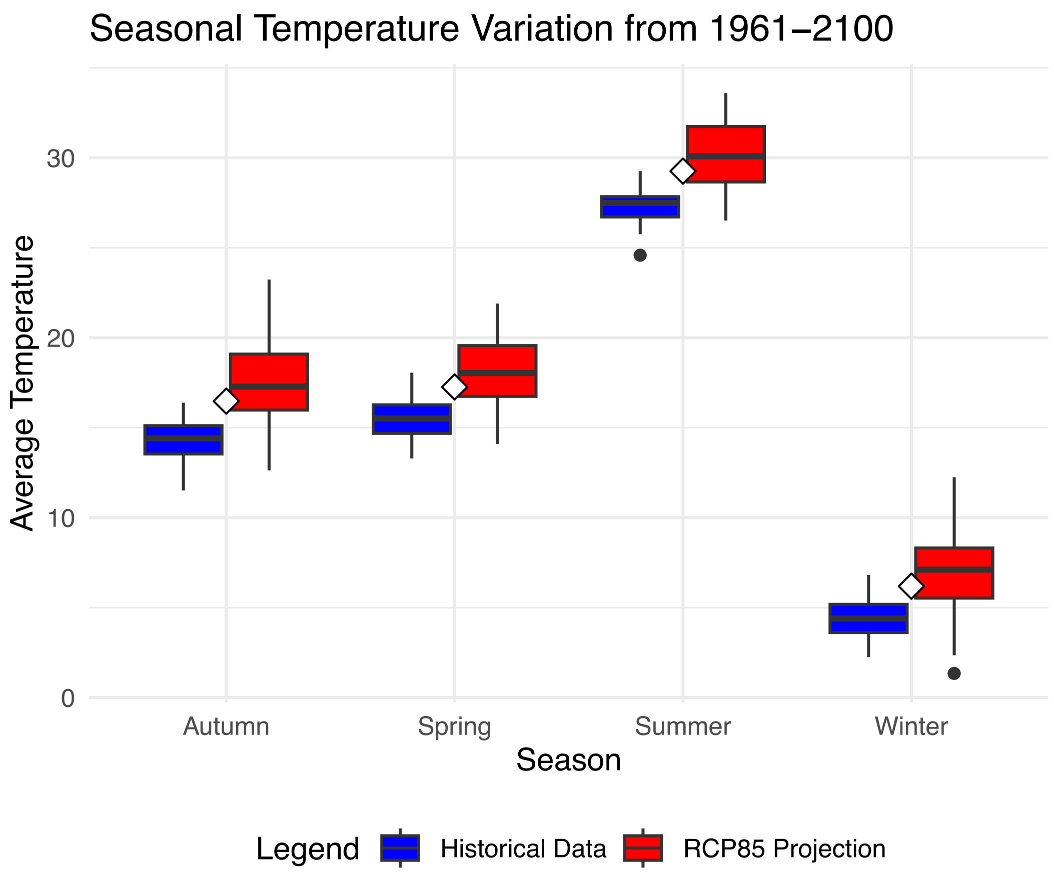

Figure 16 Seasonal Mean Temperature Comparison

Monthly Temperature Variation

Furthermore, when focusing on the summer season, historical climate data and rcp8.5 climate projections align in indicating a noteworthy uptick in mean temperatures. Specifically, the historical mean temperature for summer is recorded at 27.5 °C, but under the rcp8.5 scenario, a significant rise is anticipated, projecting a mean temperature of around 30 °C. This substantial increase underscores the potential impact of climate change on seasonal temperatures, particularly during the warmer months, and emphasizes the importance of considering these projections for informed climate planning and adaptation strategies.

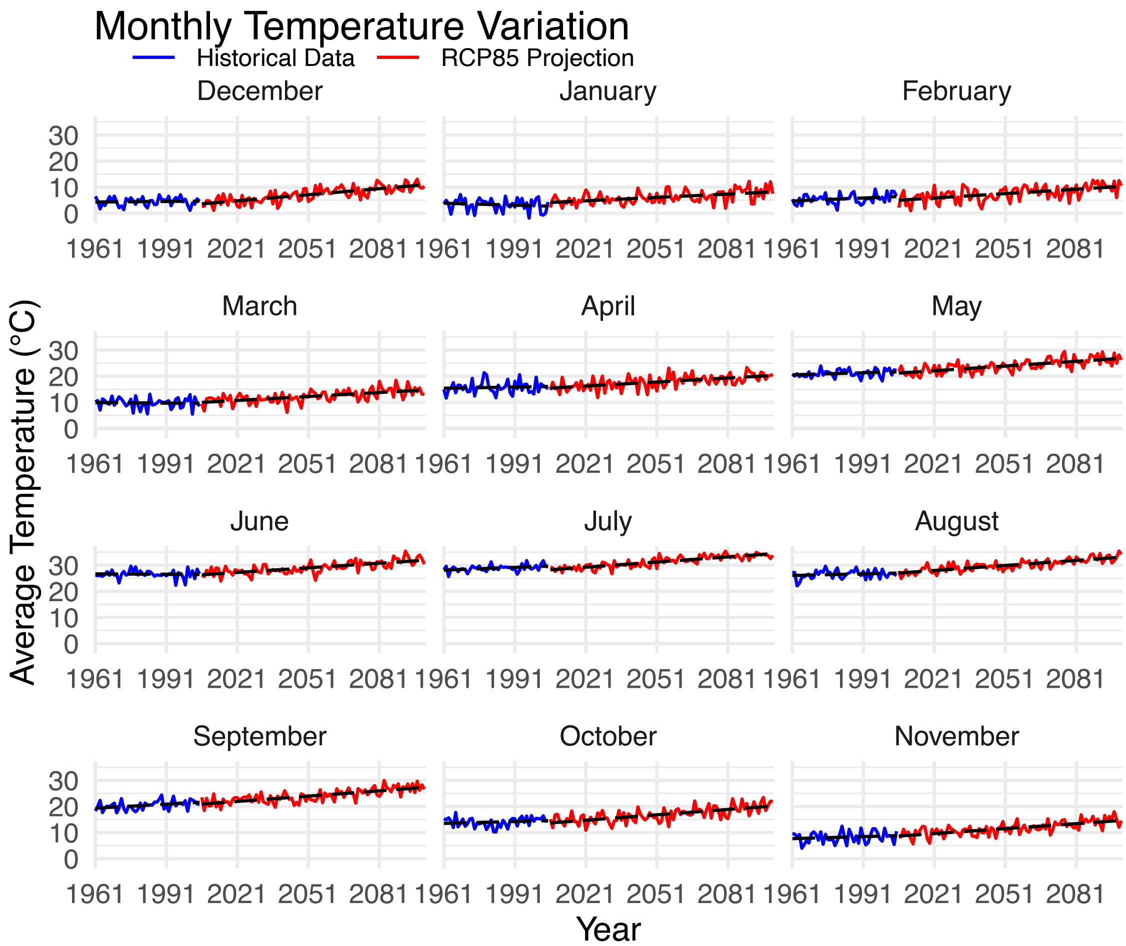

Figure 17 Monthly Temperature Variation

The monthly temperature shown in the Figure 18, shows that, overall, the mean temperature will rise through the year. This increase in the temperature is more prominent, from July to December where it is more significant compared to other months.

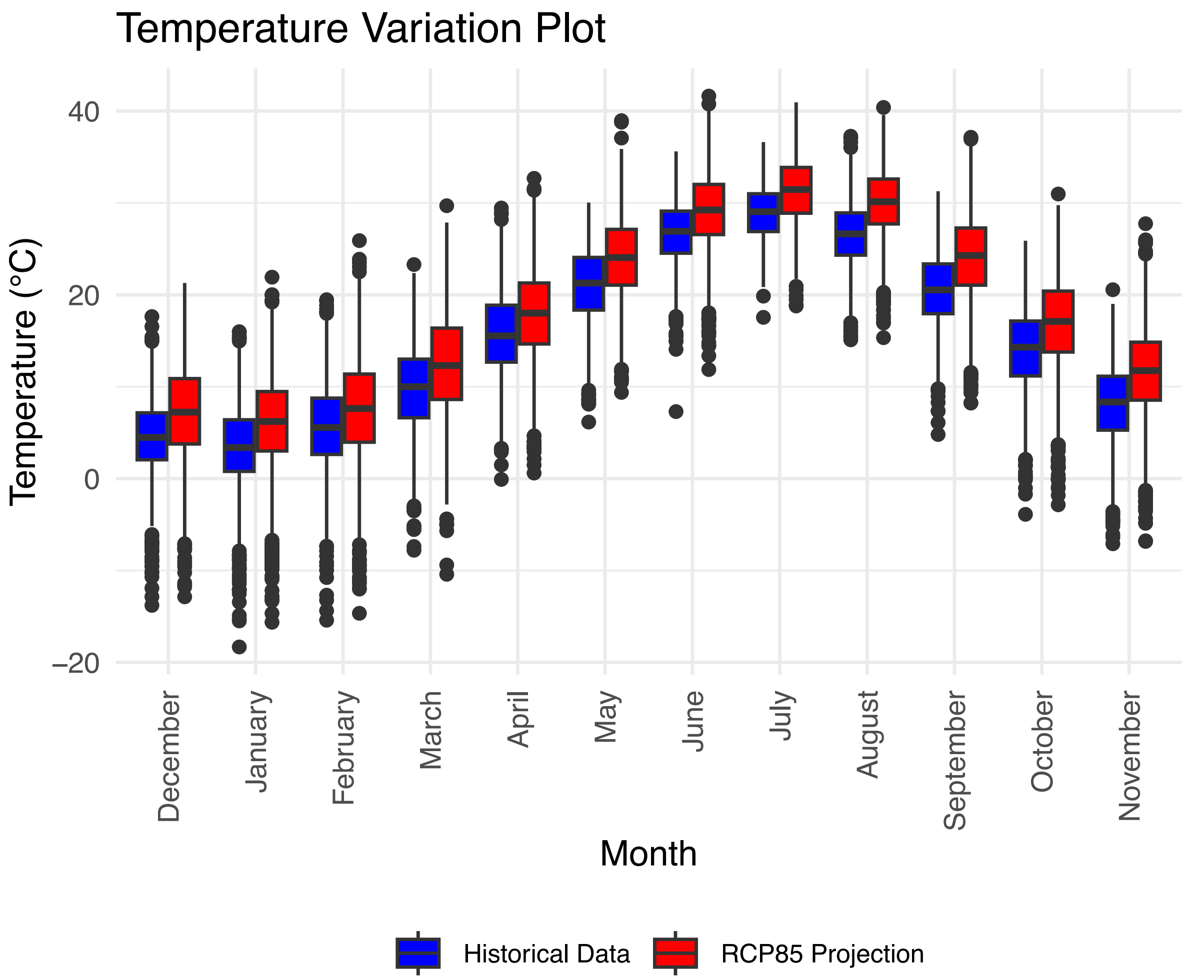

Figure 18 Mean Seasonal Temperature Comparison

Critical Analysis and Performance of the Climate Change Models

In the pursuit of a comprehensive evaluation of climate change models, Figure 19 and Figure 21, offer a detailed comparison involving the monthly average of historical precipitation data from climate models, actual measurements recorded at a city center gauge station spanning from 1979 to 2023, and the projected values under the Representative Concentration Pathway 85 (RCP85) scenario. This scrutiny aims to unveil the performance of these models across various metrics, encompassing mean, maximum, and minimum precipitation. A discernible trend emerges as the forecasted averages consistently lag behind the actual measured rainfall, prompting a closer examination of potential contributing factors. Notably, the RCP85 means, derived from the timeframe 2006 to 2100, may introduce a temporal bias, influencing the observed discrepancies in precipitation averages and highlighting the need for a nuanced understanding of the dynamic in shaping climate change projections.

Further analysis reveals that the inclusion of data up to 2100 in the RCP85 means introduces a temporal dimension that may influence the overall precipitation averages, given the uncertainties in projecting climate patterns beyond the current timeframe. The differences observed in mean, maximum, and minimum precipitation underscore the nature of climate modeling and the importance of considering scenario-specific factors. This multifaceted examination highlights the ongoing challenges in accurately forecasting precipitation patterns and emphasizes the continuous need for refining and validating climate models to enhance their predictive capabilities in the face of evolving environmental dynamics.

Upon closer examination of the mean monthly precipitation for January shown in Figure 20, a comparison was made between the measured data, the rcp85 projection, and the model's historical data. While extreme values are closely situated, it is notable that they do not align temporally. Despite this temporal discrepancy, these models provide a reliable means to approximate future scenarios related to precipitation patterns, extreme values, and the likelihood of drought, offering valuable insights despite the challenge posed by the non-synchronous occurrence of extreme events.

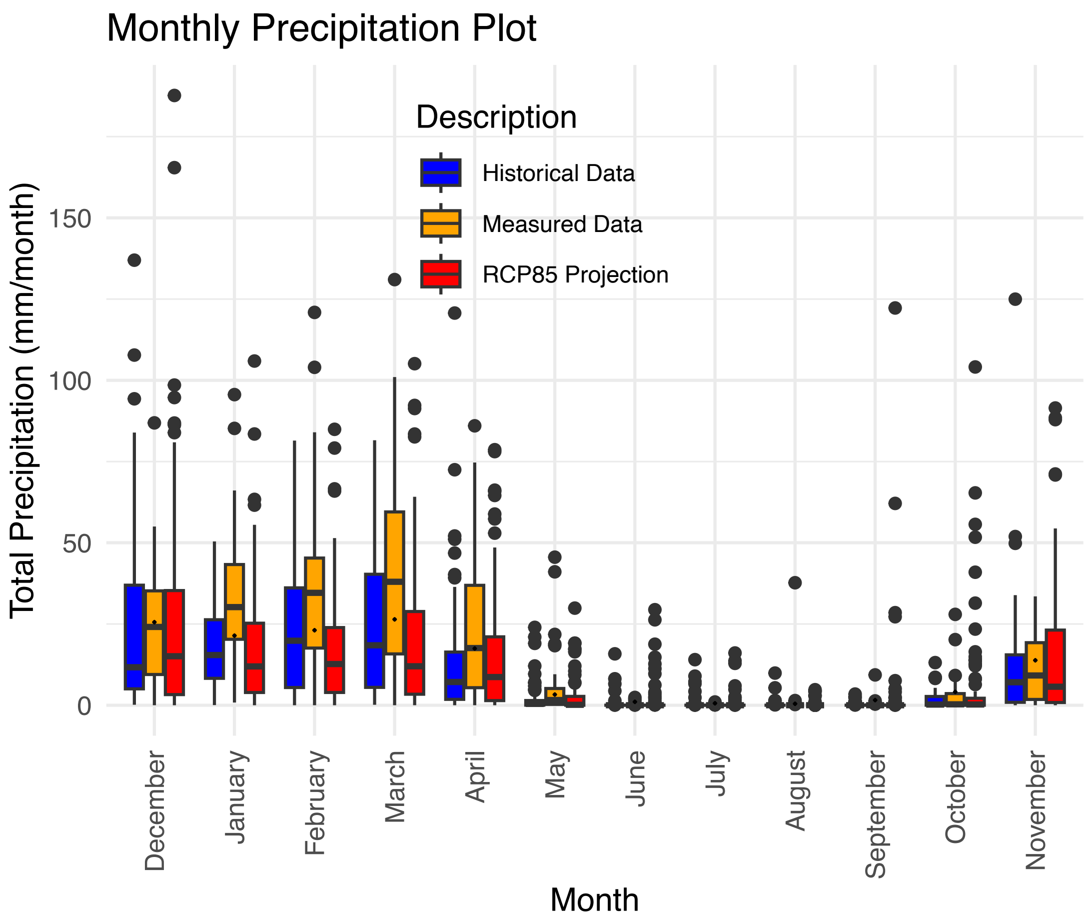

Figure 19 Figure of Historical, Measured, rcp85 projection Rainfall Data in a Station in Herat City

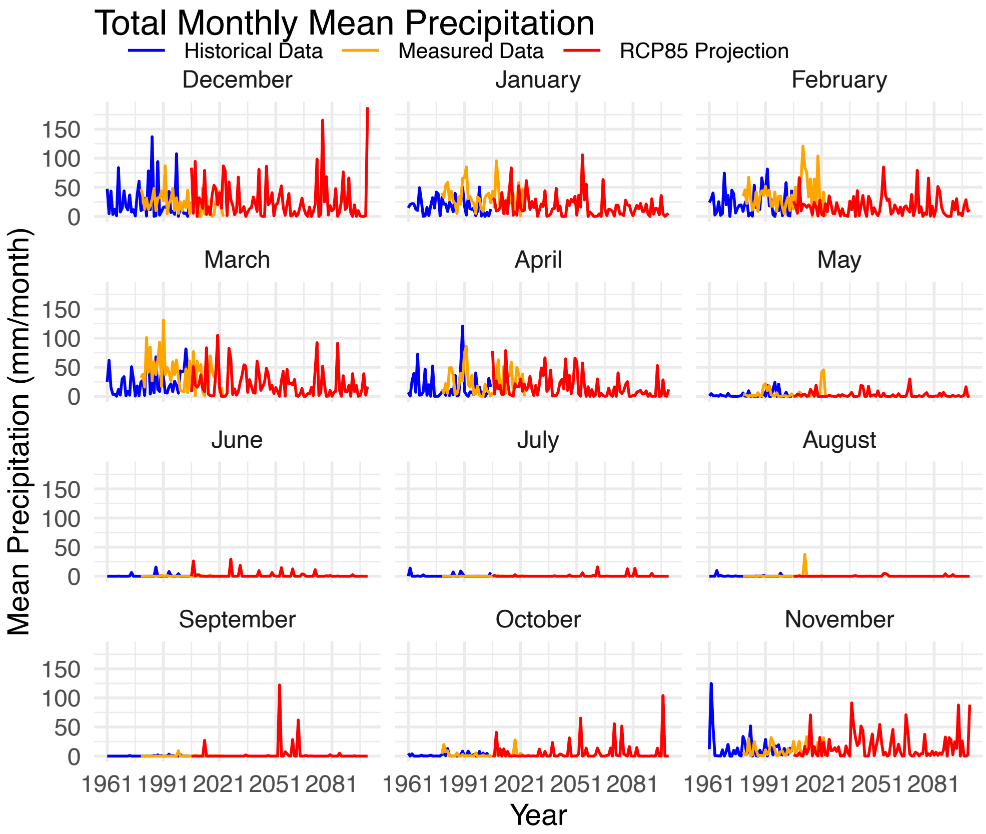

Figure 21 Mean Monthly Precipitation

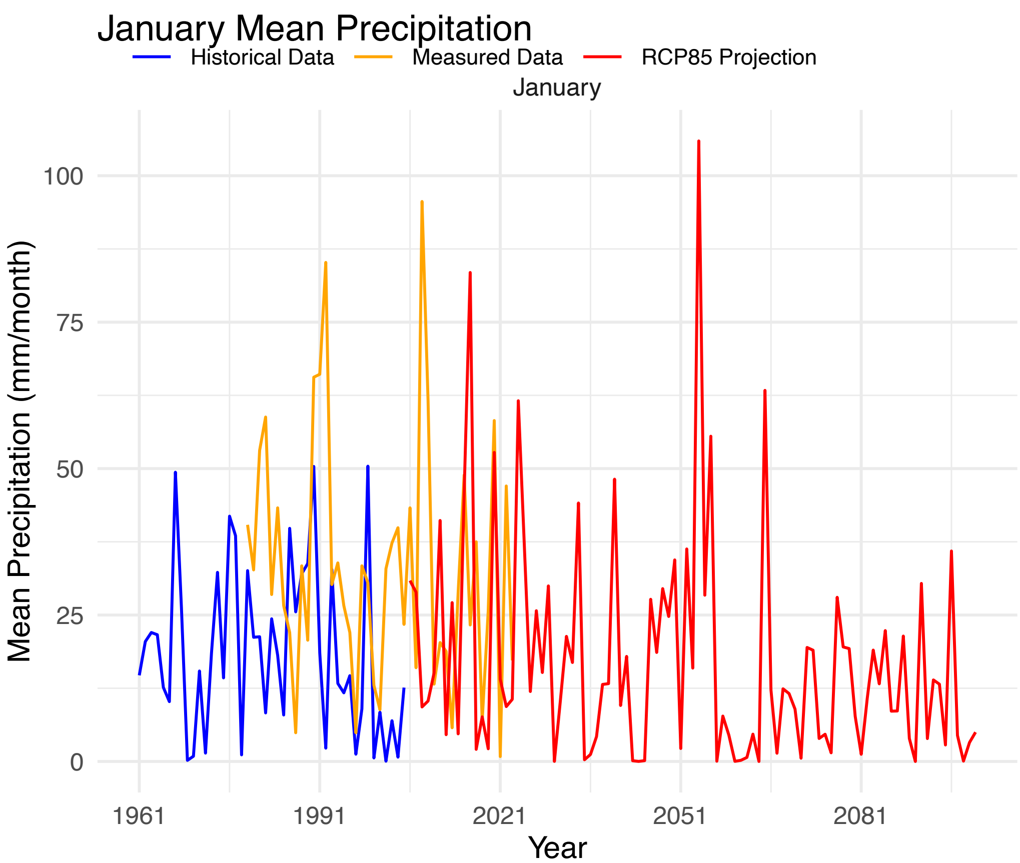

Figure 20 Mean Monthly Precipitation

References

1. National Weather Service. (2023) Understand Drought and Know How to Respond: https://www.weather.gov/safety/drought#:~:text=Drought%20is%20a%20deficiency%20in,duration%20of%20droughts%20varies%20widely.
2. Miyan, M. A., Kuruppu, N., Dube, O. P., Rahman, M. A., Dewan, T., Willie, R., & Miah, S. (2017). Barriers, needs and potential solutions to reducing vulnerability to global environment change for least developed countries in the Asia-Pacific Region. *APN Science Bulletin*.
3. ABC News. (2012, March 10). 145 “presumed dead” in Afghan avalanche: http://www.abc.net.au/news/2012-03-10/death-toll-from-afghan-avalanches-rises-to-56/3881862
4. https://esgf-data.dkrz.de/search/cordex-dkrz/