PAKISTAN METEOROLOGICAL DEPARTMENT

SCIENTIFIC REPORT

# HOW THE CLIMATE OF PAKISTAN HAS CHANGED

SEPTEMBER 2026

EVIDENCE FROM 45-YEAR DATA RECORD


AUTHORS

Dr. Faisal Saeed Syed
Burhan Ahmed
Sultan Muhammad Zaheer Ud Din
Shahzad Ali
Anwar Sadiq

**Note**

This report is prepared by the officials of the Pakistan Meteorological Department (PMD). The opinions, findings, interpretations, and conclusions expressed in this work are those of the authors and do not necessarily reflect the views or the official policy or position of PMD. The right to publish this report is reserved by PMD only. Short extracts from this publication may be reproduced without authorization, provided that the complete source is clearly cited. Any correspondence and requests related to this publication should be addressed to:

Dr. Faisal Saeed Syed, Chief Meteorologist, Pakistan Meteorological Department, Pitras Bukhari Road, Sector H-8/2, Islamabad, Pakistan.

**ISBN** 978-627-94996-0-8 (electronic)

For citation purposes, this report may be cited as:

"Syed, FS; Ahmed, B; Zaheer Ud Din, SM; Ali, S; Sadiq, A (2026) *How the Climate of Pakistan has Changed: Evidence from 45-year Data Record.* Pakistan Meteorological Department, Islamabad."

## LIST OF ACRONYMS AND ABBREVIATIONS

| Acronym | Expansion | Acronym | Expansion |
|---|---|---|---|
| A/B | Air Base (meteorological station suffix) | KP | Khyber Pakhtunkhwa |
| A/P | Airport (meteorological station suffix) | MA | March-April (spring) |
| ADB | Asian Development Bank | MJ | May-June (pre-monsoon) |
| AJK | Azad Jammu and Kashmir | MODIS | Moderate Resolution Imaging Spectroradiometer |
| AR6 | Sixth Assessment Report (of the IPCC) | ON | October-November (post-monsoon) |
| CDD | Consecutive Dry Days | PBO | Pilot Balloon Observatory |
| CDPC | Climate Data Processing Centre | PDMA | Provincial Disaster Management Authority |
| CIHGGO | Cressman Interpolated High-resolution Gauge-based Gridded Observations | PMD | Pakistan Meteorological Department |
| CODED | Cooling Degree Days | PR | Precipitation |
| CWD | Consecutive Wet Days | R150 | Precipitation ≥ 150 mm in one day |
| DJF | December-February (winter) | Rx5day | Mean 5-day cumulative precipitation |
| DTR | Diurnal Temperature Range | SDII | Simple Daily Intensity Index |
| ETCCDI | Expert Team on Climate Change Detection and Indices | SOP | Standard Operating Procedure |
| GB | Gilgit-Baltistan | SU40 | Hot Days > 40 °C (summer days) |
| GIS | Geographic Information System | Tmax | Maximum temperature |
| HKH | Hindu Kush Himalayas | Tmean | Mean temperature |
| HW | Heat Wave Events | Tmin | Minimum temperature |
| ICIMOD | International Centre for Integrated Mountain Development | TR30 | Warm Nights > 30 °C (tropical nights) |
| IPCC | Intergovernmental Panel on Climate Change | UIB | Upper Indus Basin |
| ISBN | International Standard Book Number | WMO | World Meteorological Organization |
| JAS | July-September (monsoon) | | |

# CONTENTS

# LIST OF FIGURES

# EXECUTIVE SUMMARY

This report presents a comprehensive assessment of long-term climate trends and extreme weather events across Pakistan over a 45-year period from 1981 to 2025. Using spatial and temporal analyses supported by climate maps, it provides a detailed understanding of variations in temperature and precipitation across the country. It also focuses on regional distinctions across provinces and territories, thereby enabling region-specific policy interventions and adaptation planning. Particular emphasis is placed on the assessment of climate extremes to support disaster preparedness and resilience efforts.

Pakistan is warming, its nights are warming faster than its days, and its rainfall has become less dependable rather than simply less abundant with the burden falling very differently on the northern mountains than on the plain areas. At country level, Pakistan experienced significant national warming between 1981 and 2025. Maximum, minimum and mean temperatures increased by +0.20°C, +0.26°C, and +0.21°C per decade, respectively. In contrast, annual precipitation exhibited a modest decrease of -7.40 mm per decade, although this trend was not statistically significant, reflecting the high interannual variability of rainfall across the country. The country also holds one of the highest temperatures reliably measured anywhere on Earth, 54.0°C at Turbat on 28 May 2017, verified by the World Meteorological Organization (WMO). On the rainfall side, the winter of 2024-25 brought a -67% national deficit (-90% in Sindh, -69% in Punjab), while only three years earlier the 2022 monsoon delivered up to +450% above-average rainfall in the south, submerging a third of the country and affecting 33 million people. Fog, historically a winter phenomenon of the eastern plains where more than ten foggy days a year were normal, has increased significantly across Punjab and Sindh. The report links this to the winter cooling of daytime temperatures over the same regions.

The long-term linear trends describe the rate at which the climate has been changing, while the composite comparison of the two twenty-year periods (2001-2020 minus 1981-2000) expresses the magnitude of change that has already accumulated. Both analyses point consistently in the same direction, and are therefore presented together below.

**Monthly Trends and Composite Changes in Temperature and Precipitation:** Monthly climate trends across Pakistan exhibit significant regional and seasonal variability. Warming is not spread evenly through the year, the change is concentrated in late winter and spring. Spring now arrives earlier and hotter, advancing conditions conducive of early snowmelt in the northern catchments. Spatial trend analysis indicates that maximum temperatures increased by up to +1.0°C per decade during February-April across northern Khyber Pakhtunkhwa (KP), Gilgit-Baltistan (GB), Punjab, and parts of Balochistan and Sindh. Over the two twenty-year periods, this late-winter and spring warming amounts to an increase of +1.5°C to +2.5°C between February and May across GB, Balochistan, Sindh, KP and Azad Jammu and Kashmir (AJK). Conversely, decreasing trends of up to -0.6°C per decade were observed during the summer (June-September) and winter (December-January) periods, corresponding to a cooling of -0.5°C to -2.0°C in parts of northern and central Pakistan over the same interval. This summer cooling trend is attributed to increase in cloud cover associated with the increase in precipitation during the monsoon.

Minimum temperatures have exhibited warming over most of the regions of Pakistan, reaching +0.5°C per decade from February to November in southern and central regions such as Sindh, southern Punjab and Balochistan. The composite comparison confirms substantial night-time warming of +1.0°C to +2.0°C during spring, particularly over southern and central Punjab, upper Sindh and Balochistan. Localized winter cooling in northern KP and GB is evident in both the trend and the composite analyses.

Precipitation trends reveal an increase in rainfall in Punjab and Sindh during the monsoon season (more than +10 mm per decade), which translates into composite increases exceeding +40 mm in southern KP, Sindh and Balochistan, indicating wetter monsoon conditions in these regions. In contrast, precipitation has decreased in the northern regions, particularly KP, AJK and GB, during spring, late summer and early winter, with composite reductions exceeding -70 mm in some areas. Many of these temperature and precipitation changes were statistically significant, highlighting notable shifts in Pakistan's regional climate patterns.

**Seasonal and Annual Trends and Composite Changes:** Seasonal and annual climate trends across Pakistan indicate widespread warming alongside regionally contrasting precipitation patterns, and the comparison of the two twenty-year periods (1981-2000 and 2001-2020) reveals a pronounced nationwide warming of the same character.

Maximum temperatures have increased beyond +0.6°C per decade during spring and winter across Punjab, Balochistan, Sindh, KP and AJK, accumulating to composite increases of up to +2.0°C, particularly in southern Balochistan and northern KP during spring and on an annual basis. Widespread warming exceeding +1.0°C was also observed across Sindh, AJK, GB and several other regions. Localized cooling trends remain evident in parts of central and northern Pakistan during the monsoon season, with composite cooling of up to -1.5°C occurring in parts of GB, KP and northwest Punjab.

Minimum temperatures exhibit significant warming, particularly during spring and winter, with increases of up to +0.6°C per decade. The composite analysis shows an even stronger signal, with night-time warming exceeding +2.0°C in central and southern Punjab, Sindh and eastern Balochistan, one of the widespread changes identified anywhere in this assessment. In contrast, some areas of KP, GB and Balochistan have experienced slight cooling during winter and the monsoon season, while AJK shows modest but spatially consistent warming during spring.

Precipitation changes show substantial spatial variability. Punjab, KP and Sindh have generally experienced increasing rainfall, exceeding +30 mm per decade in some areas, primarily during the pre-monsoon and monsoon seasons, with composite increases of more than +100 mm in parts of the region. Conversely, AJK, GB and northern KP have recorded declines of up to -50 mm per decade, particularly during spring, monsoon and winter, with composite decreases reaching -200 mm over northern Punjab, AJK and GB. The precipitation composites do also indicate a prominent statistical significance.

**Extreme Climate Indices (1980-2025):** Pakistan has experienced substantial changes in the frequency and intensity of extreme temperature and precipitation events over the past four decades. Southern regions, including Punjab, Sindh, and western Balochistan, recorded the highest occurrence of hot days (>+100 days per year), with increasing trends of up to +5.0 days per decade, whereas parts of central Punjab exhibited declines of up to -5.0 days per decade. The frequency of extreme heatwave events has also increased, particularly in KP and Balochistan provinces.

Punjab and Sindh recorded the highest values of cooling degree days, exceeding +6000 units, reflecting a high demand for cooling energy. However, decreasing trends in central Punjab suggest a modest reduction in cooling requirements in some areas. The frequency of warm nights increased markedly across central Punjab, upper Sindh, and Balochistan. The diurnal temperature range exceeded +14.0°C in KP, GB, Sindh and Balochistan, with contrasting trends observed across the regions, declining in Sindh but increasing in parts of GB, KP and Balochistan province.

Precipitation extremes exhibited considerable spatial variability. Southern Sindh recorded the highest precipitation intensity values, converging +20 mm/day, while significant increases were observed across the country. However, upper KP, GB and Balochistan experienced declining trends in the precipitation intensity. The highest 5-day cumulative precipitation totals, exceeding +200 mm, were recorded in northern Punjab, KP, and AJK, with increasing trends evident in eastern Punjab. The greatest frequency of consecutive wet days was experienced in KP and AJK, however they showed declining trends over time. Conversely, prolonged consecutive dry days were most common in Balochistan and Sindh, with slight reductions observed in recent decades. Heavy rainfall events (≥150 mm/day) occurred most frequently in AJK, Sindh, and northeastern Punjab.

# 1. INTRODUCTION

This report presents a comprehensive analysis of spatial and temporal changes in Pakistan's climate, focusing on key trends in mean climatic conditions and extreme climate indices. Pakistan's diverse topography and climatic zones make it highly vulnerable to climate variability and change, underscoring the importance of understanding long-term shifts in temperature, precipitation, and extreme weather events. By analyzing historical climate data, the report provides a detailed assessment of how climatic conditions have evolved across different regions of the country, offering valuable insights for policymakers, researchers, and stakeholders involved in climate adaptation, mitigation, and intervention strategies.

The primary objective of this report is to present a series of maps illustrating trends in key climatic variables, including mean temperature, precipitation, and fog, to highlight spatial and temporal variability in Pakistan's changing climate. These visualizations help identify regions experiencing the most significant changes, whether in terms of warming trends, altered rainfall patterns, or increasing climatic extremes, thereby providing a clear and accessible overview of climate change impacts across the country and supporting targeted interventions in the most affected areas.

In addition to national-scale analysis, the report examines sub-regional variations, particularly across provinces where climatic conditions differ markedly. For example, the arid plains of Sindh, the monsoon-influenced regions of Punjab, and the high-altitude areas of Gilgit-Baltistan each exhibit distinct climatic characteristics. By assessing provincial and sub-provincial trends, the report provides a detailed understanding of localized climate change, enabling region-specific policy formulation and adaptation planning.

Beyond general climate trends, the report also examines extreme climate indices, which are critical for understanding the frequency and intensity of events such as heatwaves, heavy rainfall and droughts. These indices offer deeper insight into how climate extremes are evolving and the associated risks to agriculture, water resources, infrastructure, and public health. By quantifying these extremes, the report identifies areas most vulnerable to climate-induced hazards, thereby supporting disaster preparedness and resilience planning.

A broader objective of this study is to translate climate trends into actionable insights for stakeholders, including government agencies, development organizations, and local communities. By identifying regions facing increasing risks as well as areas experiencing potential shifts in rainfall patterns, the report aims to bridge the gap between climate science and decision-making.

Ultimately, the findings are intended to inform sustainable development strategies that leverage climatic information to enhance resilience and socio-economic stability in Pakistan.

## 1.1 GLOBAL PERSPECTIVE

The Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC) underscores unequivocal evidence of climate change, with global surface temperatures rising by approximately +1.1°C above pre-industrial levels (1850-1900) as of 2022, primarily driven by greenhouse gas emissions[1]. Observed global warming has accelerated significantly since the 1970s, with the decade 2011-2020 recorded as the warmest decade globally for both land and ocean temperatures. Precipitation patterns have shifted globally, with intensified heavy rainfall events and associated flooding in many areas, alongside increased aridity and drought frequency in others[2]. Cryospheric changes are pronounced, including sustained declines in Arctic Sea ice extent, glacier mass loss, and accelerated ice sheet melt in Greenland and Antarctica, all of which contribute to global mean sea level rise[3]. Extremes such as heatwaves, marine heatwaves, and intense tropical cyclones have become more frequent and severe.

## 1.2 SOUTH ASIAN PERSPECTIVE

While global-scale assessments provide clear evidence of climate change, the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC) also highlights pronounced climate trends across regions such as South Asia, characterized by accelerated warming, shifting monsoon patterns, and heightened extremes. Surface temperatures over South Asia have risen faster than the global average, increasing by +0.5°C per decade[4]. The South Asian monsoon has exhibited greater variability since the mid-20$^{th}$ century, with intensified heavy precipitation events and a weakening of overall monsoon circulation, leading to erratic rainfall distribution and prolonged dry spells in some subregions. The Hindu Kush Himalayas (HKH) have experienced accelerated glacier mass loss (approximately -0.17 to -0.28 m water equivalent per year during 2010-2019), contributing to altered river flows and heightened risks of glacial lake outburst floods[5].

1 IPCC, 2021: Summary for Policymakers

2 Water Cycle Changes. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1055-1210, doi: 10.1017/9781009157896.010.

3 Ocean, Cryosphere and Sea Level Change. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1211-1362, doi: 10.1017/9781009157896.011.

4 Adeliyi, T. E., & Akinsanola, A. A. (2024). Recent trends and variability of temperature and atmospheric water vapor over South Asia. Atmospheric Research, 309, 107556.

5 Wester, P., Chaudhary, S., Chettri, N., Jackson, M., Nepal, S., & Steiner, J. F. (2023). Water, ice, society, and ecosystems in the Hindu Kush Himalaya: An outlook. International Centre for Integrated Mountain Development (ICIMOD). https://doi.org/10.53055/ICIMOD.1028

Heatwaves have become more frequent, intense, and prolonged, while concurrent droughts and floods have exacerbated vulnerabilities. Sea levels along South Asia's coastlines have risen at a rate exceeding +3.7 mm/year (2006-2018), compounding risks of coastal flooding and salinity intrusion[6]. These trends, linked to regional climate forcing, underscore the urgent need for credible local-scale assessments of climate trends and changes in this climate-sensitive region.

## 1.3 REGIONAL PERSPECTIVE AS PER WMO

The World Meteorological Organization (WMO) has emphasized that South Asia, including Pakistan, faces escalating climate risks driven by global warming, with impacts manifesting through extreme weather, shifting monsoons, and rapid environmental degradation. In its annual State of the Climate in Asia report, the WMO highlighted that South Asia is warming faster than the global average, exacerbating heatwaves and glacial melt. The 2022 Pakistan floods, triggered by unprecedented monsoon rainfall up to three times the 30-year average and linked to climate change by WMO analyses, served as a stark example of intensifying hydro-meteorological extremes, displacing millions and causing over $30 billion in losses. The WMO has further noted accelerated glacier retreat in the Indus Basin, threatening long-term water security for Pakistan.

## 1.4 PAKISTAN PERSPECTIVE AS PER PREVIOUS REPORTS

According to reports from the Pakistan Meteorological Department (PMD), Pakistan's climate has undergone significant shifts in recent decades, marked by rising temperatures, erratic precipitation patterns, and an increased frequency of extreme weather events. As per PMD, the winter of 2024-2025 was one of the driest in Pakistan's history. As per records, the country has experienced a staggering -67% rainfall deficit compared with normal conditions. Sindh, the hardest-hit province, recorded a -90% deficit, while Punjab, the agricultural heartland, saw a -69% reduction. In contrast, the 2022 monsoon season exemplified extreme hydro-climatic volatility, with rainfall up to +450% above average in southern provinces[7], triggering catastrophic floods that submerged one-third of the country and affected 33 million people, locally. In the past century, mean temperatures have increased by approximately +0.57°C[8], with accelerated warming in northern mountainous regions, contributing to accelerated glacial melt in the Himalayas and Karakoram ranges. Heatwaves have intensified, particularly in Sindh, with recorded temperatures exceeding +50.0°C in 2024, underscoring the growing threat of deadly heat stress[9]. Coastal areas have also experienced the

6 Das, A., & Swain, P. K. (2024). Navigating the sea level rise: Exploring the interplay of climate change, sea level rise, and coastal communities in india. Environmental Monitoring and Assessment, 196(11), 1010.

7 CDPC, (2022). https://cdpc.pmd.gov.pk/Monsoon_2022_update/Pakistan_Monsoon_2022_Rainfall_Update.pdf

8 ADB (2017). Climate Change Profile of Pakistan. Asian Development Bank 978-92-9257-722-3 (e-ISBN).

9 PDMA Sindh, SOPs Heatwave Management, 2025. https://www.ndma.gov.pk/storage/guidelines/March2025/tlhzTl9tvzQvvkrSjFnj.pdf

impacts of climate change, including Karachi, where sea level has been rising at a rate of approximately +3.5 mm per year, contributing to saline intrusion and threatening livelihoods and ecosystems[10].

In 2025, Pakistan recorded its warmest annual mean minimum temperature on record, with a national annual mean minimum temperature of 16.7°C, representing an anomaly of +1.4°C above the long-term average. At the regional scale, AJK recorded its highest annual mean minimum temperature of 12.2°C (+1.8°C) , while KP recorded its highest annual mean minimum temperature of 16.2°C (+1.7°C). During the same year AJK, KP, and GB recorded their highest annual mean temperatures on record, with annual mean temperatures of 15.5°C (+1.5°C) , 21.1°C (+1.3°C), and 17.1°C (+1.6°C), respectively. In addition, AJK recorded its highest annual mean maximum temperature of 18.8°C (+1.3°C).

The 2025 pre-monsoon (April-June) season was the second warmest on record nationally, with a mean temperature of 30.5°C, +1.9°C above the long-term average (record: 30.5°C in 2000). Regionally, AJK recorded its warmest pre-monsoon season on record (23.4°C; +2.4°C anomaly) and KP also experienced its warmest pre-monsoon season on record (27.3°C; +2.4°C anomaly).

Monthly warming also reached record levels in several regions. Balochistan recorded its warmest April on record, with a mean temperature of 28.3°C, +3.6°C above normal, surpassing the previous record of 28.1°C (2022). Likewise, AJK experienced its warmest September on record, with a mean temperature of 24.7°C, +2.3°C above normal, exceeding the previous record of 24.4°C (2019).

10 Khan, F. A., Khan, T. M. A., Ahmed, A. N., Afan, H. A., Sherif, M., Sefelnasr, A., & El-Shafie, A. (2020). Complex extreme sea levels prediction analysis: Karachi coast case study. Entropy, 22(5), 549.

# 2. DATA AND METHODOLOGY

This report is based on in-situ observational data of temperature, precipitation and fog recorded at daily and monthly temporal scales from all around Pakistan. Locations of the stations used for the study are presented in Figure 1. Names and coordinates of meteorological stations used in the study are presented in Table I. Four variables, namely maximum temperature (Tmax) minimum temperature (Tmin), precipitation (PR) and fog are considered in this report. Long-term data comprising a period of 45 years (1981-2025) was used in this study for analysis.

Climatology, trend analysis, and composite computation for Tmax, Tmin, PR and fog were based on in-situ station observations, originally sourced at monthly resolution. These records were first subjected to quality control checks, and the relatively few missing observations were reconstructed using multiple imputation method, where data gaps were found seldom, at the monthly scale. The resulting point-based climatology, trends and composites were subsequently interpolated across the study domain using GIS software to generate spatially continuous surfaces. Climate indices, by contrast, required daily rather than monthly data. In addition to temporal gaps, instances of which

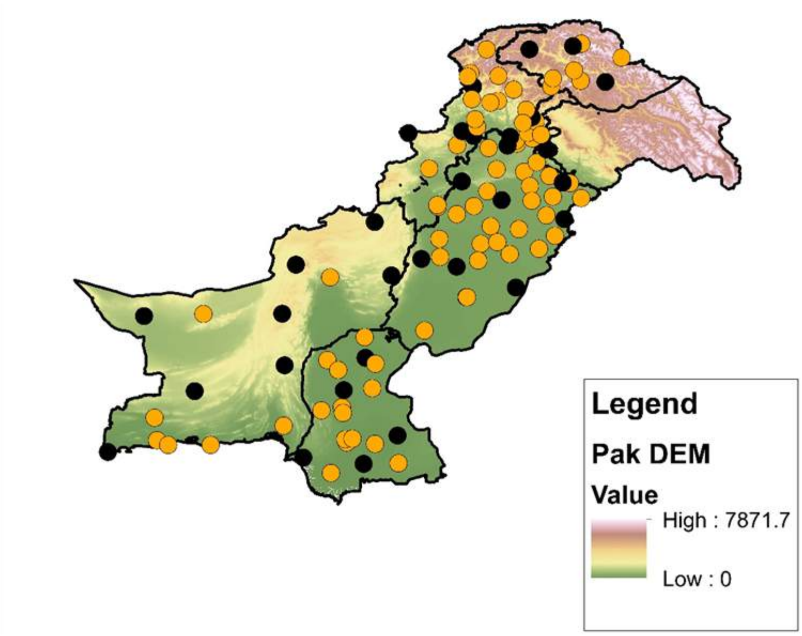



*Figure 1: Locations of stations used in this study. Yellow filled dots represent stations with monthly data, while black filled dots represent stations with data at both daily and monthly temporal scales. Topography (m) of the country is shown in the background.*

**Table I.** Names and coordinates of meteorological stations used in this study.

| Sr. No. | Station | Lat (°) | Lon (°) | Elevation (m) | Sr. No. | Station | Lat (°) | Lon (°) | Elevation (m) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Astore | 35.34 | 74.90 | 2167 | 34 | Khuzdar | 27.83 | 66.63 | 1231 |
| 2 | Badin | 24.63 | 68.90 | 10 | 35 | Kohat | 33.57 | 71.43 | 510 |
| 3 | Bahawalnagar | 29.95 | 73.25 | 161 | 36 | Kotli | 33.52 | 73.90 | 613 |
| 4 | Bahawalpur | 29.40 | 71.78 | 116 | 37 | Lahore A/P | 31.52 | 74.40 | 215 |
| 5 | Balakot | 34.38 | 73.35 | 980 | 38 | Lahore PBO | 31.52 | 74.40 | 213 |
| 6 | Bannu | 33.00 | 70.10 | 406 | 39 | Larkana | 27.53 | 68.20 | 174 |
| 7 | Barkhan | 29.88 | 69.72 | 1097 | 40 | Lasbela | 26.23 | 66.12 | 88 |
| 8 | Benazirabad | 26.25 | 68.37 | 37 | 41 | Mianwali | 32.55 | 71.55 | 210 |
| 9 | Bunji | 35.67 | 74.63 | 1372 | 42 | Mohenjo-daro | 27.37 | 68.10 | 52.1 |
| 10 | Cherat | 33.82 | 71.88 | 1301 | 43 | Multan | 30.20 | 71.43 | 122 |
| 11 | Chhor | 25.52 | 69.18 | 5 | 44 | Murree | 33.85 | 73.41 | 2167 |
| 12 | Chilas | 35.67 | 74.10 | 1250 | 45 | Muzaffarabad | 34.25 | 74.04 | 701 |
| 13 | Chitral | 35.85 | 71.83 | 1499 | 46 | Nokkundi | 28.82 | 62.75 | 682 |
| 14 | Dalbandin | 28.88 | 64.40 | 848 | 47 | Ormara | 25.42 | 64.62 | 2 |
| 15 | D.I. Khan | 31.82 | 70.92 | 173 | 48 | Padidan | 26.85 | 68.13 | 46 |
| 16 | Dir | 35.20 | 71.85 | 1369 | 49 | Parachinar | 33.87 | 70.08 | 1725 |
| 17 | Drosh | 35.57 | 71.78 | 1464 | 50 | Pasni | 25.47 | 63.48 | 4 |
| 18 | Faisalabad | 31.43 | 73.10 | 183 | 51 | Peshawar | 34.02 | 71.58 | 359 |
| 19 | Garhi Dupatta | 34.12 | 73.62 | 812 | 52 | Panjgur | 26.97 | 64.10 | 980 |
| 20 | Gilgit | 35.92 | 74.33 | 1459 | 53 | Quetta | 30.25 | 66.88 | 1600 |
| 21 | Gupis | 36.17 | 73.40 | 2155 | 54 | Quetta (Sh.M) | 30.18 | 66.95 | 1625 |
| 22 | Hyderabad | 25.38 | 68.42 | 40 | 55 | Rawalpindi | 33.60 | 73.04 | 508 |
| 23 | Islamabad | 33.74 | 73.06 | 543 | 56 | Risalpur | 34.07 | 71.98 | 315 |
| 24 | Islamabad A/P | 33.65 | 73.08 | 508 | 57 | Rohri | 27.70 | 68.90 | 66 |
| 25 | Jacobabad | 28.30 | 68.46 | 55 | 58 | Saidu Sharif | 34.73 | 72.35 | 961 |
| 26 | Jhelum | 32.93 | 73.72 | 232 | 59 | Sargodha A/B | 32.05 | 72.67 | 187 |
| 27 | Jiwani | 25.37 | 61.80 | 56 | 60 | Shorkot | 30.78 | 72.10 | 150 |
| 28 | Kakul | 34.18 | 73.25 | 1308 | 61 | Sialkot | 32.50 | 74.53 | 251 |
| 29 | Kalat | 29.03 | 66.58 | 2015 | 62 | Sibi | 29.55 | 67.88 | 133 |
| 30 | Kamra | 33.87 | 72.40 | 303.3 | 63 | Skardu | 35.30 | 75.68 | 2317 |
| 31 | Karachi A/P | 24.90 | 67.17 | 21 | 64 | Sukkur | 27.80 | 68.70 | 58 |
| 32 | Karachi (Faisal) | 24.88 | 67.12 | 6 | 65 | Turbat | 25.98 | 63.07 | 155 |
| 33 | Khanpur | 28.65 | 70.68 | 87 | 66 | Zhob | 31.35 | 69.47 | 1405 |

were identified in the processing of the monthly data, the daily data bore the spatial density gap due to its limited available volume. The daily data was therefore reconstructed over grids after routing it through the other aforementioned quality control procedures. This data was thereafter interpolated at 0.5-degree grid resolution and was subsequently extended to the year 2025 by appending it to the Cressman Interpolated High-Resolution Gauge-Based Gridded Observations (CIHGGO) which originally comprised the period 1980-2018, thus spanning 46 years.

The Cressman Interpolation method[11] [12] helps filling data gaps by generating estimated values through objective analysis. Additionally, interpolating station data into gridded form rearranges the data by assigning a representative value to each grid cell, thereby enabling the maximum possible number of stations to contribute to the analysis.

Several types of analyses were performed in this report. With the help of monthly long-term climatic date, the following analyses were performed. 1) Spatial representation of temporal trends in Tmax, Tmin, PR and fog on monthly basis. 2) Spatial representation of temporal trends in Tmax, Tmin, PR and fog on seasonal basis. 3) Spatial representation of composites in Tmax, Tmin, PR and fog in two 20-year periods (2001-2020 minus 1981-2000) on monthly basis. 4) Spatial representation of composites in Tmax, Tmin, PR and fog in two 20-year periods (2001-2020 minus 1981-2000) on seasonal basis. 5) Provincial and sub-provincial scale, spatially averaged temporal trends in Tmean, Tmax, Tmin and PR on annual basis.

In addition to analyses performed on Tmean, Tmax, Tmin, PR and fog, some extreme climate indices derived from daily climatic data were also computed and analysed using locally customized thresholds. The 0.5-degree grid-resolution CIHGGO dataset that integrates quality-controlled data of 31 stations at daily scale for Tmean, Tmax, Tmin and PR was used for the computation of these extreme climate indices. Table II represents the titles of computed indices with their aliases, definitions and calculation thresholds.

11 Cressman, G. P. (1959). An operational objective analysis system. Monthly Weather Review, 87(10), 367-374.

12 Burhan, A., Bukhari, A., & Cheema, B. (2019). Generation of Cressman Interpolated High-resolution Gauge-based Gridded Observations (CIHGGO) for climatic variables using in-situ data over Pakistan. Eur. J. Sci. Explor, 2(4), 7.

**Table II. Aliases, definitions and set thresholds of the extreme climate indices analysed in this study.**

| Sr. No. | Extreme Climate Index | Definition | Comments |
|---|---|---|---|
| | | **Temperature-based Indices** | |
| 1 | Diurnal Temperature Range (DTR) | Diurnal temperature range: Tmax - Tmin, daily mean over a year. | - |
| 2 | Cooling Degree Days (CODED) | max (0, Tmean–Threshold) | Threshold is set at 18 degrees Celsius |
| 3 | Heat Wave Events (HW) | Tmax threshold sustains or gets warmer for at least two consecutive days in a year | Tmax threshold is set at +6.5 degrees Celsius above Tmax normal |
| 4 | Warm Nights > 30°C (TR30) | Number of tropical nights in a year when Tmin > Threshold | Tmin threshold is set at 30 degrees Celsius |
| 5 | Hot Days > 40°C (SU40) | Number of summer days in a year when Tmax > Threshold | Tmax threshold is set at 40 degrees Celsius |
| | | **Precipitation-based Indices** | |
| 6 | Consecutive Wet Days (CWD) | Maximum number of consecutive days in a year with PR ≥ Threshold | Threshold is set at 01 mm |
| 7 | Simple Daily Intensity Index (SDII) | Total precipitation / Number of wet days | Wet day threshold is set at 01 mm |
| 8 | Mean 5-day Cumulative Precipitation (Rx5day) | Highest 5-day consecutive precipitation total in a year. | - |
| 9 | Precipitation ≥ 150 mm in One Day | Number of days when daily precipitation is ≥ Threshold | Threshold is set at 150 mm |
| 10 | Consecutive Dry Days (CDD) | Maximum number of consecutive days with PR < Threshold | Threshold is set at 01 mm |

All trends calculated from the time series data were run through non-parametric Mann Kendall test to identify significant trends in the engaged time series data. Slopes of the trends are determined via Sen's slope estimate which is a robust technique with less sensitivity to outliers[13]. The test cuts down reliance on the assumption that the data should follow a normal distribution in order to apply a significance test. The test was also applied to gridded trends to identify grids with significant slopes.

13 Chervenkov, H., & Slavov, K. (2019). Theil-Sen estimator vs. ordinary least squares-trend analysis for selected ETCCDI climate indices. Comptes Rendus Acad. Bulg. Sci, 72, 47-54.

# 3. RESULTS

## 3.1 CLIMATOLOGY OF TEMPERATURE AND PRECIPITATION

### 3. 1. 1. Maximum Temperature

The Tmax climatology presents heterogeneous patterns of spatially distributed day time temperature bins that fall to as low as 0.0-5.0 degrees, prevailing over the high-altitude northern regions during the months of January, particularly over the eastern extents of the region. Similar cold prevailing patterns are also revealed in February and December whose spatial extents are similar to those observed in January, yet with warmer magnitudes of mean Tmax encapsulating larger domain towards the eastern realms. During these cold months, the southern, and particularly the south most regions of the country are dominated with higher degrees of the Tmax with monthly climatology of 25.0-30.0 degrees, normally. This pattern of warm intensifies during March that signals 35.0+ degrees of Tmax over the south east extents of the country. Warming patterns further aggravate along April that features expansion of the 35.0-40.0 degrees bin of the Tmax and further invites the 40.0+ degrees of temperature thresholds over the southern extents of the country.

The month of May instils extended warming that protrudes to higher latitudes, particularly encompassing southeast extents of the country. As per Köppen Climate classification map of Pakistan, the southeast extents are part of the desert hot climate which remain void of any significant rains in the winter season. The month of June further extends 40.0+ degrees of Tmax bin to even higher latitudes and further towards western longitudes, thereby encompassing major realms of the country. During this month, even the high-altitude regions experience Tmax beyond 35.0 degrees which attributes to significant melting of snow and glaciers during this month. With the inception of monsoon rains in the month of July, 40.0+ degrees of Tmax bins initiate retreat and remain confined to southern extents only. These extents retain their heat even during the monsoon season due to their high aridity and desert hot climate. Impacts of subseasonal cooling attributed to July rains persist during the month of August, which also contribute substantial rains to the monsoon season. The warmer echelons of the Tmax shooting beyond 40.0 degrees begin to depart from the south eastern extents of the country. This pattern of diminishing warmer echelons continues to plummet during the month of September with re-emergence of Tmax bins lying below 30.0 degrees in the south.

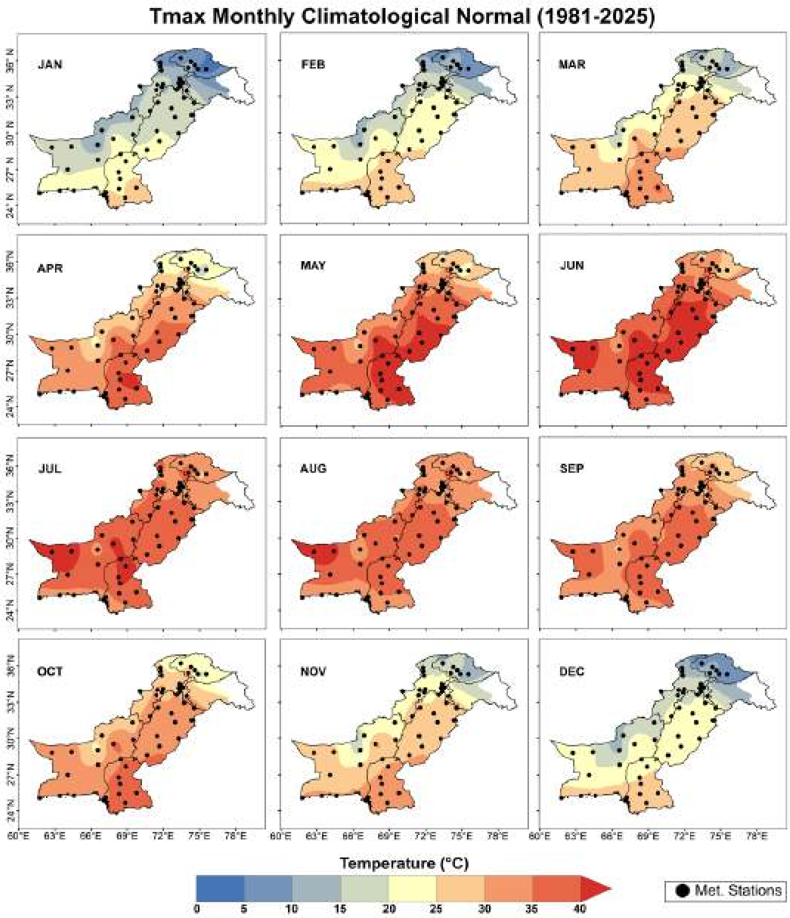



*Figure 2: Monthly climatology of maximum temperature (Tmax) over Pakistan for the period 1981-2025, with each panel corresponding to the month of a year, expressed in °C. Dots indicate locations of engaged meteorological stations used in the analysis.*

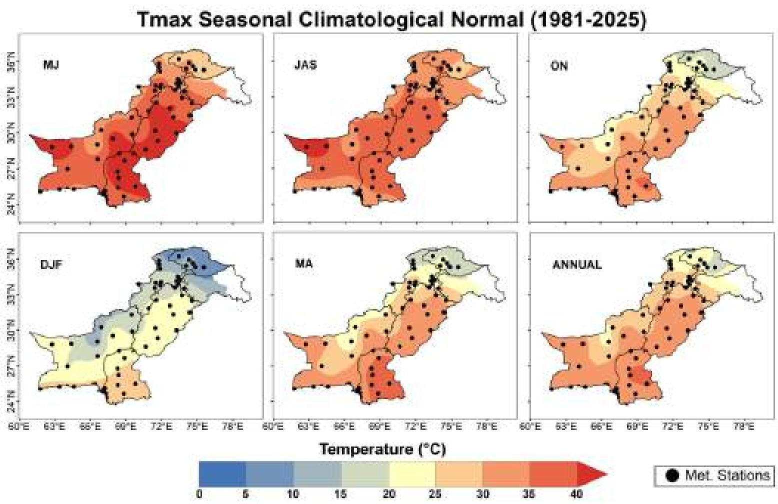



*Figure 3: Seasonal climatology of maximum temperature (Tmax) over Pakistan for the period 1981-2025, with each panel corresponding to the season of a year, expressed in °C. Dots indicate locations of engaged meteorological stations used in the analysis.*

It is pertinent to mention here that due to glacier cover and permafrost regions in the north, patterns of cooler Tmax bins remain apparent in the region throughout the year, though with smaller expansion in coverage. This cooler Tmax further recedes in magnitude and attain below 20.0 degrees in the north whilst sustaining the 35.0+ degrees intact in the south during October, thereby creating sharp Tmax gradients along the spatial expanses of the country. The month of November further extends cooler Tmax bins to lower latitudes and bring the daytime temperatures down to as low as 20.0 degrees. Moreover, Tmax further cools down to below 10.0 degrees in the high-altitude region during the month of December.

### 3. 1. 2. Minimum Temperature

December and January are seen as the coldest months, climatologically, whose mean Tmin could go as low as -10.0 degrees over the northbound and westbound high-altitude regions of the country. Even in the presence of such cool Tmin over one side of the domain, the southern extents simultaneously exhibit contrastingly warmer Tmins with magnitudes exceeding 10.0 degrees during

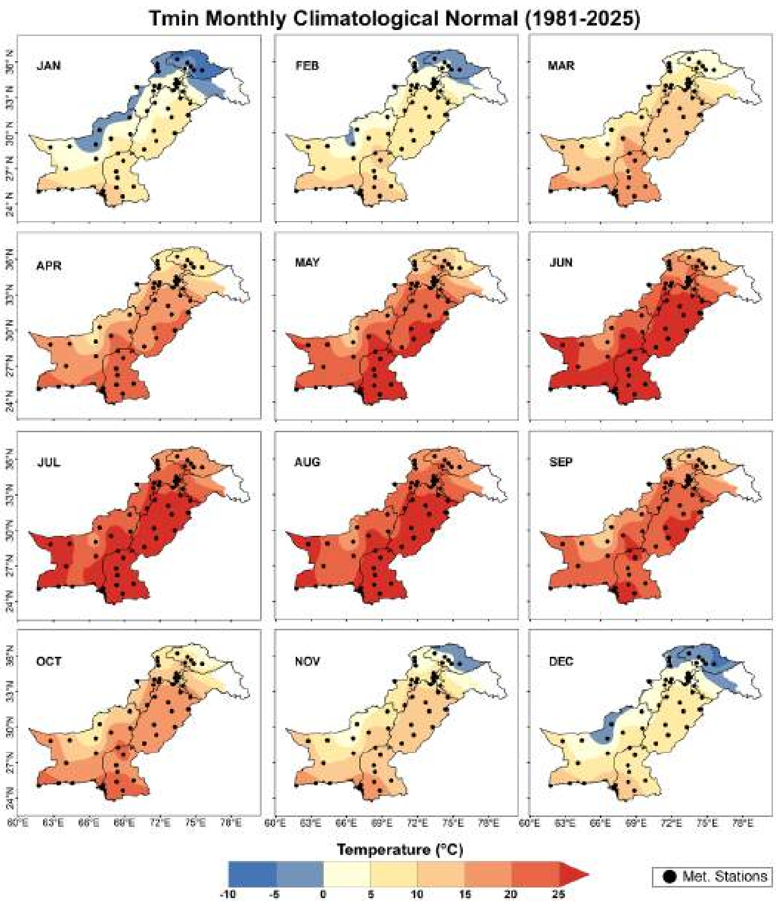



*Figure 4: Monthly climatology of minimum temperature (Tmin) over Pakistan for the period 1981-2025, with each panel corresponding to the month of a year, expressed in °C. Dots indicate locations of engaged meteorological stations used in the analysis.*

these months. This is particularly due to the impact of oceans along the south that remain warmer in winter nights due to their high specific heat capacity, than their land surface shoreline counterparts that span along the coastal belt of the country. Normal climatology in February maintains sub-zero Tmin bins in the North but with smaller magnitude and spatial expanse as compared to the preceding months.

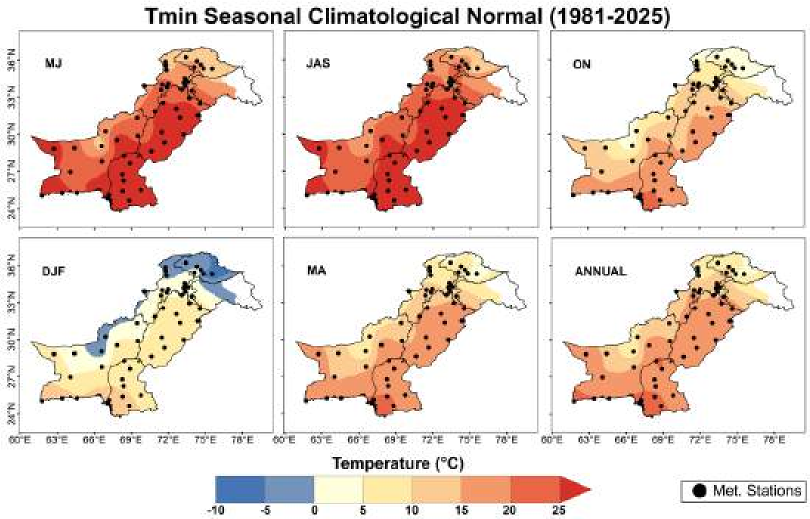



*Figure 5: Seasonal climatology of minimum temperature (Tmin) over Pakistan for the period 1981-2025, with each panel corresponding to the season of a year, expressed in °C. Dots indicate locations of engaged meteorological stations used in the analysis.*

March departs the sub-zero Tmin and induces warmer night-time temperatures that begin to root from the southern extents and start protruding towards the higher latitudes of the country. Tmin get strengthened in April, particularly in the south, thereby converging to night time temperatures beyond 20.0 degrees. With the departure of the spring, May arrives with even warmer Tmin encouraging the advent of 25.0+ degrees of mean night time temperature for the first time in the year. It is pertinent to mention here that the Expert Team on Climate Change Detection and Indices (ETCCDI) declares the Tmin beyond the 20.0 degrees threshold as tropical nights which is a key climate change indicator highlighting night-time heat stress associated with health impacts and triggering of heatwaves. Extension of these scorching night time temperatures is normally seen in June where nearly all stretches of the country experience these heat stressing Tmins during the month. Even with the arrival of monsoon in July, no relief is granted in the stretches of the night time temperature during the month. Instead it further aggravates normally. This is partially due to apparent increase in relative humidity during the month that in turn increases heat index. The heat index, due to its inclusion of moisture availability in the atmosphere, renders the night time temperatures to remain stable and restricts them to cool down, creating very small gradients in the diurnal temperatures during the month. August sees the similar patterns, however with smaller extensions of 25.0+ degrees in the southwest. With the departure of the monsoon and the fuelled-up moisture with it, the month of September reverts to patterns similar to those of May, confining the 25.0+ degrees of minimum temperatures to isolated pockets towards the eastern extents of the domain only.

With the advent of the fall season, October emerges with cooler temperatures, particularly in the north, with Tmin significantly converging to zero degrees during the month. Nevertheless, the north to south gradient of the Tmin persists that still renders the south to experience 20.0+ degrees of night time temperature during the month. Thereafter, for the second time in the year, November emerges with recurrence of sub-zero night time temperatures in the north, still holding the 20.0+ degrees of minimum temperature gradient from the south. With the ending of the calendar year, December reiterates the patterns of January and renders the Tmin to plummet below -5.0 degrees in the north. The exclusive residence of such sub-zero minimum temperatures towards the north and the western extents of the country may be attributed to recurrent approaches of rain and snow bearing westerly systems over these regions. Attributed to land use and land cover properties of these regions, which mostly comprises of barren land, rocks and glacier, the cold impact of albedo triggered land surface temperature to the planetary boundary layer rapidly infuses with the atmospheric temperature in winter which quickly cools down the night time temperature via rapid emission of longwave radiation.

### 3. 1. 3. Precipitation

The overall water availability to the country is through two dominant weather systems in the region. One is triggered through western disturbance, usually found at 500 hPa heights while the other is through south-westerly systems that originate from the sea surface pressure anomalies of the Mascarenes and are directed towards the subcontinent via Somali Jets. These systems thereafter make entrance in the country via south coast and via currents diverted through Bay of Bengal to the eastern border and finally, in to the country. Together these systems maintain an annual water budget of 175 billion cubic meters across the country.

Of all the monthly bifurcation of precipitation climatology, the 31-35 degrees of latitude remains the dominant source of precipitation recurrences which is seen evident in the mean. January is blessed with both snowfalls in the north and rainfall in the rest of the country, reaching to magnitudes between 50-100 mm, normally. February supplements this magnitude by maintaining a normal of up to 150 mm during the month. March is protracted with extended ranges of precipitation, dominant over the northwest extents, which includes both solid and liquid forms of precipitation, most prominent over the high-altitude regions. Of the climatological peaks attained by precipitation of the high-altitude regions, one is triggered along the winter months whose climatological depth of water availability is higher as compared to the rest of the regions during these months. However, this portion of the budget mainly comprises of frozen water that liquefies during the following spring and summer months.

April draws back precipitation magnitude and extent virtually to the precipitation state observed in February, however, under warmer temperature conditions that are attributed to occasional occurrences of heatwaves across the country. May is relatively drier, due to which temperatures

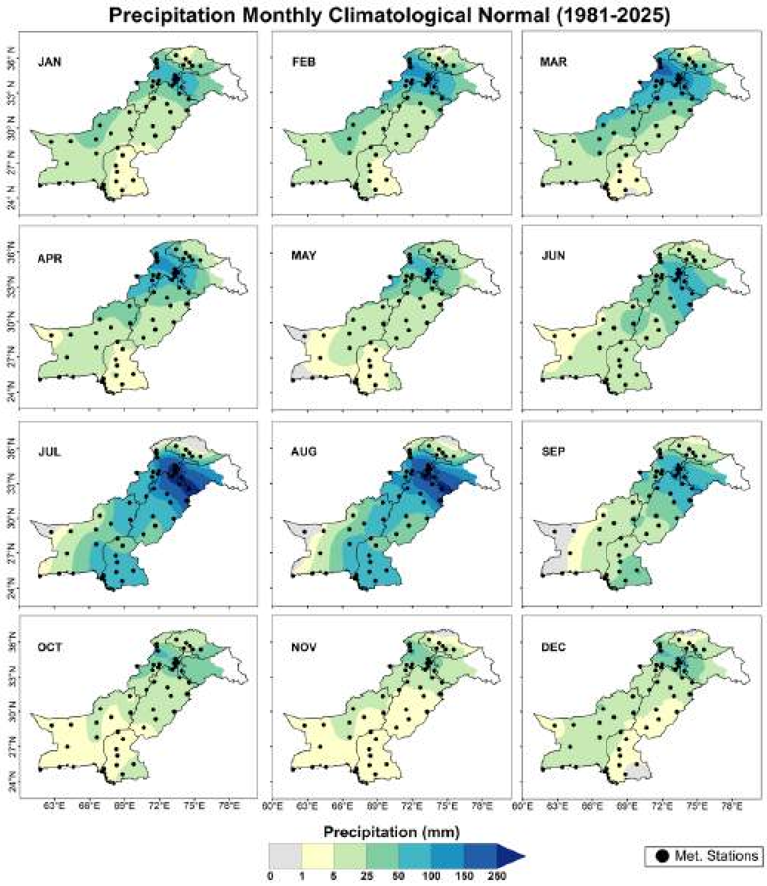



*Figure 6: Monthly climatology of precipitation (PR) over Pakistan for the period 1981-2025, with each panel corresponding to the month of a year, expressed in mm. Dots indicate locations of engaged meteorological stations used in the analysis.*

further aggravate during this month. The month of June arrives with both pre-monsoon and monsoon rain spells that concentrate their focus over the monsoonal domain of the country. The mean arrival or onset of monsoon is July 1, with 12 days of standard deviation. This means historically it has approached quite a few times in the month of June attributed to which a prominent reversal of winds in the core monsoon region transitioning from May to June is seen. This reversed pattern of precipitation originating from east to northwest has its angle of influence particularly moulded with the presence of the low pressure systems as well as with the obstructions faced through the high-altitude extents of the Himalayas. This unique pattern converges the precipitation maxima to the core monsoon region with intermediate rainfall patterns to the south during the month of July. The month of August redeems signals from the month of July and present similar patterns of normal August precipitation up to the extents of the monsoon domain. September being the departure month of monsoon significantly curtails down on precipitation extents, particularly towards the southern reaches thereby signalling the withdrawal of monsoon. It is of interest to note here that both urban and riverine floods usually occur between these monsoon months as they hold the major share summing to more than 60% of the overall precipitation receipt in the country, annually. Precipitation spells falling over the Indus take up to 422 hours (17.5 days approx.) to reach the extreme southern extents if originated from the extreme northern extents of the country. Attributed

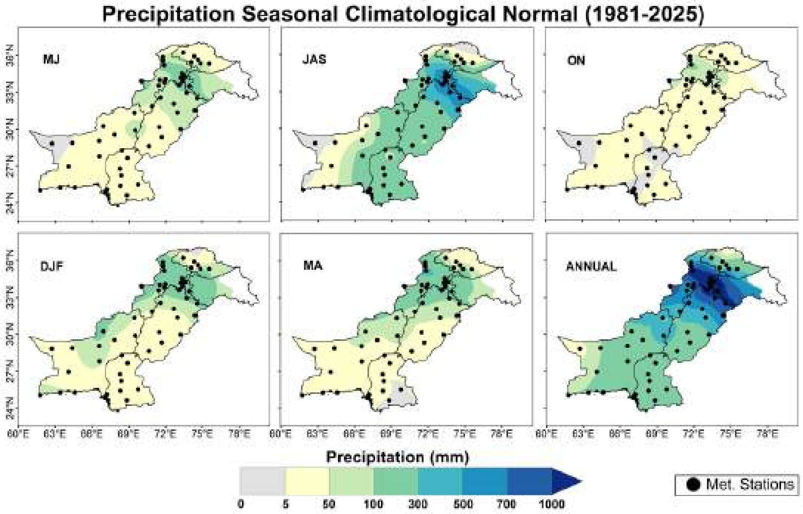



*Figure 7: Seasonal climatology of precipitation (PR) over Pakistan for the period 1981-2025, with each panel corresponding to the season of a year, expressed in mm. Dots indicate locations of engaged meteorological stations used in the analysis.*

to dynamically triggered atmospheric anomalies and their resultant impacts on normal precipitation amounts, longer break phases in monsoon spells could trigger larger lag times and consequent water deficit across the region.

The month of October, being the inception of fall season suppresses monsoon currents and re-establishes the western dominant rainfall pattern through reversal of winds. November instigates snowfall over the northeastern regimes and declares arrival of winter season. This snow fall pattern extends down further to high-altitude regions of the lower latitudes of the southwestern extents, thereby signalling arrival of full fledge winter dominated month of December.

### 3. 1. 4. Fog

The purpose to see fog climatological patterns is to establish attributions related to the deviations in temperature phenomenon. The fog is normally a winter phenomenon which establishes its presence whenever atmospheric inversion takes place. The atmospheric inversion is a process in which temperature of the troposphere is impacted by two cold columns of air separated by a warmer column of air, thereby restricting conditions conducive of forming convective updrafts. January is particularly dominant in presenting this pattern where more than 10 fog days are seen each year normally. The core of the fog appearance is towards the eastern plains of the country. February maintains the pattern but diminishes the magnitude by curtailing down the frequency to less than 5 days, normally. Furthermore, foundation of a unique pattern at the southwest coast is seen that emerges in February and continues to dwell till May, along the year. This pattern indicates an up to 5 days of fog days normally. Although such fog appearances are not very significant yet their isolated emergence calls for investigation of the fact. It appears that the fog over the coastal region is the extension of sea fog which is formed due to temperature gradient of warmer ocean

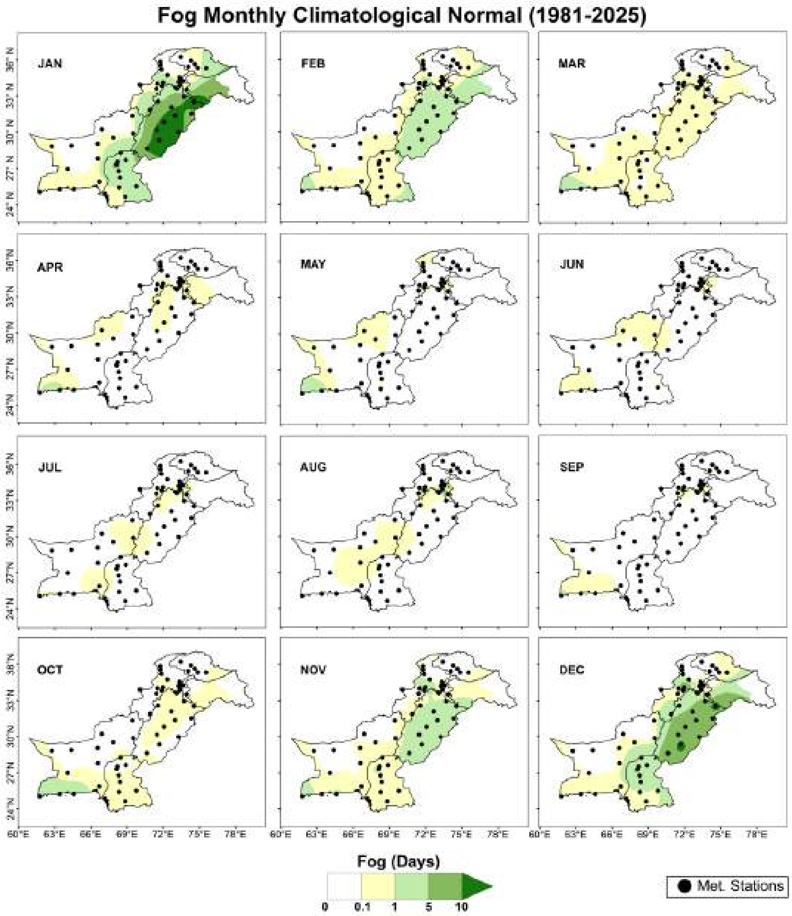



*Figure 8: Monthly climatology of fog (days) over Pakistan for the period 1981-2025, with each panel corresponding to the month of a year, expressed in days. Dots indicate locations of engaged meteorological stations used in the analysis.*

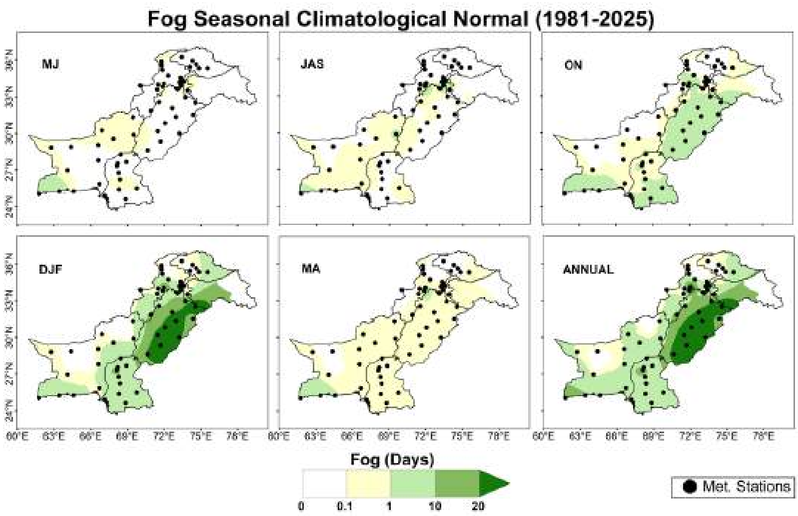



*Figure 9: Seasonal climatology of fog (days) over Pakistan for the period 1981-2025, with each panel corresponding to the season of a year, expressed in days. Dots indicate locations of engaged meteorological stations used in the analysis.*

waters and relatively cooler gradients of coastal waters immediately annexed with cooler land surfaces of the shoreline along the southwest coast. This pattern diminishes when the temperature gradients between ocean and land reduces during the months of June, July and August. However, it reappears in September when gradients once again start to strengthen during September October and November. The month of November once again sees the inception of advection fog over the eastern plains that strengthens in magnitude and extends towards the south east extents during the month of December.

## 3.2 TRENDS ON MONTHLY BASIS

### 3. 2. 1. Maximum Temperature

Figure 10 illustrates monthly trends in maximum temperature (Tmax) across Pakistan from 1981 to 2025. The analysis covers all months of the year and presents trends in °C per decade. The observed range spans from moderate cooling of less than -0.5°C per decade to strong warming exceeding +0.9°C per decade across different months and regions.

Overall, a clear seasonal structure emerges. From February to April, a strong and widespread warming signal dominates most of Pakistan. February and March, in particular, exhibit intense and spatially extensive warming across GB, AJK, KP, Punjab, Balochistan, and Sindh. The strongest warming during these months is consistently observed in Balochistan. April continues this warming tendency across GB, KP, Punjab, Balochistan, and Sindh, although with fewer areas showing statistically significant increases.

From June to September, the pattern shifts, and cooling trends emerge over notable extents of the country, including parts of GB, KP, Sindh, and Punjab. However, these cooling signals coexist with localized warming trends reaching up to approximately +0.3°C per decade, indicating strong spatial heterogeneity. June stands out as the month with the most widespread cooling, particularly across central and eastern Pakistan, with statistically significant decreases over KP, adjoining areas of Balochistan with KP, Sindh, and Punjab. Cooling signals are less extensive in July, August, and September, although localized decreasing trends remain evident in parts of GB, KP, and Punjab.

The southern regions of Pakistan, particularly Sindh and southern Balochistan, consistently exhibit increasing Tmax trends from February through May. Warming is especially pronounced in February and persists through March and April, with several areas showing statistically significant trends. This sustained warming raises important concerns regarding heat stress, water demand, and agricultural impacts in these vulnerable regions.

October marks a partial resurgence of warming, particularly in western Pakistan and especially in Balochistan. Although weaker than the strong springtime warming, these trends are statistically significant. November, marking the onset of winter, shows a shift toward cooling across much of the country; however, these cooling trends are generally not statistically significant. December presents a

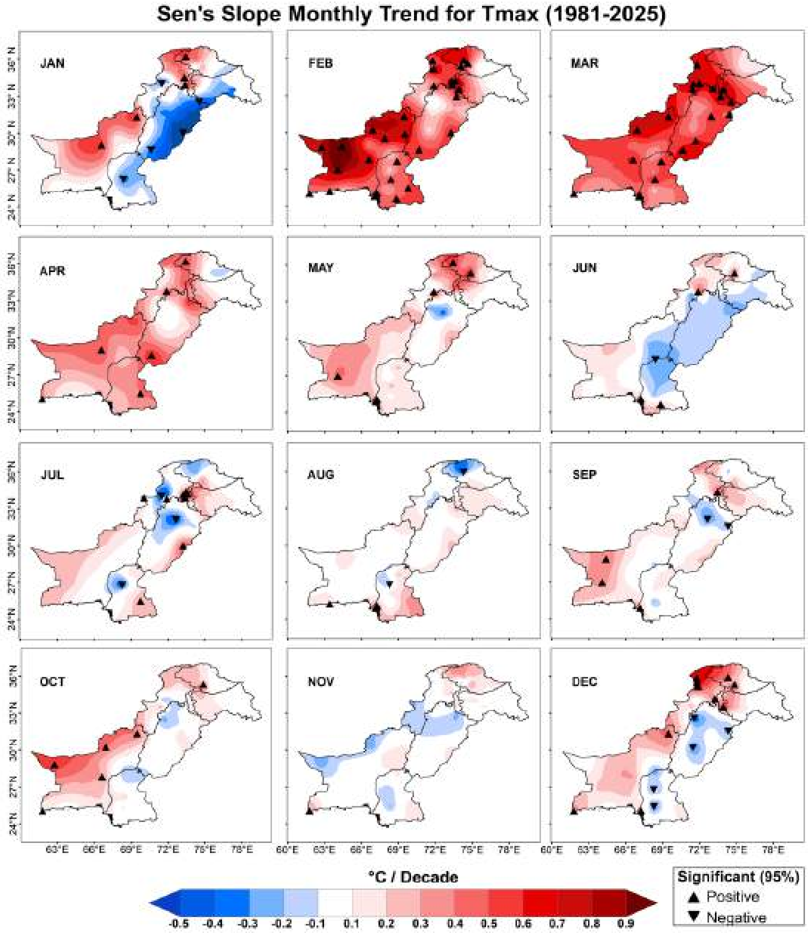



*Figure 10: Monthly trends in maximum temperature (Tmax) over Pakistan for the period 1981-2025, with each panel corresponding to the month of a year. The trends are expressed in °C per decade. Arrow heads indicate statistically significant trends at the 95% confidence level.*

mixed spatial pattern; warming is observed in northern regions, particularly over GB, AJK, Balochistan, and KP (with statistical significance), while Punjab and Sindh show cooling tendencies during the same period.

Notably, certain regions consistently show warming across multiple months. Northern KP, GB, and parts of northern Punjab show consistent warming during February, March, April, and December. In contrast, southern Sindh and Balochistan display sustained warming from February through October. Conversely, GB, eastern Punjab, and parts of KP experience recurring cooling trends during June to September and again in November.

In terms of magnitude, warming peaks above +1.0°C per decade in several regions during spring (February-April), whereas the strongest cooling approaches -0.6°C per decade, most notably in June and in parts of the winter months (November-December). The observed trends during February to April for warming and June for cooling are robust and are not due to random variability.

## 3. 2. 2. Minimum Temperature

Figure 11 illustrates monthly trends in Tmin across Pakistan from 1981 to 2025. The analysis covers all months of the year and presents decadal changes in the Tmin. The observed range spans from modest cooling of less than -0.2°C per decade to significant warming exceeding +0.5°C per decade. Several regions also exhibit statistically significant trends, indicating that the observed changes are unlikely to be due to random variability.

Overall, the spatial patterns indicate a clear nationwide tendency toward increasing Tmin, particularly across southern and central Pakistan. This warming is most pronounced and

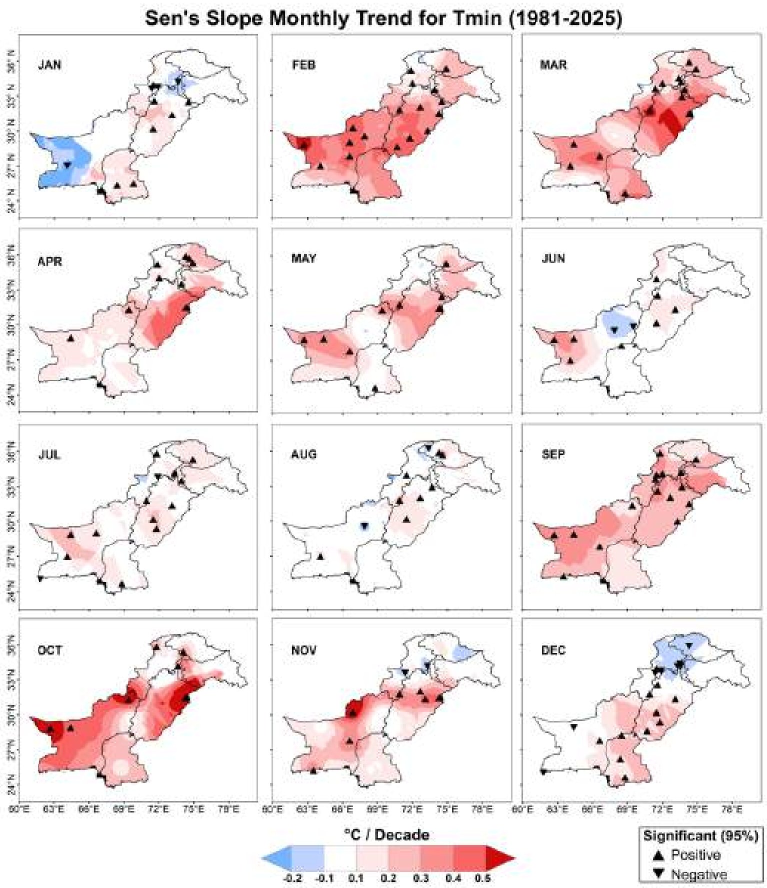



*Figure 11: Monthly trends in minimum temperature (Tmin) over Pakistan for the period 1981-2025, with each panel corresponding to the month of a year. The trends are expressed in °C per decade. Arrow heads indicate statistically significant trends at the 95% confidence level.*

widespread from February through November, with strong and persistent increases in Sindh, southern Punjab, and western Balochistan. In these regions, warming often exceeds +0.5°C per decade and bears statistical significance, reflecting robust shifts in night-time temperatures. The signal is especially strong in February, March, April, October, and November, when most of the country, except parts of the north, exhibits consistent warming.

In contrast, northern Pakistan, including GB, northern KP, upper Balochistan, and parts of northern Punjab, shows localized cooling during certain months. This is most evident in January, August, and December, with the strongest cooling (below -0.2°C per decade) occurring in December and January. Some of these cooling trends are statistically significant, indicating robustness despite their limited spatial extent.

The rest of the country, particularly central Pakistan, including Punjab, parts of KP, and southern Balochistan, shows a persistent warming signal throughout most of the year. From March to November, warming in these regions is not only widespread but also statistically significant in many areas. The strongest increases are generally observed in southern Punjab and Sindh.

A month-by-month perspective further clarifies these patterns. January shows mild warming in southern and central Pakistan alongside cooling in northern regions. February marks the onset of stronger and more extensive warming, particularly in Sindh and Punjab. March and April are characterized by intense and widespread warming across nearly all provinces and regions. In May and June, warming continues, although localized cooling pockets emerge in parts of western Pakistan. From July to September, widespread warming persists, although high-altitude areas of the Hindu Kush-Himalayan region continue to show slight cooling during July and August. In October and November, nearly the entire country experiences significant warming. December, however, shows a reversal in northern and western regions, with statistically significant cooling, while southeastern Pakistan continues to warm.

Outside the winter season, the most consistently warming regions include Sindh, southern Punjab, and western Balochistan. These areas exhibit statistically significant warming in nearly every month, indicating a sustained increase in night-time temperatures. In contrast, northern Pakistan, particularly GB, shows recurrent cooling during winter and parts of the monsoon season, especially in August.

The magnitude of these trends underscores their climatic significance. Warming frequently exceeds +0.4°C per decade across southern and central Pakistan, reaching close to +0.5°C per decade in some locations. By comparison, cooling trends in the north are less spatially extensive but can reach -0.2°C per decade, particularly during winter months.

### 3. 2. 3. Precipitation

Figure 12 illustrates monthly PR trends across Pakistan for the period 1981-2025. The analysis covers all months of the year and presents changes in total monthly PR, expressed in mm per decade. Each panel represents a specific month, with shaded gradients indicating spatial variations in long-term trends. The figure highlights both increasing and decreasing PR patterns, which are highly heterogeneous across space and time. It also identifies areas with statistically significant trends in both directions, indicating regions where observed changes are robust and unlikely to be the result of random variability.

A clear pattern of increasing PR emerges during the pre-monsoon and monsoon seasons, particularly from June to September. Positive trends are most evident across central and eastern Pakistan, including parts of GB, KP, Punjab, and Sindh. In June and September, these increases are especially pronounced and statistically significant, with PR rising by up to +10 mm per decade.

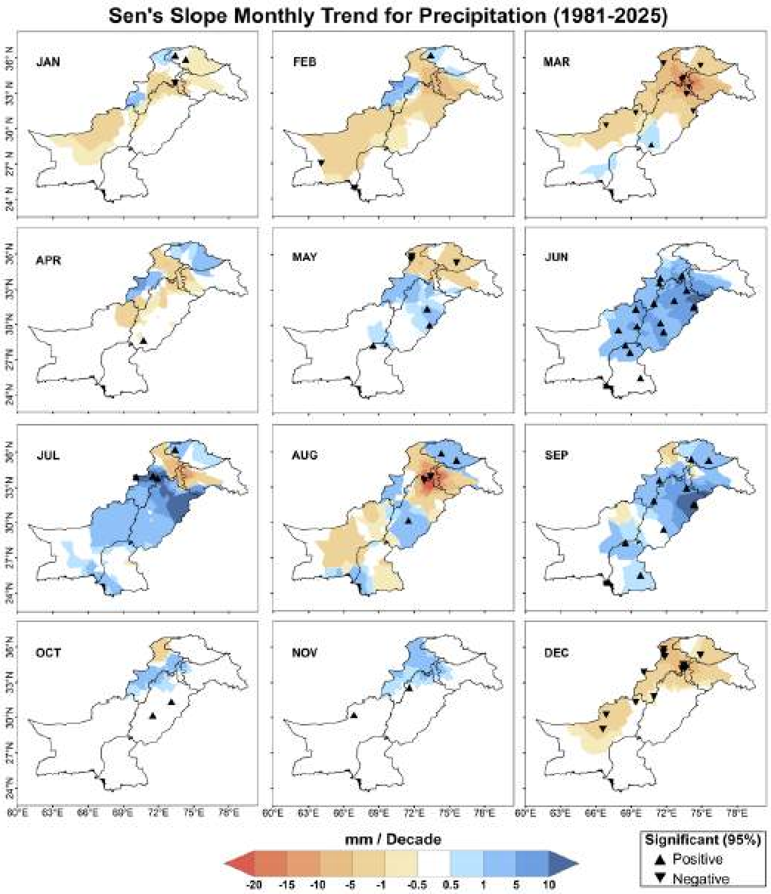



*Figure 12: Monthly trends in precipitation (PR) over Pakistan for the period 1981-2025, with each panel corresponding to the month of a year. The trends are expressed in mm per decade. Arrow heads indicate statistically significant trends at the 95% confidence level.*

July and August also show positive trends, although with relatively lower magnitudes and more limited spatial extent of statistical significance. Modest increases are also observed during transitional months such as March, April, October, and November; however, these trends are generally weak and rarely statistically significant.

In contrast, decreasing PR trends are observed in northern and northwestern Pakistan. Northern KP and parts of GB show declining precipitation during March, May, August, and December. These declines recede significantly below -20 mm per decade, particularly in upper Punjab and KP, where statistically significant decreases are most prominent. No substantial declines are observed during October and November.

Regions such as central and southeastern Punjab show relatively consistent positive PR trends throughout the monsoon season. These areas not only exhibit sustained increases in rainfall but also contain statistically significant zones during June and September. This could reflect an intensification of the monsoonal system or a shift toward heavier or more frequent PR events during these months.

As statistically significant trends are most visible in June and September, particularly over eastern and southeastern Pakistan, these represent reliable increases in pre-monsoon and post-monsoon rainfall over the country. On the other hand, March and December feature statistically significant decreases in the PR in the northern parts of the country, particularly towards the northern KP, suggesting a decrease in the approach of western disturbances towards this region in the pre-spring and winter season. Such spatial and seasonal distinctions indicate that the PR changes are becoming more intense but also more concentrated within a narrower seasonal window.

In terms of magnitude, the positive PR trends go higher than +10 mm per decade, particularly in areas like northern Punjab and northern Sindh during the core monsoon months. Negative trends go lower than -20 mm per decade, predominantly in northern areas during the winter, summer and early spring months. This evolving PR pattern suggests a shift of monsoon towards regions formerly associated with drier conditions, and consequently exhibit drier summers and winters in the core monsoon region.

# 3.3 TRENDS ON SEASONAL AND ANNUAL BASIS

## 3. 3. 1. Maximum Temperature

Figure 13 illustrates seasonal and annual trends in the Tmax across Pakistan from 1981 to 2025. The data is presented as decadal trends (°C per decade), with indication of both increasing and decreasing temperature trends. Different seasonal averages, MJ (May-June, pre-monsoon), JAS (July-September, monsoon), ON (October-November, post-monsoon), DJF (December-February, winter), MA (March-April, spring), and the annual mean present ample spatial variability within and amongst the analysed seasons. The trends bear support of statistical significance at certain spatial extents that indicate robustness in the trends of the analysed region.

A dominant warming trend is observed across most of the country, particularly during MJ, MA, DJF, and the annual mean. The MA panel shows the most widespread warming, with regions of the country experiencing temperature increases beyond +0.6°C per decade. This trend is statistically significant across all provinces, including vast areas of Balochistan, Sindh, Punjab, and KP, as well as GB and Azad Jammu and Kashmir (AJK). Similarly, DJF reveals strong warming trends in southern Balochistan and parts of KP, with values ranging from +0.1°C to as high as +0.5°C per decade. The annual trend also confirms persistent warming in most regions, especially in southwest of northern provinces and regions of Pakistan, where warming rates exceed +0.2°C per decade and are statistically significant over extensive zones.

The MJ shows a warming pattern. However, contrasting mixed trends are seen during JAS, where central and northern regions, including KP, Punjab, and GB, experience slight cooling, whereas

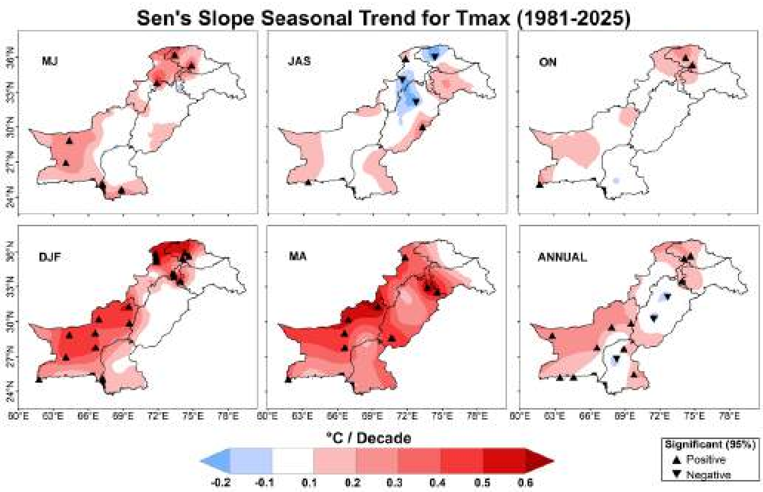



*Figure 13: Seasonal trends in maximum temperature (Tmax) over Pakistan for the period 1981-2025, with each panel corresponding to the season of a year. The trends are expressed in °C per decade. Arrow heads indicate statistically significant trends at the 95% confidence level.*

Balochistan and Sindh continue to warm. The ON shows a relatively milder warming signal in GB and Balochistan reflecting positive trends of around +0.3°C per decade.

Areas with consistently increasing Tmax throughout all seasons include southern Balochistan, parts of Sindh, KP and AJK region. These areas display warming in every season, with many zones reaching +0.6°C per decade. These trends are statistically significant in nearly all seasons, especially during MA, DJF, and the annual mean, indicating a robust and persistent warming signal over the entire country.

In terms of inter-seasonal comparison, MA emerges as the most uniformly warming season across all provinces, followed by DJF and the annual mean. Balochistan, AJK and Northern KP shows most consistent warming in every season, while Sindh exhibits similar but slightly smaller trends. Punjab reveals a more complex seasonal pattern, with warming in spring but mild cooling or neutral trends during the monsoon and post-monsoon periods.

### 3. 3. 2. Minimum Temperature

Figure 14 illustrates the decadal trends (°C/decade) in seasonal and annual Tmin across Pakistan from 1981 to 2025, representing different periods: the MJ, the JAS, the ON, the DJF, the MA and the annual mean. Overall, warming patterns dominate spatially in the analysed trends, whilst indicating notable extents of the cooled ones in the analysed variable. Trends are dominantly significant statistically and hence are indicative of robust warming and cooling in the Tmin along the analysed period.

The figure reveals a leading warming trend in the seasonal Tmin particularly along the ON and MA seasons with widespread statistical significance. Nearly the entire country, including Punjab, KP,

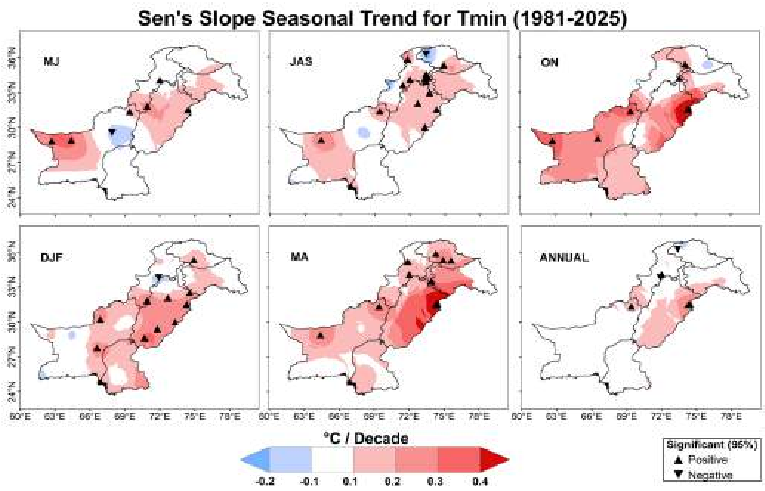



*Figure 14: Seasonal trends in minimum temperature (Tmin) over Pakistan for the period 1981-2025, with each panel corresponding to the season of a year. The trends are expressed in °C per decade. Arrow heads indicate statistically significant trends at the 95% confidence level.*

Balochistan, Sindh, GB and AJK, is experiencing decadal increases exhibiting a convergence of trends beyond 0.4°C per decade, indicating that the warming trends in the Tmin are not only widespread but also intense during the post-monsoon season.

In contrast, some localized cooling patterns appear during the MJ, the DJF and the JAS. Small pockets of central Balochistan, parts of KP and GB show negative trends, though the magnitude typically ranges between -0.1°C to -0.2°C per decade. These cooling zones are rarely statistically significant.

Regions consistently showing increasing Tmin across all seasons include eastern Punjab, western Balochistan, and large portions of KP. These areas display warming in most of the panels, and the trends are statistically significant in most seasons, especially in spring, post-monsoon, and annual mean. AJK also exhibits warming trends in most seasons, particularly during ON, MA, JAS and the annual average.

In terms of inter-seasonal comparison, spring and post-monsoon stand out as the seasons with most uniform and significant warming across Pakistan. Winter shows more spatial variability with some cooling pockets, particularly in Balochistan and KP. Monsoon exhibits mixed trends, with some cooling in northern and western regions but warming in the rest. Among provinces, Punjab, Balochistan and Sindh display most pronounced and consistent warming throughout the seasons. Punjab shows seasonal variability but with strong warming in ON and MA. KP and AJK follow a similar pattern, with clear warming during spring and post-monsoon, but with relatively neutral trends in DJF.

### 3. 3. 3. Precipitation

Figure 15 illustrates seasonal and annual precipitation (PR) trends, expressed as seasonal totals in mm per decade, across Pakistan from 1981 to 2025. Clear regions of increasing precipitation are evident over monsoon-influenced parts of the country, particularly during the pre-monsoon, monsoon, and annual periods. In particular, large areas of Punjab, central KP, upper Sindh, and parts of Balochistan exhibit notable upward trends, with increases of around 30 mm per decade. In some locations, especially central KP and northwestern Punjab in the annual analysis, these increases reach even higher values.

In contrast, decreasing precipitation trends are primarily concentrated in northern Pakistan, particularly northern AJK, upper KP, and parts of GB, especially during winter, spring, and on an annual basis. These regions show declines of up to -50 mm per decade, with the most pronounced reductions occurring during DJF and in the annual totals.

Several regions exhibit consistent multi-seasonal increases in precipitation. Notably, northwestern Punjab and parts of southern KP show persistent positive trends across the pre-monsoon, monsoon, and annual scales. This pattern suggests a sustained enhancement of moisture availability and a possible north-westward extension of monsoon-related precipitation regimes. Conversely,

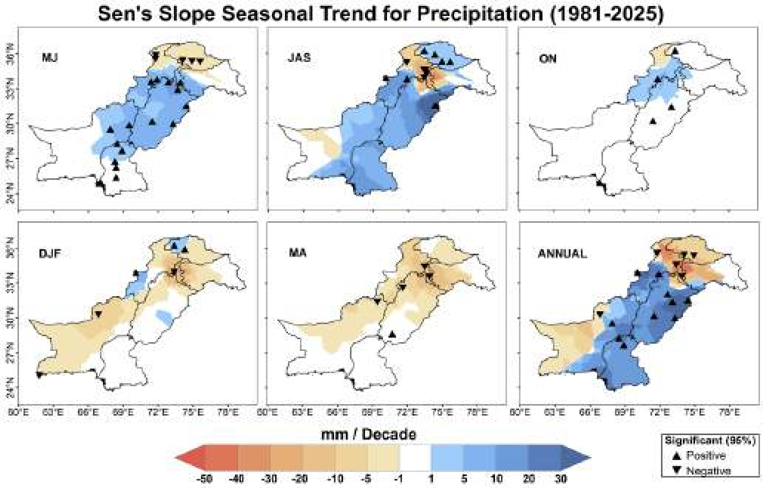



*Figure 15: Seasonal trends in precipitation (PR) over Pakistan for the period 1981-2025, with each panel corresponding to the season of a year. The trends are expressed in mm per decade. Arrow heads indicate statistically significant trends at the 95% confidence level.*

northern AJK, northwestern Balochistan, and GB display recurring negative trends across multiple seasons and in the annual mean, indicating a persistent drying tendency in the northern highlands.

Statistically significant trends are primarily concentrated in Punjab, southern KP, and parts of Sindh, particularly during the pre-monsoon, monsoon, and annual periods. These significant signals suggest robust climatic changes rather than random variability. The annual panel, in particular, highlights a broad corridor of significant positive trends across northwestern and eastern Pakistan, reinforcing the likelihood of increased frequency or intensity of high-magnitude rainfall events, especially those associated with the monsoon system. In contrast, the few statistically significant negative trends are confined mainly to northern and southwestern regions, including parts of AJK, GB, and upper KP, indicating meaningful reductions in winter and spring precipitation.

In terms of magnitude, the strongest increases are observed in monsoon and annual precipitation over northern Punjab, GB, and southern KP, suggesting a possible spatial redistribution of monsoon rainfall and a shift in its traditional core influence zones. Meanwhile, the most pronounced decreases occur in pre-monsoon precipitation in GB, indicating a gradual retreat or weakening of early-season rainfall activity in this region.

## 3.4 COMPOSITE CHANGES ON MONTHLY BASIS

### 3. 4. 1. Maximum Temperature

The monthly analysis of the Tmax composites between the periods 2001-2020 and 1981-2000 across Pakistan provides clear evidence of spatial and temporal heterogeneity in warming and cooling trends (Figure 16). This monthly breakdown reveals both consistent patterns and monthly specific changes, offering a detailed view of regional climate shifts.

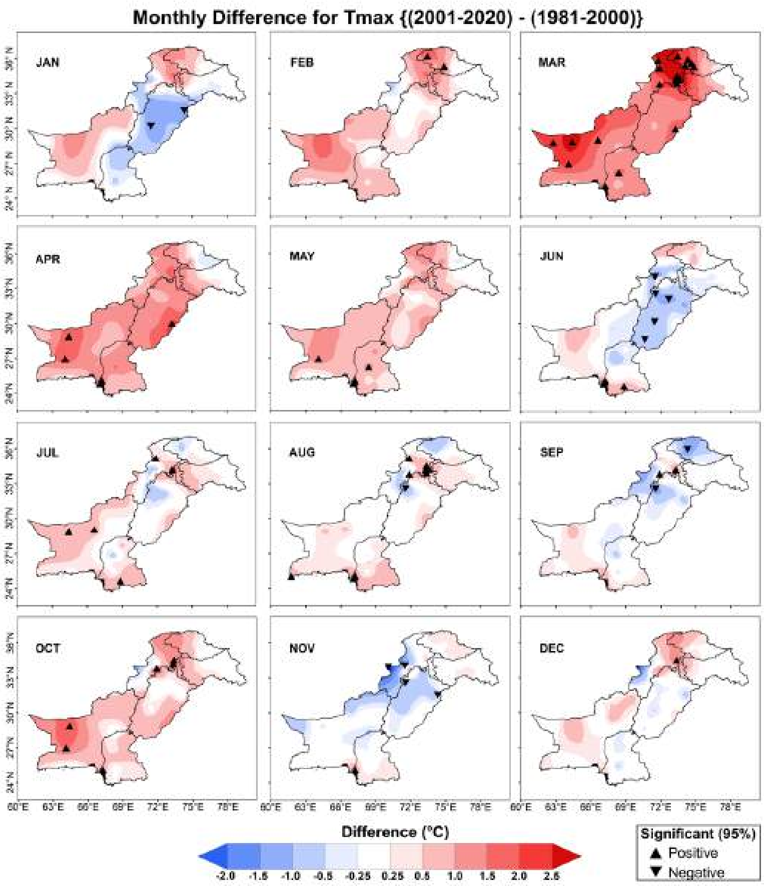



*Figure 16: Monthly composites in maximum temperature (Tmax) over Pakistan (2001-2020 minus 1981-2000). The composites are indicated in °C. Arrow heads indicate regions whose composites are statistically significant at the 95% confidence level.*

From February through May, a strong and widespread warming is observed across most of Pakistan. Northern GB and western Balochistan, as well as parts of southern Sindh, and AJK exhibit increases in the Tmax ranging between +1.5°C and +2.5°C. The warming is most intense in March, April, and May, particularly over the northern half of the country. Many of these areas are indicating statistically significant warming during these months.

From June to September, the pattern shifts markedly. Northern and central Pakistan, including GB, Punjab, Balochistan, and parts of southern KP, show a cooling trend during the monsoon months. This cooling, often between -0.5°C and -2.0°C, is particularly noticeable in June and September, and is statistically significant in parts of south Punjab in the month of June. These cooler Tmax may be linked to already reported increased trends in the PR during the monsoon season, which is already seen to moderate daytime temperatures. However, southwestern Balochistan and parts of southern Sindh continue to show slight warming even during these months.

October marks a return to warming, particularly in northern Pakistan, with Tmax anomalies exceeding +1.0°C in some areas of Balochistan and KP. This warming reverses to cooling in November through January and extends towards Punjab, while maintaining its warming pattern over Balochistan. Cooling during November, December and January, bear anomalies ranging between -0.5°C and -2.0°C. The statistical significance of the changes in January is prominent over Punjab and Sindh, and hence it is witnessed as a significantly cooled down month among the winter months in the province. Atmospheric drivers that attribute to such cooling over Punjab may include increased fogginess during late winter, instance of which is a reported cloudiness/fogginess over Punjab for more than 40 consecutive days during the winter spanning 2023-24.

Certain regions emerge as consistently warming across most months. These include parts of northern KP, AJK, western Balochistan and Sindh. In terms of magnitude, the observed changes are significant. Warming in the pre-monsoon and spring months frequently converges to +3.0°C, while cooling during the monsoon season can be as low as -0.5°C to -2.0°C in localized pockets. However, the shifts associated with the warming are dominantly statistically significant, particularly in spring, adding confidence to the observed trends.

### 3. 4. 2. Minimum Temperature

The monthly Tmin composites between the periods 2001-2020 and 1981-2000 over Pakistan reveal widespread and persistent warming with some localized cooling over particular extents, along with clear spatial and seasonal variations (Figure 17). This analysis reveals that not only has the warming of Tmin dominated in the region, it has increased significantly during the analysed period.

The dominant warming pattern which is evident throughout most months, is particularly resident over the country from February to May and then October. Southern and central Pakistan, including Sindh, southern Punjab, and southern Balochistan, show consistent and pronounced increases in Tmin year around. These areas experience warming anomalies generally of the magnitude of up to +2.0°C, with the highest values striding beyond this magnitude in some southern pockets. These regions also show statistically significant warming.

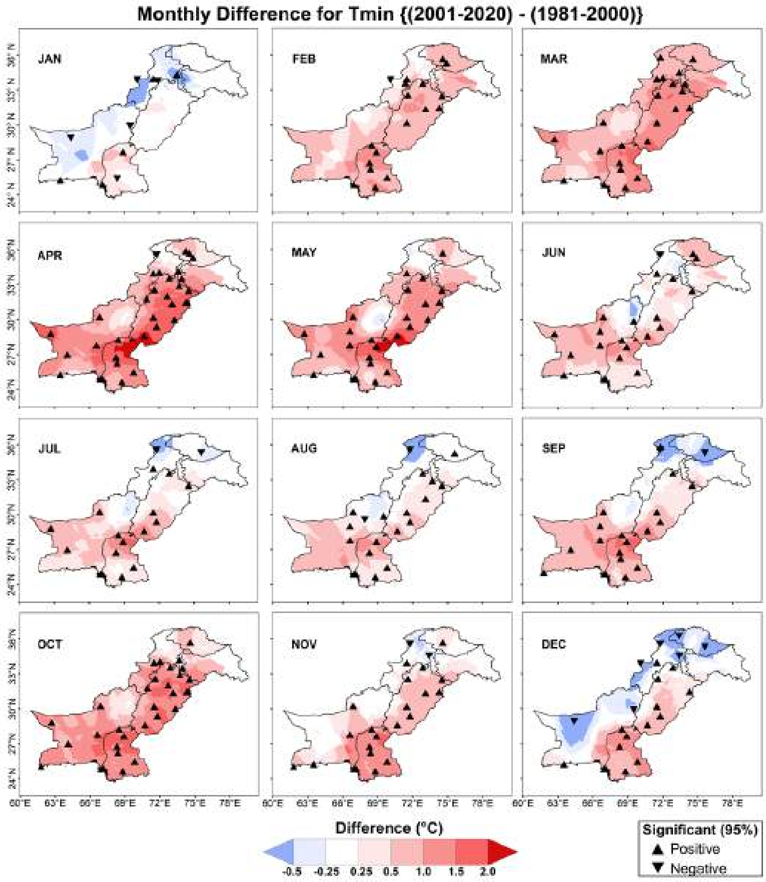



*Figure 17: Monthly composites in minimum temperature (Tmin) over Pakistan (2001-2020 minus 1981-2000). The composites are indicated in °C. Arrow heads indicate regions whose composites are statistically significant at the 95% confidence level.*

In contrast, western and northern Pakistan, including Balochistan, KP and GB demonstrates a distinct cooling trend during the winter months of December and January. This cooling show declines of as steep as -0.5°C. These colder Tmin in winter are significant statistically. Additionally, this region also shows brief cooling and bears statistical significance in the core monsoon months of July to August, though with smaller spatial extents.

### 3. 4. 3. Precipitation

The monthly PR difference maps for Pakistan (comparing the 2001-2020 period to the 1981-2000 baseline) reveal pronounced spatial shifts in patterns across the country (Figure 18). The PR changes represent both drying and wetting, with magnitude dominantly ranging between -70 to +40 mm distributed heterogeneously. While the changes across the year may not be statistically significant as a whole, there are still clear trends that require analytical attention.

During the winter months (December and January), northern Pakistan, particularly AJK, northern Punjab, GB and KP, exhibits a noticeable decrease in the PR. However, February stands out with widespread wetting, especially over northern regions, where increases converge to +40 mm over KP and over isolated extents of AJK and Punjab. December shows positive PR anomalies in south Punjab, whole of Sindh and adjoining areas of Balochistan, while January presents a contrasting picture, with stable and drying patterns, most prominent over AJK and northwest Balochistan.

Spring months (March-May) display a mix of drying and wetting trends, especially in March, when rainfall prominently increases in Punjab and decreases in GB, AJK and KP, suggesting lateral reaches of western disturbances to lower latitudes and lateral regression of the same from the higher ones, during the month. In April and May, the picture becomes more mixed, with the change signal not as strong as in earlier months.

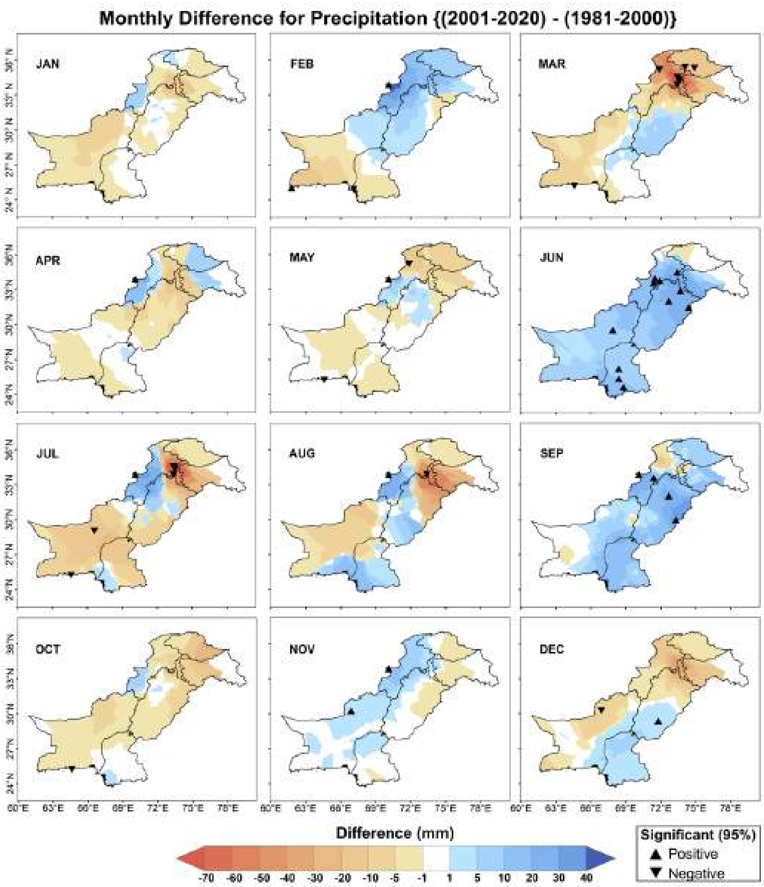



*Figure 18: Monthly composites in precipitation (PR) over Pakistan (2001-2020 minus 1981-2000). The composites are indicated in mm. Arrow heads indicate regions whose composites are statistically significant at the 95% confidence level.*

The core monsoon season (June to September) presents a complex and regionally varied picture. June shows strong wetting signals throughout the country (with the exception of GB where changes are negligible), with increases of up to +40 mm. However, July and August, traditionally the peak of the monsoon, exhibit combinations of widespread drying (northern Punjab, eastern KP, southern

GB, Balochistan and AJK) and wetting (south KP, south Punjab, lower Sindh and southern Balochistan) across the country. The PR surpluses and deficits in these areas frequently meet the pre-ascribed range, indicating both strengthening and weakening of monsoonal rains, respectively. September marks a return to wetter conditions, that virtually span the whole country, with the PR gains of up to +40 mm. AJK also experiences moderate wetting in this month.

Autumn months show a similar mixed behavior. October is notably drier across much of Pakistan, especially in GB, eastern Punjab and northwest Balochistan, with declines of the lesser magnitude. AJK also registers reduced PR during this month. However, November reverses this pattern, with widespread PR increases in north and northwestern parts of the country, especially over KP, east Punjab, AJK, upper Sindh and Balochistan.

Certain regions demonstrate consistent change. KP experience increased PR in multiple months, especially February, April, June, July, August, September and November. These months suggest a potential strengthening of weather systems concentrated over KP. In contrast, AJK and Balochistan experience persistent drying, particularly during January, March, April, May, July, August, October and December. These regions show reductions of less than -70 mm, suggesting a concerning trend of reduced water availability in both humid and arid zones of the country.

## 3.5 COMPOSITE CHANGES ON SEASONAL AND ANNUAL BASIS

### 3. 5. 1. Maximum Temperature

To detect long-term changes that are distinct from short-term variability, climate regime shifts through the comparison of two 20-year time periods (1981-2000 vs. 2001-2020) are analysed on seasonal and annual basis. By examining the differences in the analysed parameters between these two periods, we can assess whether the experienced warming or cooling is recent.

Figure 19 depicts seasonal and annual differences in the Tmax across Pakistan. The analysis shows that most parts of Pakistan have warmed in recent decades, although the intensity and spatial extent of warming vary by season. Warmed up regions that dominate the country are particularly identified during spring and annual periods. The most intense warming (up to +2.0°C) occurs in southern Balochistan and northern KP, throughout the analysed seasons and annual period, but is particularly prominent during the spring season. Consistent warming is observed across southern and western Pakistan, covering large parts of Balochistan, Sindh and KP, where nearly all seasons exhibit positive Tmax differences.

In contrast, cooled down regions are comparatively sparse and localized. The most prominent cooling zones appear in northwest Punjab, GB and KP, visible especially in the pre-monsoon, monsoon, post monsoon and winter seasons. These areas show cooling of up to -1.5°C, with scattered patches suggesting localized reductions in the Tmax.

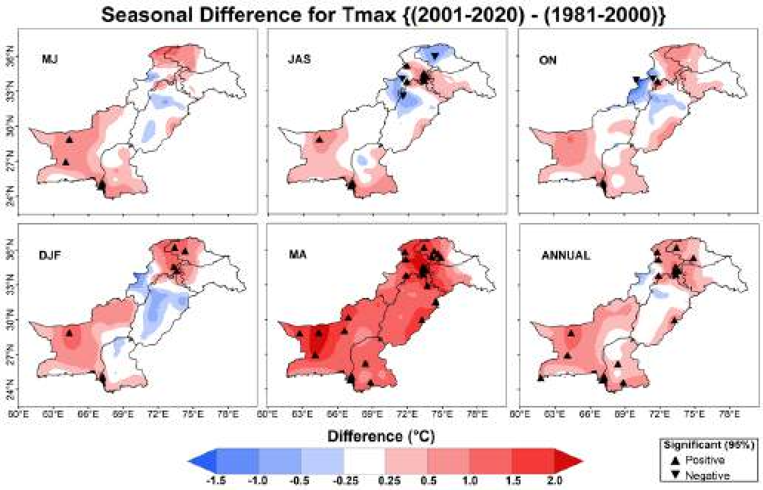



*Figure 19: Seasonal and annual composites in maximum temperature (Tmax) over Pakistan (2001-2020 minus 1981-2000). The composites are indicated in °C. Arrow heads indicate regions whose composites are statistically significant at the 95% confidence level.*

Regions showing consistent warming throughout all seasons include southern Balochistan, much of Sindh, northern KP, GB and AJK, all of which show warming exceeding +1.0°C. However, GB stands out for displaying intermittent cooling in the monsoon season.

Statistically significant differences in the Tmax are predominantly located in spring across almost the entire country, suggesting a robust, widespread warming trend during this season. Statistically significant warming is also present in annual period, especially across extents of western Balochistan, north KP, Sindh, Punjab and GB. These significant changes affirm a true climate shift, homogeneously spanned over the entire country.

### 3. 5. 2. Minimum Temperature

The analysis of seasonal and annual Tmin composites between the two 20-year periods (1981-2000 and 2001-2020) across Pakistan reveals widespread warming, with some localized pockets of cooling (Figure 20). These shifts in the Tmin are significant indicators of shifts in nocturnal temperature patterns.

The majority of Pakistan shows a consistent increase in the Tmin across all seasons, especially in central and southern parts of Punjab, most of Sindh, and eastern Balochistan. The most pronounced warming is observed during spring and post-monsoon seasons, where temperature composites exceed +2.0°C, departing beyond this threshold in some parts of Balochistan province. The conjunction of southeast Balochistan, upper Sindh and southern Punjab, exhibit a clear and uniform warming signal across the entire analysed seasons.

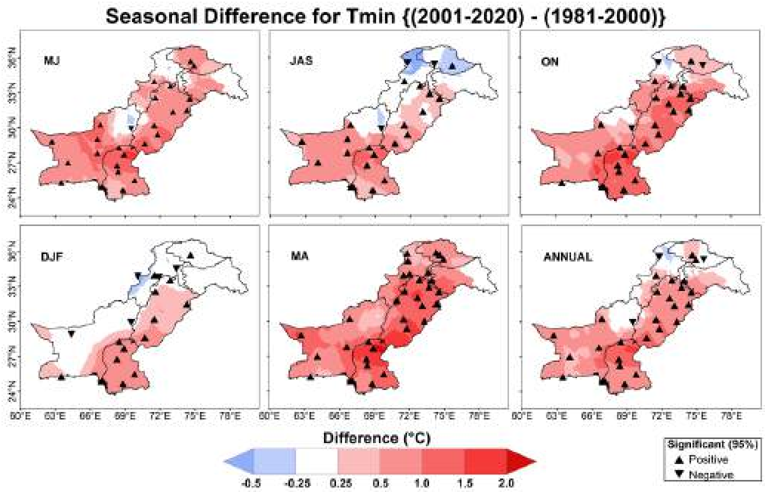



*Figure 20: Seasonal and annual composites in minimum temperature (Tmin) over Pakistan (2001-2020 minus 1981-2000). The composites are indicated in °C. Arrows indicate regions whose composites are statistically significant at the 95% confidence level.*

Isolated pockets of cooling appear, primarily in Balochistan, GB and upper KP. These regions show composites extending below -0.5°C. Such magnitude of cooling though marginally significant, appears consistently across all the analysed seasons, except spring.

Consistent warming throughout all seasons is evident across eastern Balochistan, interior Sindh, and lower Punjab. These areas show no seasonal reversals and remain dominated by the warming signal year-round. In contrast, parts of upper KP and northern Balochistan reveal a modest cooling trend in multiple seasons. In AJK, the consistent warming is evident across all seasons, though generally less intense than in southern Pakistan. Most of AJK shows an increase in the Tmin particularly during spring season.

Statistically significant composites in the Tmin between the two periods are notably widespread and prominent during pre-monsoon, monsoon, post-monsoon, spring as well as during annual scale. A dense cluster of statistically significant positive difference is observed in Sindh, Punjab and Balochistan, affirming robustness of observed warming in these regions.

### 3. 5. 3. Precipitation

The analysis of seasonal and annual PR composites between the periods 1981-2000 and 2001-2020 across Pakistan reveals a complex and spatially variable pattern of wetting and drying (Figure 21). The maps indicate that several regions have experienced notable changes in rainfall distribution, with some areas consistently receiving more PR while others have undergone a marked decline.

During the monsoon season, a pronounced increase in PR is observed across much of central and south Punjab, extending into parts of southern KP. The coastal extents of Sindh and Balochistan also exhibit modest increases during the monsoon season. This wetting is further confirmed in the

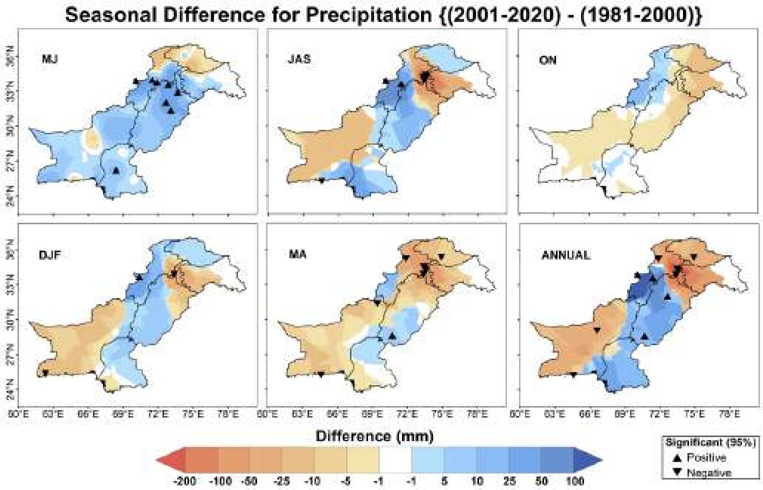



*Figure 21: Seasonal and annual composites in precipitation (PR) over Pakistan (2001-2020 minus 1981-2000). The composites are indicated in mm. Arrows indicate regions whose composites are statistically significant at the 95% confidence level.*

annual PR, where these regions show increases of up to +100 mm. Pre-monsoon rainfall also appears to have increased significantly in Punjab, southern Sindh, lower KP, AJK and parts of Balochistan. Post-monsoon season show more modest increases in certain areas, such as northwest Punjab and KP. Winter and spring both declare Punjab, lower KP and Upper Sindh as wetter than before, nevertheless upper KP and GB display opposing patterns, upper KP being drier in spring and GB being wetter in winter. Overall, regions such as northwest Punjab, lower KP and northern Sindh display consistent wetting trends throughout the seasons.

Drying is observed too, particularly across GB, in north Pakistan, throughout the analysed seasons, with the exception of winter. This drying is also most apparent in northern KP, northeast Punjab, and AJK, where deficit in PR go below -200 mm in several seasons. The annual scale difference confirms this trend, with consistent rainfall decreases across these northern regions. Northeast and southwest Balochistan also exhibit seasonal drying. AJK, in particular, stands out as a region with mixed signals, experiencing increased rainfall during the pre-monsoon but significant drying in spring and winter seasons.

The PR changes depicted in the maps reflect significant hydrological implications for Pakistan. The magnitude of changes indicate that these are not marginal fluctuations but rather substantial shifts. Moreover, the PR composites do also indicate a prominent statistical significance.

## 3.6 EXTREME CLIMATE INDICES: MEAN AND TRENDS

### 3. 6. 1. Hot Days > 40°C

Figure 22 displays mean annual number of hot days and their trend per decade across Pakistan for the period 1980-2025. The spatial pattern highlights that Punjab, central and upper Sindh, and western extents of Balochistan experience the highest frequency of hot days, exceeding 100 days annually in some grids. One such hot day was observed in Turbat where the temperature reached 54.0°C on 28th May 2017, which was later confirmed by WMO and which thereafter established a record for highest ever temperature recorded in Pakistan till date. In contrast, the northern regions including KP, GB, and AJK exhibit modest hot day occurrences, with values largely below 5 days. Upper and central Punjab, and southern KP register moderate values ranging from 5 to 50 days, while much of upper KP and AJK remain below 25 hot days on average.

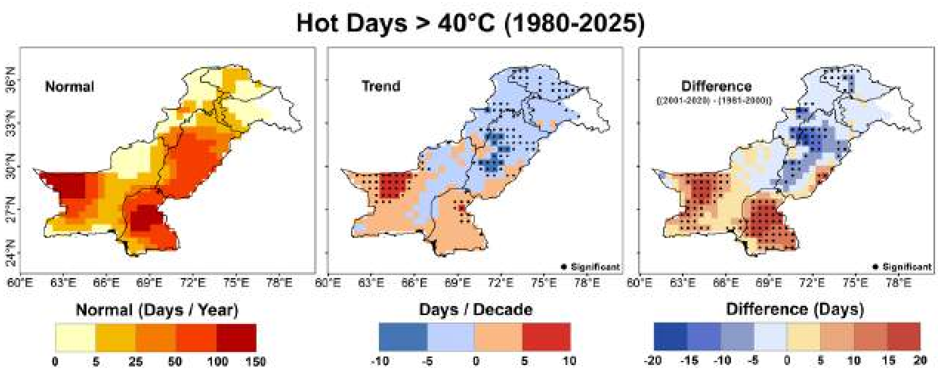



*Figure 22: Mean annual number of hot days and their trend/decade across Pakistan for the period 1980-2025. Dots indicate regions whose trends/composites are statistically significant at the 95% confidence level.*

As per trends in hot days per decade, a clear spatial contrast is apparent. Notably, western Balochistan, upper and eastern Sindh and southeastern Punjab show a significant positive trend, with an increase of up to +5 days per decade. In contrast, a marked decreasing trend is observed in most of Punjab, central and lower KP, and parts of GB, with statistically significant declines plummeting below -5 days per decade. Overall, while the southern Pakistan is warming in terms of extreme hot days, the central and northern parts are witnessing a notable cooling. The 20-years composite replicates the patterns of the described trends and therefore indicates that the reflected trends are predominantly influenced by the changes observed in recent decades.

## 3. 6. 2. Heat Wave Events

Figure 23 displays mean annual number of extreme heat wave events and their trends per decade across Pakistan for the period 1980-2025. The most affected regions, experiencing the highest frequency (15+ events), are located in the upper latitudes including KP and GB, forming distinct hotspots in the upper half of the country. Rest of the areas including Punjab and Balochistan experience moderate occurrences ranging from 10 to 15 events, while southern Punjab, much of Sindh, and southern Balochistan record relatively fewer events, typically under 5.

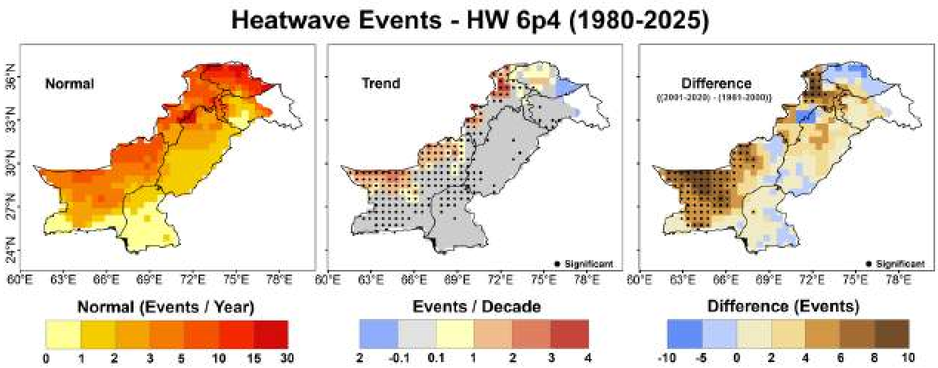



*Figure 23: Mean annual number of extreme heat wave events and their trend/ decade across Pakistan for the period 1980-2025. Dots indicate regions whose trends/composites are statistically significant at the 95% confidence level.*

There is a widespread and statistically significant trend across Balochistan, Sindh, and some extents of southern Punjab. The upward trend extends into upper and lower KP, Balochistan and GB (insignificantly), indicating zones with an increase of +3 events per decade. The 20-years composites are reflective of the patterns in the trends, thereby indicating that the trends are apparently influenced by changes in recent decades, over the country.

## 3. 6. 3. Cooling Degree Days

Mean cooling degree days across Pakistan from 1980 to 2025 show significant spatial variation (Figure 24). Sindh exhibit the highest magnitudes, with values exceeding 6000 degree days in several grids, indicating a strong need for cooling. Central Punjab and parts of Balochistan also show high values, ranging from 3000 to 5000 degree days. In contrast, northern areas, including KP and AJK, display lower magnitudes, with values dropping below 4500 degree days, reflecting dominancy of cooler climates. The northwestern parts of Balochistan and GB also show relatively lower values, generally between 2000 and 4000 degree days. The GB due to its typical colder climate bears a tendency of recording subzero temperatures, normally, and hence offsets any significant cooling requirements. Lowest temperature ever recorded in GB was -24.1°C, observed at Skardu on 7th January 1995, which also established the record for coldest ever temperature recorded in Pakistan's history.

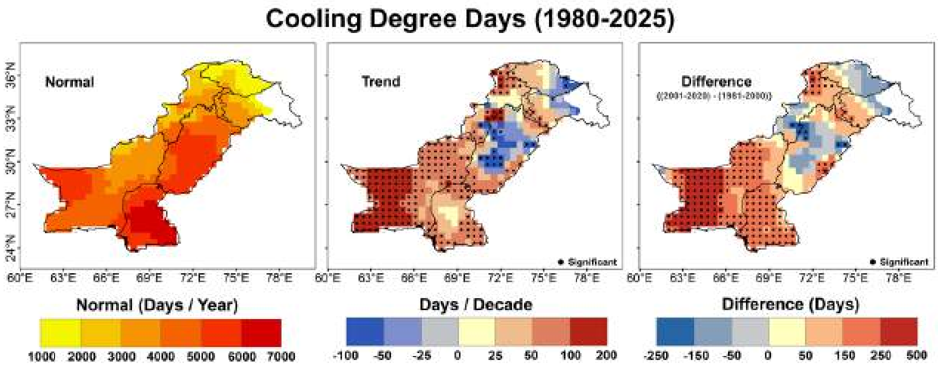



*Figure 24: Mean annual number of cooling degree days and their trend/decade across Pakistan for the period 1980-2025. Dots indicate regions whose trends/composites are statistically significant at the 95% confidence level.*

Trends in cooling degree days indicate varying patterns of change in cooling degree days across Pakistan's provinces. Balochistan, southern Sindh, northern and central KP and parts of southern Punjab show the most significant increasing trends, with magnitudes exceeding +100 degree days per decade, suggesting a rising demand for cooling. Central Punjab, along with eastern parts of GB, exhibit decreasing trends, with magnitudes receding -50 degree days per decade, indicating a reduced need for cooling. It is noteworthy that central Punjab, characterized by a generally warm climate and a high number of cooling degree days, exhibits a significant decreasing trend in cooling degree days, while northern KP, a glaciated region with a cold climate and fewer cooling degree days, shows a significant increasing trend in cooling degree days.

## 3. 6. 4. Warm Nights > 30°C

The mean annual number of warm nights (Tmin > °30C) from 1980 to 2025 reveals distinct spatial patterns across Pakistan (Figure 25). Central Punjab and eastern Balochistan experience the highest magnitudes, with values exceeding 30 warm nights per year, indicating persistent nocturnal

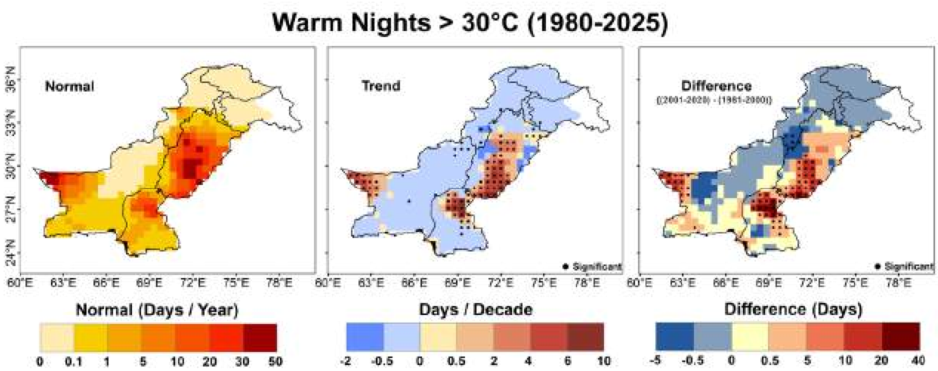



*Figure 25: Mean annual number of warm nights and their trend/decade across Pakistan for the period 1980-2025. Dots indicate regions whose trends/composites are statistically significant at the 95% confidence level.*

heat stress. Upper Sindh also records high values, ranging from 20 to 30 warm nights per year, while large parts of Balochistan and southern KP show moderate frequencies between 5 and 10 warm nights per year. In contrast, northern regions, including upper KP, GB, and AJK, exhibit the lowest magnitudes, typically below 1 warm night per year, reflecting relatively cooler night-time conditions.

Trends in warm nights show considerable spatial variability across Pakistan. Central and southern Punjab, along with upper Sindh, exhibit the strongest increasing trends, exceeding +6 warm nights per decade, indicating a marked intensification of extreme night-time heat. Southern KP and parts of upper Balochistan show weak to moderate decreasing trends, generally not plummeting below -2 warm nights per decade, although some of these signals are statistically significant.

In contrast, the central-eastern edge of Balochistan exhibits increasing trends of up to +4 warm nights per decade, highlighting a localized intensification of nocturnal heat. The remaining regions, including GB and AJK, show relatively stable conditions with little to no significant long-term change in warm nights frequency.

### 3. 6. 5. Diurnal Temperature Range

Figure 26 displays mean diurnal temperature range across Pakistan from 1980 to 2025 with notable spatial variation. Northeastern Balochistan, central Sindh and parts of GB exhibit the highest magnitudes, with values exceeding 16.0°C, indicating a wide daily temperature swing. Central and upper Punjab, AJK, upper KP and conjunction of Sindh and Balochistan also show high values, ranging from 14.0°C to 16.0°C. In contrast, central KP, southern Balochistan and southern Sindh, have the lowest magnitudes, with the range dropping below +14°C, reflecting more stable daily temperatures.

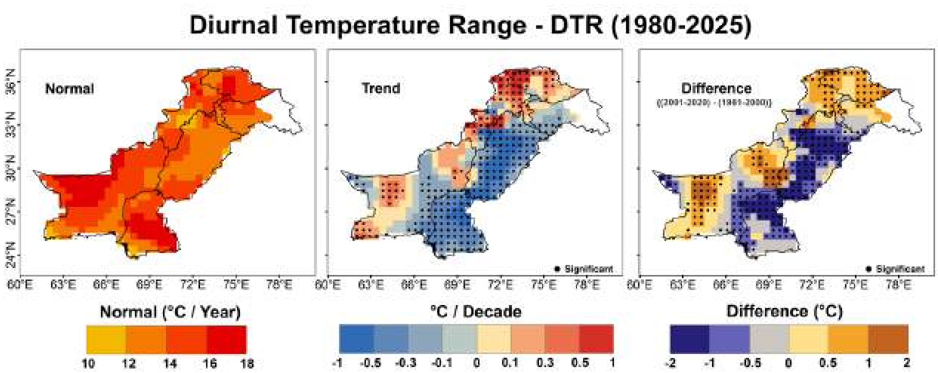



*Figure 26: Mean annual diurnal temperature ranges and their trend/decade across Pakistan for the period 1980-2025. Dots indicate regions whose trends/ composites are statistically significant at the 95% confidence level.*

Trend in the index indicates diverse patterns in the changes noted across Pakistan's provinces. Punjab and Sindh show the most significantly decreasing trends, with magnitudes converging to -1°C per decade. Northern and central KP, Balochistan and parts of GB exhibit increasing trends, with magnitudes ranging from +0.1°C to +1.0°C per decade, also marked with statistical significance. AJK displays mixed trends with modest variations which are mostly statistically insignificant and hence depict stability.

### 3. 6. 6. Simple Daily Intensity Index

Mean Simple Daily Intensity Index (SDII) from 1980 to 2025 shows notable spatial variation across Pakistan (Figure 27). Southern Sindh, upper KP, AJK and northern Punjab exhibit the highest magnitudes, with values converging to 20 mm/day, indicating intense rainfall. Central and southern Punjab, Balochistan, lower KP and GB, on the other hand, display moderate values that go as high as 13 mm/day.

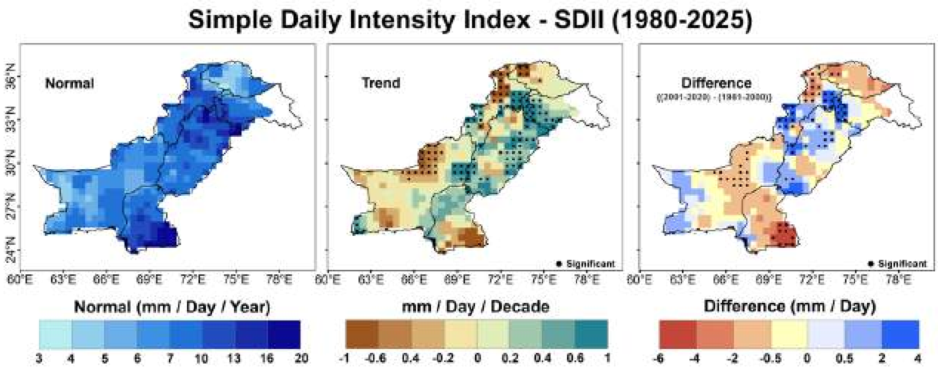



*Figure 27: Mean annual SDII and their trend/decade across Pakistan for the period 1980-2025. Dots indicate regions whose trends/composites are statistically significant at the 95% confidence level.*

Trends of the index indicate varied patterns in the change of SDII across Pakistan's provinces. Southwestern and northwestern KP, AJK, eastern Punjab and the conjunction of the Punjab, Sindh and Balochistan provinces show the most significantly increasing trends, with magnitudes exceeding +0.6 mm/day per decade. Northern KP, northwestern Balochistan, west GB and southern Sindh display decreasing trends with magnitudes receding below -0.6 mm/day per decade, also marked with statistical significance over fair expanses of the analysed grids.

## 3. 6. 7. Mean 5-day Cumulative Precipitation

Mean 5-day cumulative PR (Rx5day) from 1980 to 2025 shows significant spatial variation across Pakistan (Figure 28). Northern Punjab, northern KP and AJK exhibit the highest magnitudes, with values exceeding 200 mm, indicating strong magnitude of 5-day rainfall events. The highest annual rainfall ever recorded in Pakistan touched 2456 mm at Malam Jabba in 2020. Southern Sindh also shows high values, ranging from 100 mm to 150 mm. In contrast, upper Sindh, southern Punjab, Balochistan and GB show moderate magnitudes, with Rx5day dropping below 100 mm, reflecting lower PR accumulation in 5 days.

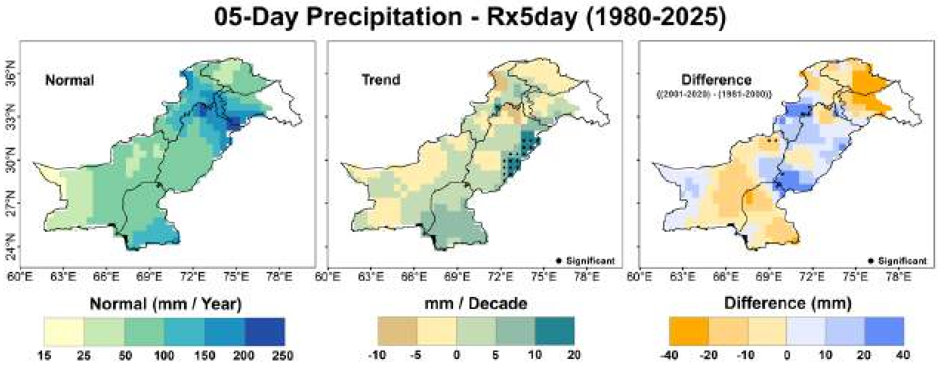



*Figure 28: Mean annual 5-day cumulative PR index and their trend/decade across Pakistan for the period 1980-2025. Dots indicate regions whose trends/composites are statistically significant at the 95% confidence level.*

The trend indicates clear distinction of patterns in the change of Rx5day across provinces and regions of Pakistan. Statistically significant trends are concentrated towards eastern extents of the Punjab with magnitudes converging to +20 mm/decade. These 5-day cumulative PR trends on the eastern Punjab side have brought potential for increased runoffs in regions where Ravi and Sutlej rivers enter into Pakistan's territory.

## 3. 6. 8. Consecutive Wet Days

Mean consecutive wet days (CWD) from 1980 to 2025 show notable spatial variation across Pakistan (Figure 29). Northern and central Punjab, KP and AJK exhibit the highest magnitudes, with values exceeding 8 days, indicating prolonged wet periods. Balochistan and Sindh show moderate values, topping at most 5 consecutive wet days in the index. In contrast, western Balochistan and GB have the lowest magnitudes, with the CWD dropping below 4 days, reflecting shorter wet spells.

Trends in the index indicate two diverse patterns in the change of the CWD across Pakistan's provinces. Southern Sindh show the most significant increasing trends (statistically significant over

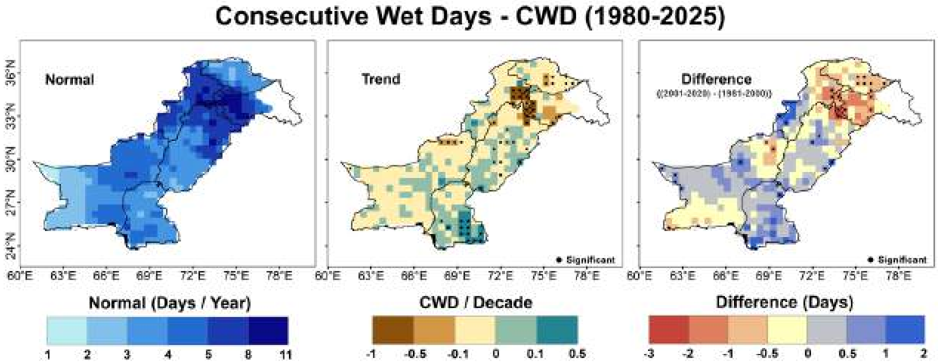



*Figure 29: Mean annual consecutive wet days (CWD) index and their trend/decade across Pakistan for the period 1980-2025. Dots indicate regions whose trends/composites are statistically significant at the 95% confidence level.*

several grids), with magnitudes converging to +0.5 days per decade. This adds up to nearly +2.3 days of increase in the index over the course of 46 years, particularly over Sindh. Parts of GB and Balochistan, eastern KP and AJK, all exhibit decreasing trends, with magnitudes converging to -1 days per decade, all marked with statistical significance. This means that over the course of 46 years, up to +4.6 days have been exempted from the consecutive wet days, particularly from over the AJK region. Trends are found stable for the index over rest of the regions.

### 3. 6. 9. Consecutive Dry Days

Mean consecutive dry days from 1980 to 2025 show significant spatial variations across Pakistan (Figure 30). Eastern Balochistan and Sindh exhibit the highest magnitudes, with values converging to or exceeding 150 days, indicating prolonged dry periods. Western Balochistan, central and southern Punjab, as well as GB also show high values, ranging from 50 to 200+ days on average in a year. The rest of the regions, including KP, AJK and upper Punjab have the lowest magnitudes, with CDD dropping below 50 days, reflecting shorter dry spells.

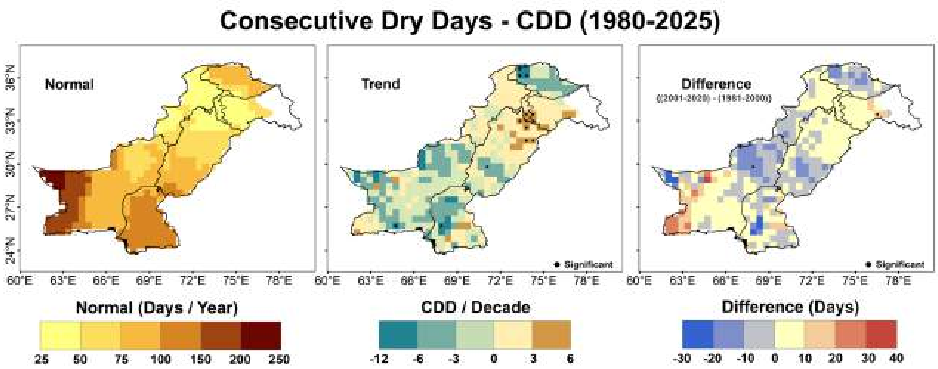



*Figure 30: Mean annual consecutive dry days index and their trend/decade across Pakistan for the period 1980-2025. Dots indicate regions whose trends/composites are statistically significant at the 95% confidence level.*

Trends indicate distinction with two patterns in the change of CDD across Pakistan's regions and provinces. The index is seen to grow at a maximum rate of +6 days per decade over the expanses of northern Punjab and AJK. KP remains stable by modulating its index trends between -3 to +3 days per decade insignificantly. Most of the expanses in the south of the country and the GB on the other hand, exhibit a decay in the index by up to -12 days per decade. However, none of the trends, except for over a few isolated grids, are seen statistically significant.

### 3. 6. 10. Precipitation ≥ 150 mm in One Day

Mean number of days with PR ≥ 150 mm from 1980 to 2025 show notable hotspots across Pakistan. AJK, northern Punjab, particularly over Pothohar region (Islamabad and Rawalpindi division), and northeastern Punjab exhibit the highest magnitudes, with mean values converging to 0.5 days per year, indicating notable occurrences of extreme rainfall events in the mentioned regions (Figure 31). Highest one-day rainfall of magnitude 592 mm recorded by PMD, did also occur over Islamabad on 27th July 2001. Southern parts of Sindh also show high values, ranging from 0.2 to 0.4 days, while KP, Balochistan and GB display moderate values that converge to 0.1 days per year in the index. However, on a larger temporal scale, the Padidan in Sindh recorded the highest monthly rainfall magnitude of 1229 mm in August 2022, despite its observed moderation in the index.

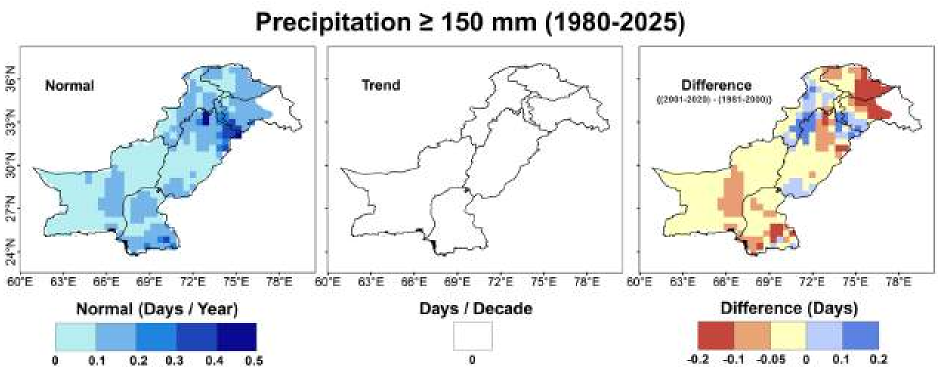



*Figure 31: Mean annual number of days with PR ≥ +150 mm/day and their trend/ decade across Pakistan for the period 1980-2025. Dots indicate regions whose trends/composites are statistically significant at the 95% confidence level.*

The hotspots of higher echelon extremes of the index are particularly resident over domains that encompass dominant summer monsoon rains of Pakistan. Trends in the index indicate no noticeable magnitude and statistical significance.

# 3.7 TRENDS ON NATIONAL, REGIONAL AND SUB-REGIONAL BASIS

## 3. 7. 1. Overall Pakistan

The Tmax in Pakistan exhibits notable interannual variability, fluctuating between 26.50°C and 29.50°C during the period from 1981 to 2025 (Figure 32). There is an indication of a statistically significant upward trend with a slope of +0.20°C per decade, corresponding to a cumulative increase of approximately +0.90°C in 45 years over Pakistan.

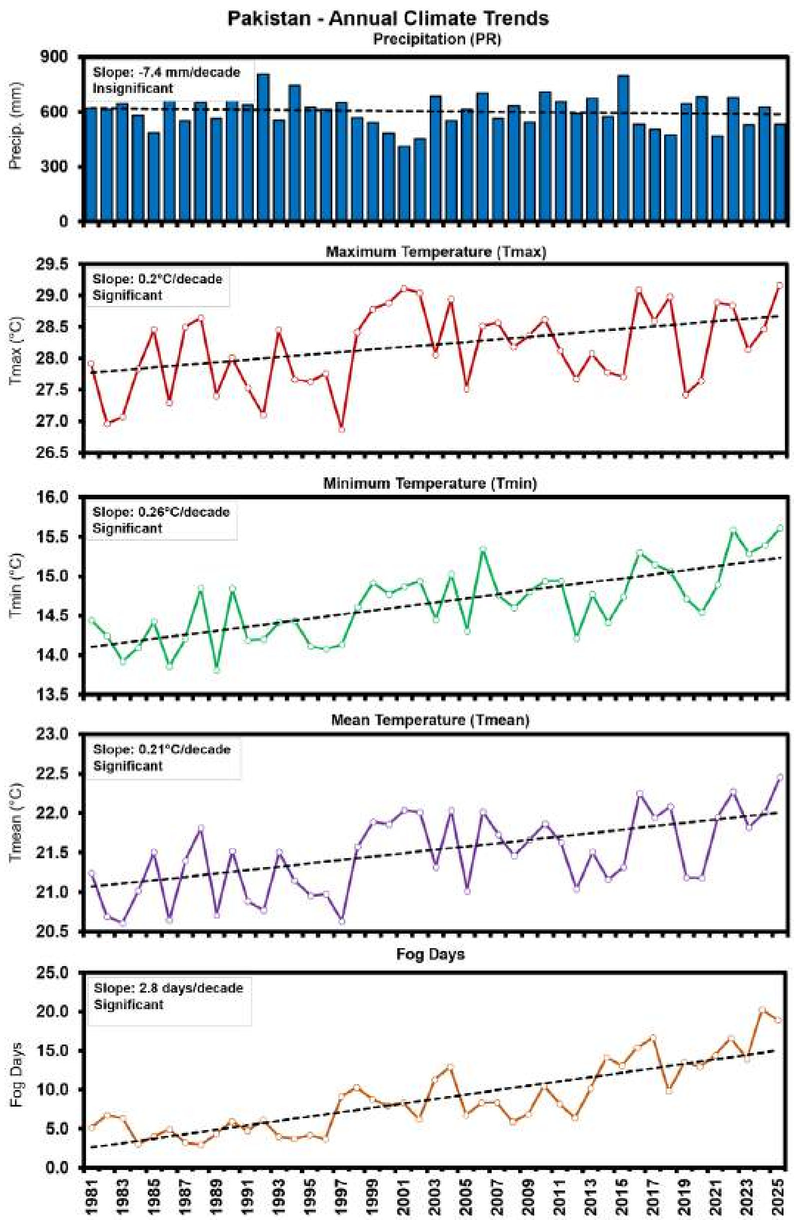



*Figure 32: Stations averaged trends and slopes of the analysed climatic variables over Pakistan, for the period 1981-2025.*

The Tmin fluctuates between 13.50°C and 16.00°C, reflecting considerable interannual variability. Tendency of the Tmin reveals a highly statistically significant upward trend with a slope of +0.26°C per decade, indicating a more pronounced warming than that of the Tmax and a cumulative increase of approximately +1.17°C during the analysed period.

The Tmean varies between 20.50°C and 23.00°C, showing interannual fluctuations consistent with the combined behavior of Tmax and Tmin. Tendency of the Tmean indicates a statistically significant increase of +0.21°C per decade, corresponding to a cumulative warming of approximately +0.95°C during the analysed period, reflecting an overall warming across Pakistan.

The PR ranges from 300 mm to 800 mm, displaying substantial interannual variability with no clear long-term pattern. However, tendency of the PR indicates a slight decrease of -7.40 mm per decade, equivalent to a cumulative decrease of approximately -33.30 mm over the analysed period. However, this trend is not statistically significant at the 95% confidence level, suggesting that annual precipitation has remained highly variable without a discernible long-term trend during the analysed period.

### 3. 7. 2. Gilgit Baltistan

The Tmax in GB exhibits significant interannual variability, fluctuating between approximately 20.00°C and 23.5°C during 1981-2025 (Figure 33). Tendency of the Tmax indicates a statistically significant increase of +0.28°C per decade, corresponding to a cumulative increase of approximately +1.26°C during the analysed period, suggesting substantial warming in daytime temperatures over GB.

The Tmin exhibits considerable interannual variability, ranging from approximately 6.50°C to 9.50°C. The trend line shows a slight increase of +0.13°C per decade, corresponding to a cumulative surge of approximately +0.59°C. However, this trend is not statistically significant at the 95% confidence level, indicating that changes in the Tmin are comparatively weaker and less certain over the GB region.

The Tmean varies between approximately 13.00°C and 16.50°C, with notable interannual fluctuations. The trend line indicates a statistically significant increase of +0.20°C per decade, corresponding to a cumulative surge of approximately +0.90°C during the analysed period. This reflects an overall warming trend in the region, driven by the combined influence of changes in Tmax and Tmin over GB.

The PR ranges from approximately 100 mm to 500 mm, displaying substantial interannual variability with no clear long-term pattern. The trend line indicates a slight decrease of -6.96 mm per decade, corresponding to a cumulative decay of approximately -31.32 mm over the study period. However,

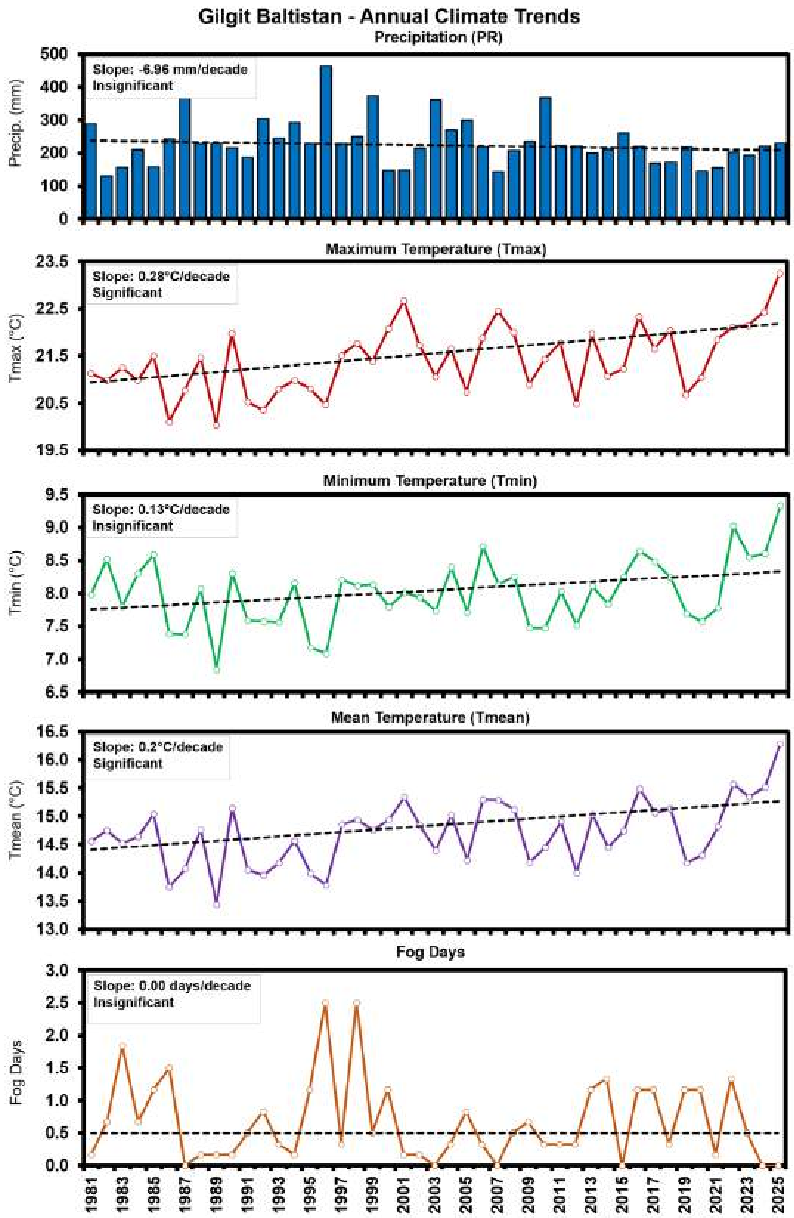



*Figure 33: Stations averaged trends and slopes of the analysed climatic variables over GB, for the period 1981-2025.*

this trend is not statistically significant, suggesting that annual precipitation remains highly variable without a discernible long-term trend during the analysed period over GB.

### 3. 7. 3. Azad Jammu and Kashmir

The Tmax in AJK exhibits significant interannual variability, fluctuating between approximately 25.50°C and 29.00°C during the period 1981-2025 (Figure 34). The trend line indicates a statistically significant increase of +0.38°C per decade, corresponding to a cumulative surge of approximately +1.71°C during the analysed period, suggesting substantial warming in the Tmax over the AJK region.

The Tmin exhibits considerable interannual variability, ranging from approximately 12.50°C to 15.00°C. The trend line indicates an increase of +0.14°C per decade, corresponding to a cumulative

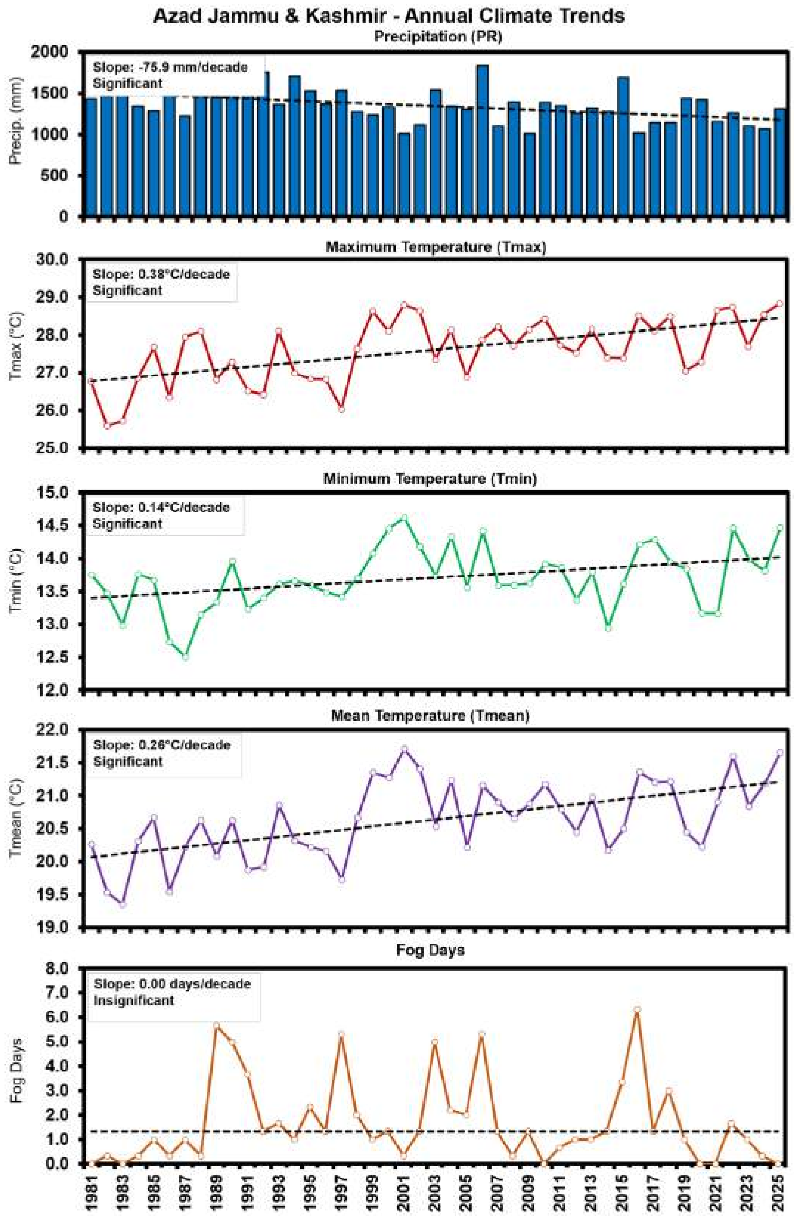



*Figure 34: Stations averaged trends and slopes of the analysed climatic variables over AJK, for the period 1981-2025.*

lift of approximately +0.63°C. This trend is statistically significant, indicating a modest but consistent increase in the Tmin over the AJK region.

The Tmean varies between approximately 19.00°C and 22.00°C, with notable interannual fluctuations. The trend line indicates a statistically significant increase of +0.26°C per decade, corresponding to a cumulative surge of approximately +1.17°C, reflecting an overall warming trend across the AJK region.

The PR ranges from approximately 900 mm to 1,900 mm, displaying substantial interannual variability while also exhibiting a clear long-term pattern. The trend line indicates a decrease of -75.90 mm per decade, corresponding to a cumulative decline of approximately -341.55 mm over the analysed period. This trend is statistically significant, suggesting a pronounced reduction in overall PR over the AJK region.

### 3. 7. 4. Northern Khyber Pakhtunkhwa

The Tmax in northern KP exhibits significant interannual variability, fluctuating between approximately 22.00°C and 25.50°C during the period 1981-2025 (Figure 35). The trend line indicates a statistically significant increase of +0.33°C per decade, corresponding to a cumulative rise of approximately +1.48°C during the analysed period, suggesting substantial warming in Tmax over the northern KP region.

The Tmin exhibits considerable interannual variability, ranging from approximately 8.0°C to 11.0°C. The trend line indicates a slight decrease of -0.02°C per decade, corresponding to a cumulative decline of approximately -0.09°C. However, this trend is not statistically significant, indicating no robust long-term change in the Tmin over the northern KP region.

The Tmean varies between approximately 15.00°C and 18.00°C, with notable interannual fluctuations. The trend line indicates a statistically significant increase of +0.16°C per decade, corresponding to a cumulative surge of approximately +0.72°C, reflecting a modest but statistically robust warming trend in the northern KP region.

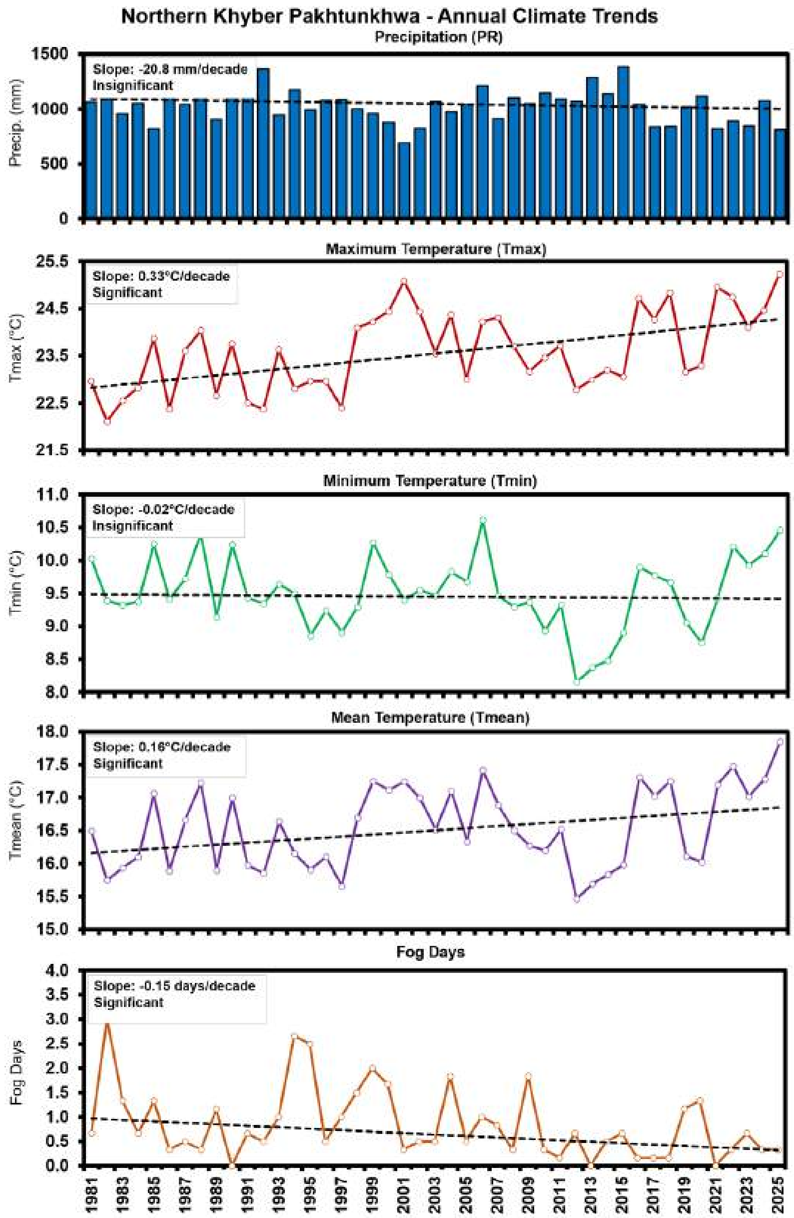



*Figure 35: Stations averaged trends and slopes of the analysed climatic variables over North KP, for the period 1981-2025.*

The PR ranges from approximately 600.00 mm to 1400.00 mm, displaying substantial interannual variability with no clear long-term pattern. The trend line indicates a slight decrease of -20.80 mm per decade, corresponding to a cumulative decline of approximately -93.60 mm over the analysed period. However, this trend is not statistically significant, suggesting that annual precipitation remains highly variable without a discernible long-term trend during 1981-2025 over the northern KP region.

## 3. 7. 5. Southern Khyber Pakhtunkhwa

The Tmax in southern KP exhibits significant interannual variability, fluctuating between approximately 26.50°C and 30.00°C during the period 1981-2025 (Figure 36). The trend line indicates an increase of +0.13°C per decade, corresponding to a cumulative rise of approximately +0.59°C, suggesting an insignificant and a modest increase in the Tmax over the southern KP region.

The Tmin exhibits considerable interannual variability, ranging from approximately 14.00°C to 17.00°C. The trend line shows significant change, with a slope of +0.20°C per decade, which is statistically significant, indicating a robust long-term change in the Tmin across the southern KP region.

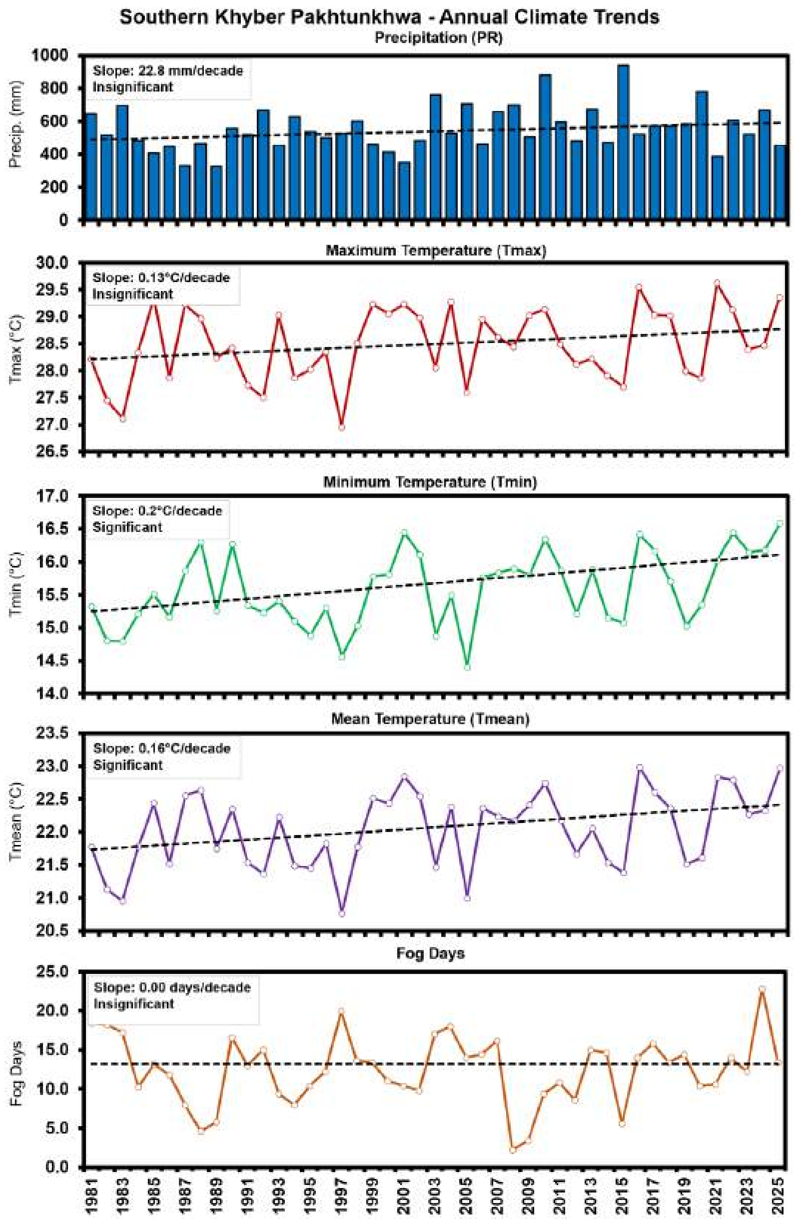



*Figure 36: Stations averaged trends and slopes of the analysed climatic variables over South KP, for the period 1981-2025.*

The Tmean varies between approximately 20.50°C and 23.50°C, with notable interannual fluctuations. The trend line indicates a slight increase of +0.16°C per decade, corresponding to a cumulative rise of approximately +0.72°C over the analysed region. This trend is statistically significant, suggesting a clear long-term change in the Tmean during 1981-2025 over the southern KP region.

The PR ranges from approximately 300.00 mm to 1000.00 mm, displaying substantial interannual variability while exhibiting a weak long-term increasing tendency. The trend line indicates an increase of +22.80 mm per decade, corresponding to a cumulative rise of approximately +102.60 mm over the analysed period. However, this trend is not statistically significant, indicating that the apparent increase in the PR is not robust over the southern KP region.

### 3. 7. 6. Northern Punjab

The Tmax in northern Punjab exhibits significant interannual variability, fluctuating between approximately 27.00°C and 30.50°C during the period 1981-2025 (Figure 37). The trend line indicates a null slope, indicating no change in the Tmax over the northern Punjab during the analysed period.

The Tmin ranges between 14.50°C to 18.00°C and exhibits lesser interannual variability., The trend exhibits a steady rise and indicates a statistically significant increase of +0.36°C per decade, corresponding to a cumulative rise of approximately +1.62°C during the analysed period, indicating pronounced warming in the Tmin across the northern Punjab region.

The Tmean varies between approximately 21.00°C and 24.00°C, with notable interannual fluctuations. The trend line indicates a statistically significant increase of +0.18°C per decade, corresponding to a cumulative rise of approximately +0.81°C, reflecting an overall warming trend in the northern Punjab region.

The PR ranges from approximately 500.00 mm to 1300.00 mm, displaying substantial interannual variability with no clear long-term pattern. The trend line indicates a slight decrease of -5.20 mm per decade, corresponding to a cumulative decline of approximately -23.40 mm over the entire period. The trend is not statistically significant, suggesting that the PR remains highly variable without a discernible long-term trend during 1981-2025 over the northern Punjab region.

Northern Punjab is further seen with up to 40.00 days of fog in a given year. The trend is towards an increase that translates to an addition of +5.30 days per decade. This altogether cumulates to

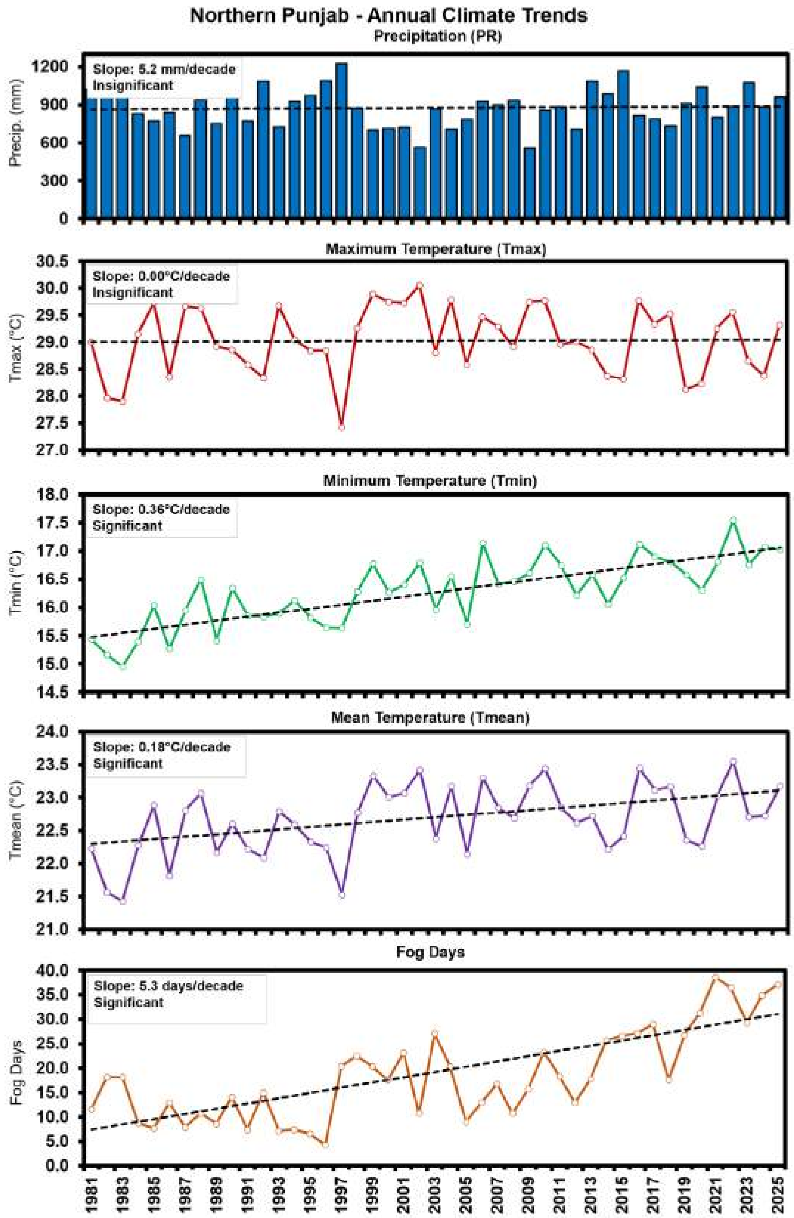



*Figure 37: Stations averaged trends and slopes of the analysed climatic variables over North Punjab, for the period 1981-2025.*

nearly +23.85 days, that are seen added to the fog frequency in the northern Punjab region since 1981. The trend is robust due to its high statistical significance.

## 3. 7. 7. Southern Punjab

The Tmax in southern Punjab exhibits significant interannual variability, fluctuating between approximately 31.50°C and 34.50°C during 1981-2025 (Figure 38). The trend line indicates a slight increase of +0.07°C per decade, corresponding to a cumulative rise of approximately +0.32°C during the analysed period. However, this trend is not statistically significant, suggesting no substantial long-term change in the Tmax over the southern Punjab region.

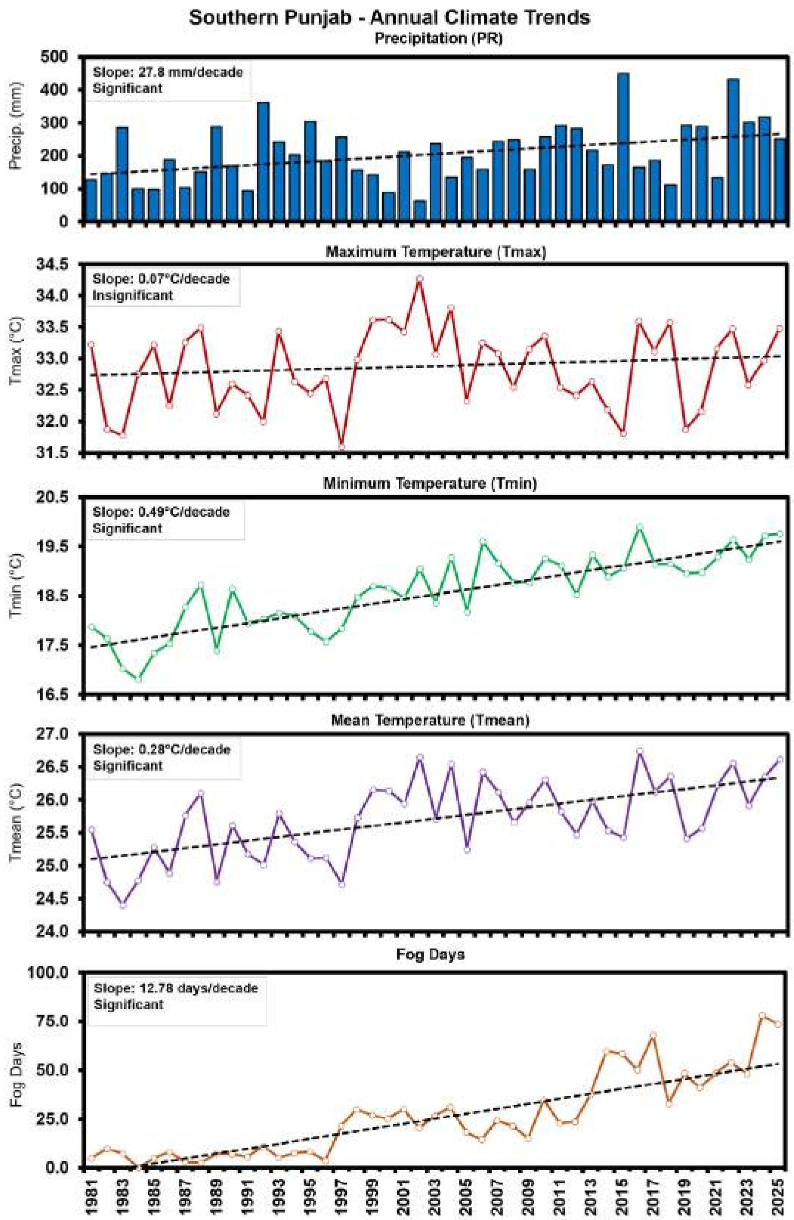



*Figure 38: Stations averaged trends and slopes of the analysed climatic variables over South Punjab, for the period 1981-2025.*

The Tmin exhibits smaller interannual variability and ranges between 16.50°C to 20.00°C. The trend line indicates a statistically significant increase of +0.49°C per decade, corresponding to a cumulative surge of approximately +2.21°C, indicating substantial warming in the Tmin across the southern Punjab region.

The Tmean varies between approximately 24.00°C and 27.00°C, with notable interannual fluctuations. The trend line indicates a statistically significant increase of +0.28°C per decade, corresponding to a cumulative surge of approximately +1.26°C, reflecting an overall significant warming trend in the Tmean over the southern Punjab region.

The PR ranges from approximately 50.00 mm to 450.00 mm, displaying substantial interannual variability while also exhibiting a clear long-term pattern. The trend line indicates an increase of +27.80 mm per decade, corresponding to a cumulative rise of approximately +125.10 mm over the analysed period. This trend is statistically significant, suggesting a robust increase in the PR across the southern Punjab region, despite a high year-to-year variability.

Annual fog days, that could stretch up to 80.00 days in a given year, also exhibit a statistically significant increasing trend, with a magnitude of +12.78 days per decade, indicating a marked increase in fog occurrences across southern Punjab region.

### 3. 7. 8. Sindh

The Tmax in Sindh exhibits significant interannual variability, fluctuating between approximately 32.50°C and 35.00°C during the period 1981-2025 (Figure 39). The trend line indicates a slight increase of +0.11°C per decade, corresponding to a cumulative rise of approximately +0.50°C during the analysed period. This trend is statistically significant, suggesting a moderate change in the Tmax over the Sindh province.

The Tmin exhibits smaller interannual variability and ranges between 18.50°C to 21.5°C. The trend line indicates a statistically significant increasing trend of +0.49°C per decade, corresponding to a cumulative surge of approximately +2.21°C, indicating pronounced warming in the Tmin across the Sindh province.

The Tmean varies between approximately 26.00°C and 28.00°C, with notable interannual fluctuations. The trend line indicates a statistically significant increase of +0.29°C per decade, corresponding to a cumulative rise of approximately +1.31°C, reflecting an overall warming tendency across the Sindh province.

The PR ranges from virtually less than 100.00 mm to approximately 800.00 mm, displaying substantial interannual variability with no clear long-term pattern. The trend line indicates a slight increase of +16.50 mm per decade, corresponding to a cumulative rise of approximately +74.25 mm over the analysed period. However, this trend is not statistically significant, suggesting that annual precipitation remains highly variable without a discernible long-term trend during 1981-2025 over the Sindh province.

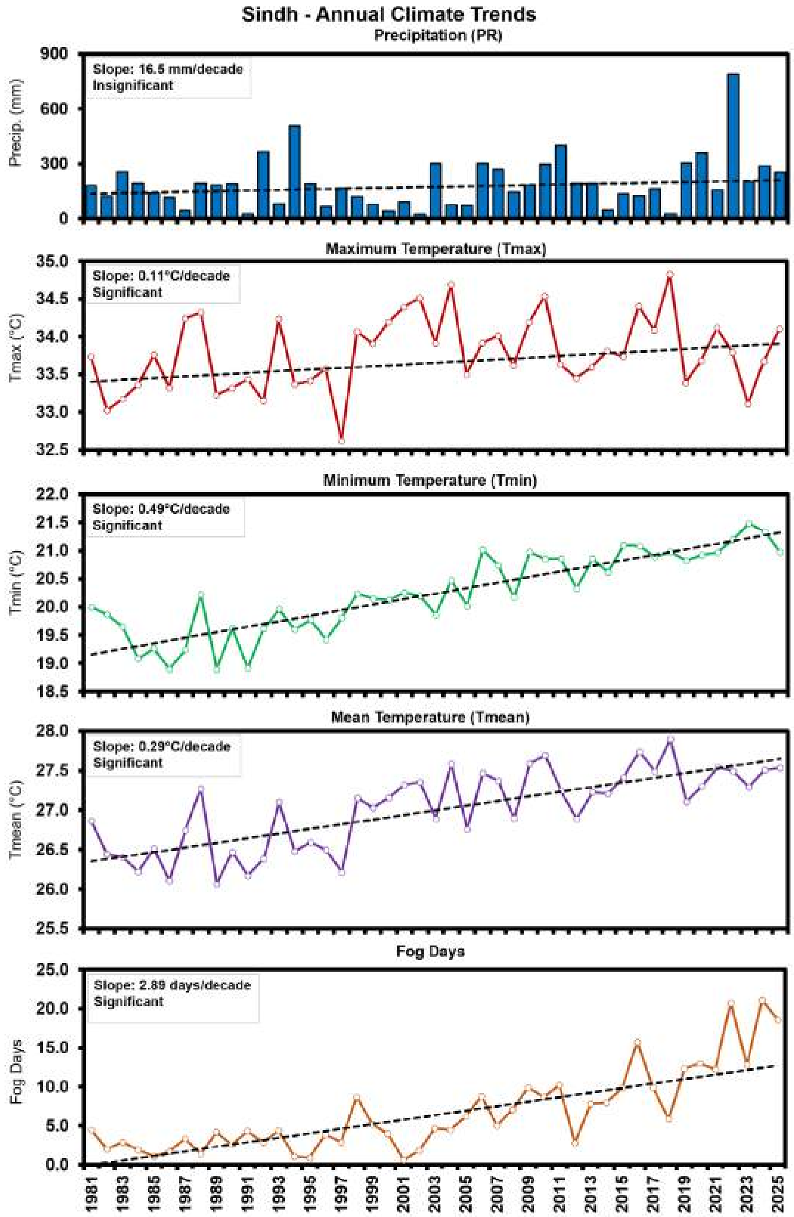



*Figure 39: Stations averaged trends and slopes of the analysed climatic variables over Sindh, for the period 1981-2025.*

Annual fog days also exhibit a statistically significant increasing trend, with a magnitude of +2.89 days per decade, indicating a gradual increase in fog occurrence across Sindh province.

### 3. 7. 9. Balochistan

The Tmax in Balochistan exhibits significant interannual variability, fluctuating between approximately 26.00°C and 30.00°C during 1981-2025 (Figure 40). The trend line indicates a statistically significant increase of +0.22°C per decade, corresponding to a cumulative rise of approximately +0.99°C during the analysed period over the Balochistan province.

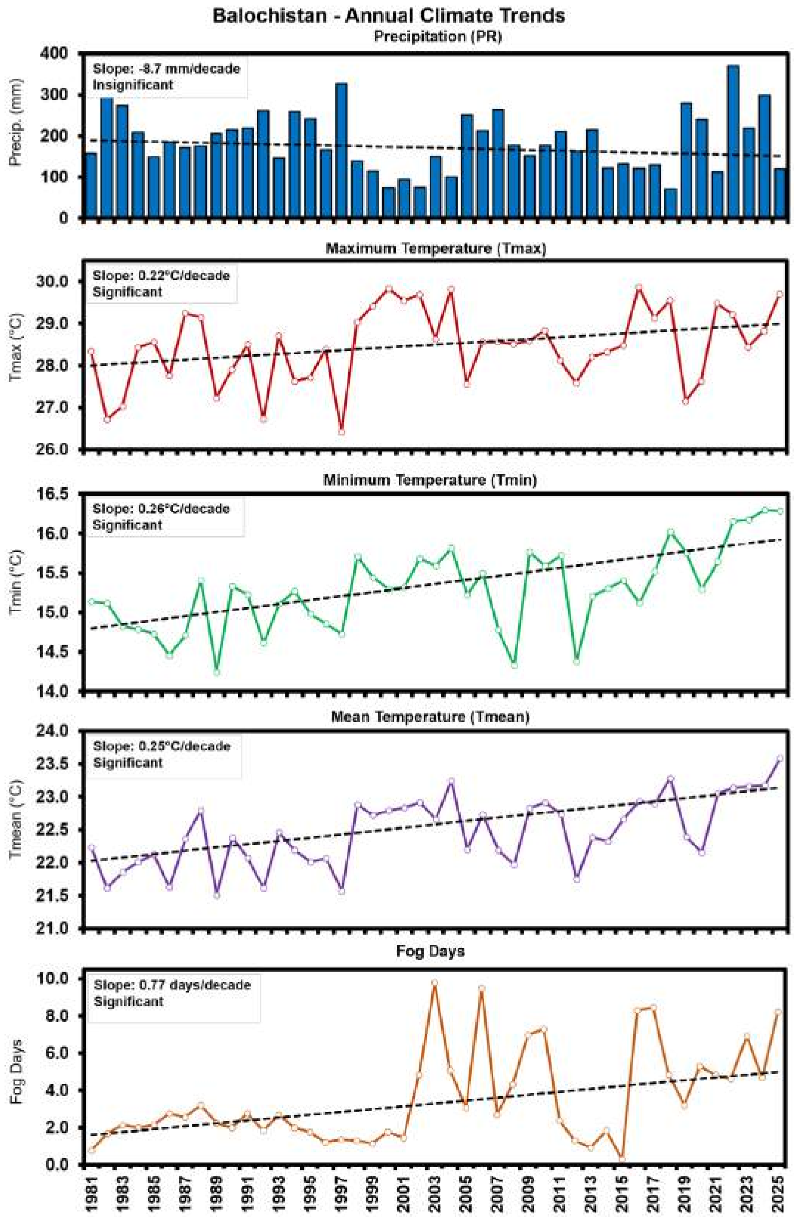



*Figure 40: Stations averaged trends and slopes of the analysed climatic variables over Balochistan, for the period 1981-2025.*

The Tmin, as well, exhibits considerable interannual variability, ranging from approximately 14.00°C to 17.00°C. The trend line indicates a statistically significant increase of +0.26°C per decade, corresponding to a cumulative rise of approximately +1.17°C in 45 years, indicating pronounced warming in the Tmin across the Balochistan province.

The Tmean varies between approximately 21.50°C and 24.00°C, with notable interannual fluctuations. The trend line indicates a statistically significant increase of +0.25°C per decade, corresponding to a cumulative surge of approximately +1.13°C, reflecting an overall warming trend across the Balochistan province.

The PR ranges from approximately 50.00 mm to 400.00 mm, displaying substantial interannual variability with no clear long-term pattern. The trend line indicates a slight decrease of -8.77 mm per decade, corresponding to a cumulative decline of approximately -39.50 mm during the analysed period. However, this trend is not statistically significant, suggesting that annual precipitation remains highly variable without a discernible long-term trend during 1981-2025 over the Balochistan province.

Annual fog days also exhibit a statistically significant increasing trend, with a magnitude of +0.77 days per decade, indicating a gradual increase in fog occurrence in the Balochistan province.

# 4. DISCUSSIONS

Analyses performed in this report highlight that climate trends across Pakistan display distinct regional and seasonal variations. Recent literature supports these findings and state critical implications attributed to such variations in the climate. Maximum temperatures have increased from late winter to early spring across northern KP, GB, northcentral Punjab, parts of northern Balochistan and Sindh, that could increase risk of early snowmelt, heat stress, and premature crop

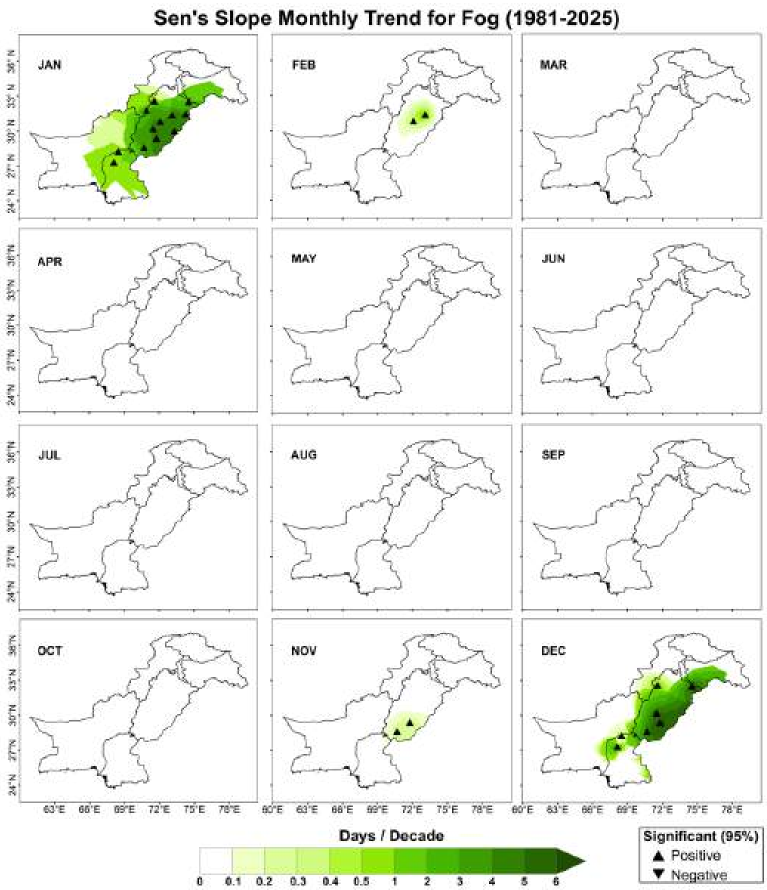



*Figure 41: Evidence of increasing trends in fog during December and January, attributed to cooling of maximum temperatures in Punjab and Sindh during these months.*

development[14]. In GB, snow cover has decreased during spring months, while temperatures have generally increased. As per Satti et al., (2023)[15] strong negative correlation exists between snow cover and temperature, indicating that decreased snow cover (reduced albedo) is allowing more solar radiation to be absorbed by the surfaces over GB, thereby accelerating local warming through snow-albedo feedback. This feedback loop intensifies melting of seasonal snowpacks, undermining the region's capacity to store water in colder months and raising risks for early snowmelt, reduced late-summer water supply, potential shifts in agricultural timing and glacier-fed hydrology in mountainous areas. In contrast, cooling during summer in central and northern Punjab, upper KP, and parts of GB is linked to intensified monsoon activity and cloud cover[16], potentially disrupting energy demand and agricultural water management.

The observed warming trend from February to November in southern Punjab, Sindh, and Balochistan may be associated with urban heat island effects, land-use changes, and regional climate forcing[17], leading to increased heatwave frequency, night-time heat stress, and vector-borne disease risks in urban and suburban zones. However, localized winter cooling persists in northern KP and GB, which could still pose frost risks to winter crops and affect glacial stability[18]. It was further seen that temperatures also followed increasing trends, showing notable warming during spring and autumn across southern and central regions, hence increasing evapotranspiration stress and irrigation demand. Meanwhile weaker winter cooling trends, associated with fog in Punjab and Sindh (Figures 41, 42, 43, and 44) could have affected chilling requirements for certain

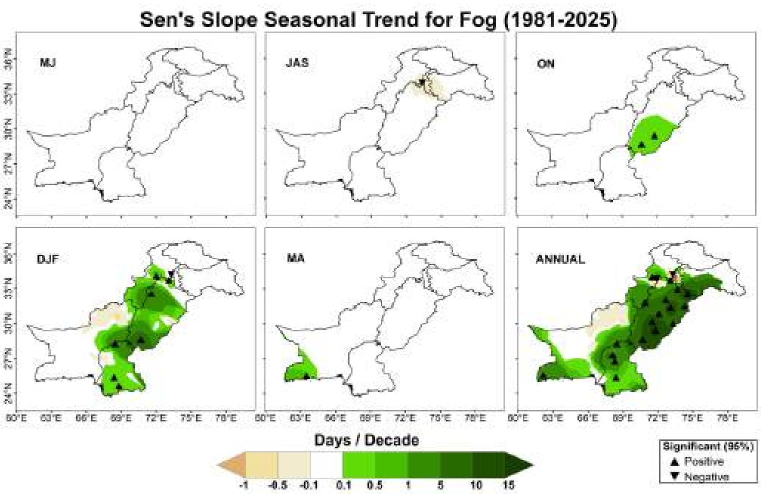



Figure 42: *Same as in Figure 41, but on seasonal basis.*

14 Bhattarai, S., Chiang, J. L., & Upadhyaya, S. (2023). Effectiveness of snow harvesting and water productivity practices in combatting climate change-induced drought in a Himalayan district of Nepal. Irrigation and Drainage, 72(2), 554-568.

15 Satti, Z., Naveed, M., Shafeeque, M., Ali, S., Abdullaev, F., Ashraf, T. M., ... & Li, L. (2023). Effects of climate change on vegetation and snow cover area in Gilgit Baltistan using MODIS data. Environmental Science and Pollution Research, 30(7), 19149-19166.

16 Ghausi, S. A., Ghosh, S., & Kleidon, A. (2022). Breakdown in precipitation-temperature scaling over India predominantly explained by cloud-driven cooling. Hydrology and Earth System Sciences, 26(16), 4431-4446.

17 Zarghamipour, M., & Malakooti, H. (2025). The projected effects of urbanization and climate change on urban Heat Island and thermal comfort over the Tehran metropolitan. Science of The Total Environment, 992, 179955.

18 Latif, Y., Yaoming, M., Yaseen, M., Muhammad, S., & Wazir, M. A. (2020). Spatial analysis of temperature time series over the Upper Indus Basin (UIB) Pakistan. Theoretical & Applied Climatology, 139.

crops[19]. In terms of precipitation, monsoonal rainfall has increased in eastern Punjab and southern Sindh, potentially increasing the risk of urban and flash flooding, especially in low-lying urban centres like Lahore, Multan, and Karachi. In contrast, precipitation during spring, late summer, and early winter has declined in northern KP, upper Punjab, and GB, due to weakened western disturbances and shifting jet stream patterns[20]. Research across Pakistan shows increasing daily monsoon precipitation extremes tied to shifts in atmospheric circulation[21], increasing flood risk, undermining food security, damaging economies, disrupting livelihoods and water systems. This significantly threatens water resource availability, glacier recharge, and early season agriculture in mountainous and upstream catchments[22].

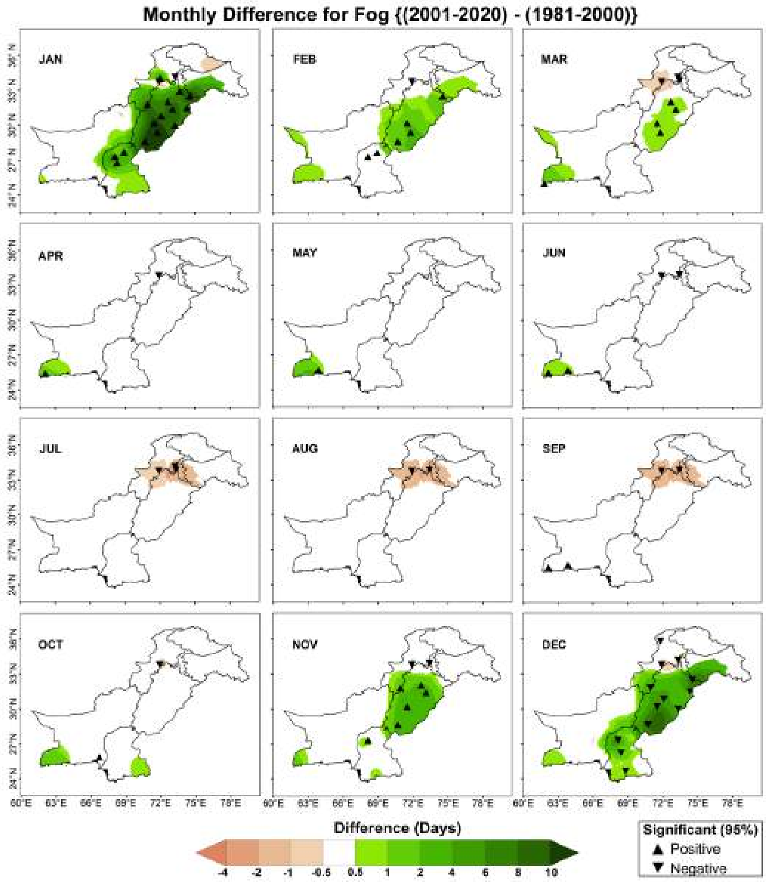



*Figure 43: Climatology of fog composites advocating significant increase in recurrences of fog events in the historically observed years of the 21st century, as compared to those historically observed years of the 20th century.*

19 Yasmeen, Z., Rasul, G., & Zahid, M. (2012). Impact of aerosols on winter fog of Pakistan. Pakist Meteorol, 8(16).

20 Ahmed, F., Adnan, S., & Latif, M. (2020). Impact of jet stream and associated mechanisms on winter precipitation in Pakistan. Meteorology and Atmospheric Physics, 132(2), 225-238.

21 Ullah, W., Karim, A., Ullah, S., Rehman, A. U., Bibi, T., Wang, G., ... & Hussain, A. (2023). An increasing trend in daily monsoon precipitation extreme indices over Pakistan and its relationship with atmospheric circulations. Frontiers in Environmental Science, 11, 1228817.

22 Muzammal, H., Zaman, M., Safdar, M., Adnan Shahid, M., Sabir, M. K., Khil, A., ... & Zaib, A. (2024). Climate change impacts on water resources and implications for agricultural management. In Transforming agricultural management for a sustainable future: Climate change and machine learning perspectives (pp. 21-45). Cham: Springer Nature Switzerland.

Seasonal climate trends in Pakistan have shown notable regional and seasonal variations, with maximum temperatures rising by up to +0.6 °C per decade during spring and winter in Balochistan and Sindh, making these southern provinces increasingly vulnerable to heat stress, urban flooding from following intensified monsoons, and pressure on water and energy infrastructure[23]. Meanwhile, localized cooling during pre-monsoon and monsoon seasons in central and northern regions coincides with shifting rainfall patterns and has affected agricultural planning[24].

In Sindh, rising counts of hot days and warm nights, alongside warming trends in maximum and minimum temperatures, have stressed agriculture, reducing rice yields, affecting fisheries and mangrove ecosystems, and increasing groundwater extraction, which in turn depletes aquifers and undermines local economies[25]. Across AJK, KP, parts of Punjab, Sindh, and Balochistan, significant upticks in heatwaves and cooling degree days demonstrate worsening heat exposure[26]. These trends directly translate into higher cooling energy demands, increased urban heat stress, and greater health risks, especially for vulnerable populations. In GB and the broader Himalayan highlands of Pakistan, analyses in this report have revealed a significant increase in diurnal temperature range. This shift undermines the cryosphere, as elevated diurnal temperature range can accelerate glacial and snowpack melt, destabilizing meltwater storage and promote earlier-season runoff, thereby threatening late-summer water availability for irrigation, hydropower, and

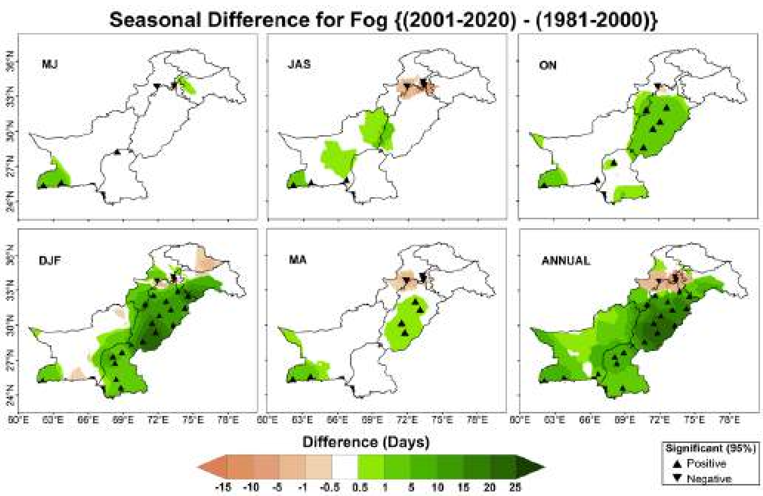



*Figure 44: Same as in Figure 43, but on seasonal basis.*

23 Wells, C., Petty, C., Saggioro, E., & Cornforth, R. J. (2023). Pakistan climate change impact storylines based on existing literature. Zenodo, 1-117.

24 Safdar, F., Khokhar, M. F., Mahmood, F., Khan, M. Z. A., & Arshad, M. (2023). Observed and predicted precipitation variability across Pakistan with special focus on winter and pre-monsoon precipitation. Environmental Science and Pollution Research, 30(2), 4510-4530.

25 Abbas, F., Rehman, I., Adrees, M., Ibrahim, M., Saleem, F., Ali, S., ... & Salik, M. R. (2018). Prevailing trends of climatic extremes across Indus-Delta of Sindh-Pakistan. Theoretical and applied climatology, 131(3), 1101-1117.

26 Sajjad, H., & Ghaffar, A. (2019). Observed, simulated and projected extreme climate indices over Pakistan in changing climate. Theoretical and Applied Climatology, 137(1), 255-281.

ecosystems[27]. Additionally, increasingly variable temperatures disrupt traditional agricultural cycles by shifting flowering and harvesting schedules, increasing pest pressures, and reducing yields in fruit- and cereal-dependent communities[28].

Precipitation extremes in Pakistan have shown marked regional variability, with distinct hydrological and socio-environmental consequences. Southern Sindh, where the daily intensity index reaches 20+ mm/day, faces heightened risks of flash flooding, infrastructure damage, and disruption of livelihoods[29]. In KP and AJK, significant increases in daily rainfall intensity and the greatest 5-day cumulative totals exacerbate flood hazards, slope instability, and erosion, particularly in mountainous terrain[30]. Conversely, upper KP shows declining trends in daily intensity, potentially reducing flood risk but raising concerns over diminished water supply reliability. Eastern Punjab's increasing 5-day rainfall totals elevate the likelihood of urban flooding and waterlogging, impacting agriculture and drainage systems[31]. Despite KP and AJK recording the highest frequency of consecutive wet days, decreasing trends suggest shorter sustained wet spells, which may affect groundwater recharge and river base flows. Meanwhile, Balochistan and Sindh, where prolonged dry spells remain most common, continue to face agricultural drought risk and water scarcity[32], despite insignificant reductions in dry-spell duration. Heavy rainfall days (≥150 mm) in AJK and northeastern Punjab, though not showing any trends, still pose periodic flood risks that demand robust adaptation planning[33].

27 Zafar, U., Anjum, M. N., Hussain, S., Sultan, M., Rasool, G., Riaz, M. Z. B., ... & Asif, M. (2024). Analyzing the spatiotemporal changes in climatic extremes in cold and mountainous environment: Insights from the Himalayan mountains of Pakistan. Atmosphere, 15(10), 1221.

28 https://www.southasiamonitor.org/spotlight/now-climate-change-hits-farmers-mountainous-areas-pakistan

29 Buriro, T. Z., & un nisa Jatoi, Q. (2025). Pakistan's Flood Management Strategies: A Critical Review of Disaster Preparedness, Response, and Risk Mitigation. Metallurgical and Materials Engineering, 31(4), 84-90.

30 Mir, R. A., Aziz, K., Singh, S., Sharma, I., Shah, Z. A., & Ahmed, R. (2025). Pre-and post-landslide phenomena in Pernote area, Ramban District, Jammu and Kashmir, India: implications for early warning, mitigation, and preparedness. Landslides, 22(5), 1577-1596.

31 Bezdan, J., Bezdan, A., Blagojević, B., Antić, S., Greksa, A., Milić, D., & Lipovac, A. (2024). Impact of climate change on extreme rainfall events and pluvial flooding risk in the Vojvodina region (North Serbia). Atmosphere, 15(4), 488.

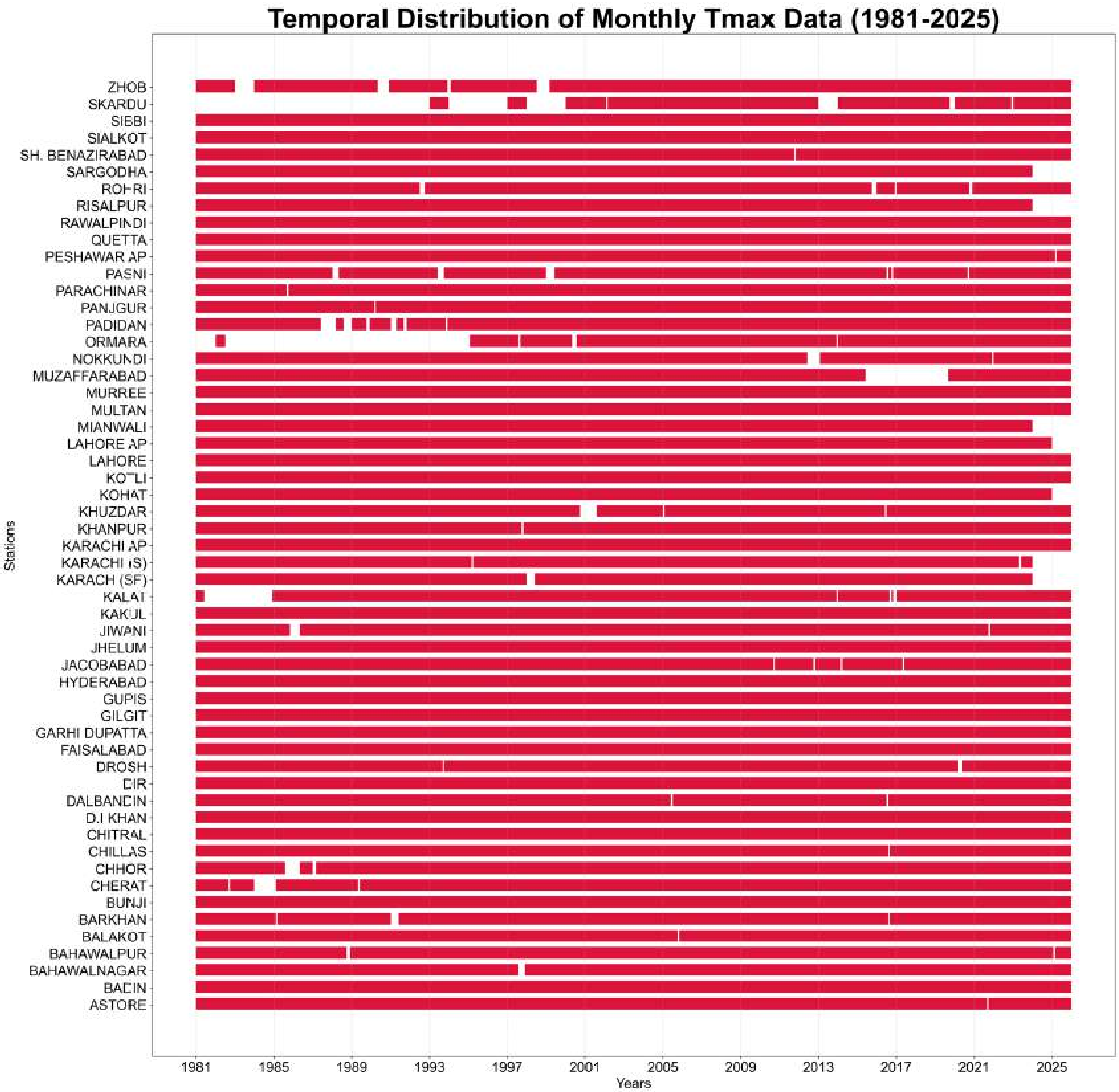
32 Qasim, M., Ahmed, K., Jan, A., Khan, N., & Ali, A. M. (2025). Spatiotemporal pattern of climatic water balance over Balochistan, Pakistan for the period 1961-2016. Theoretical and Applied Climatology, 156(2), 110.

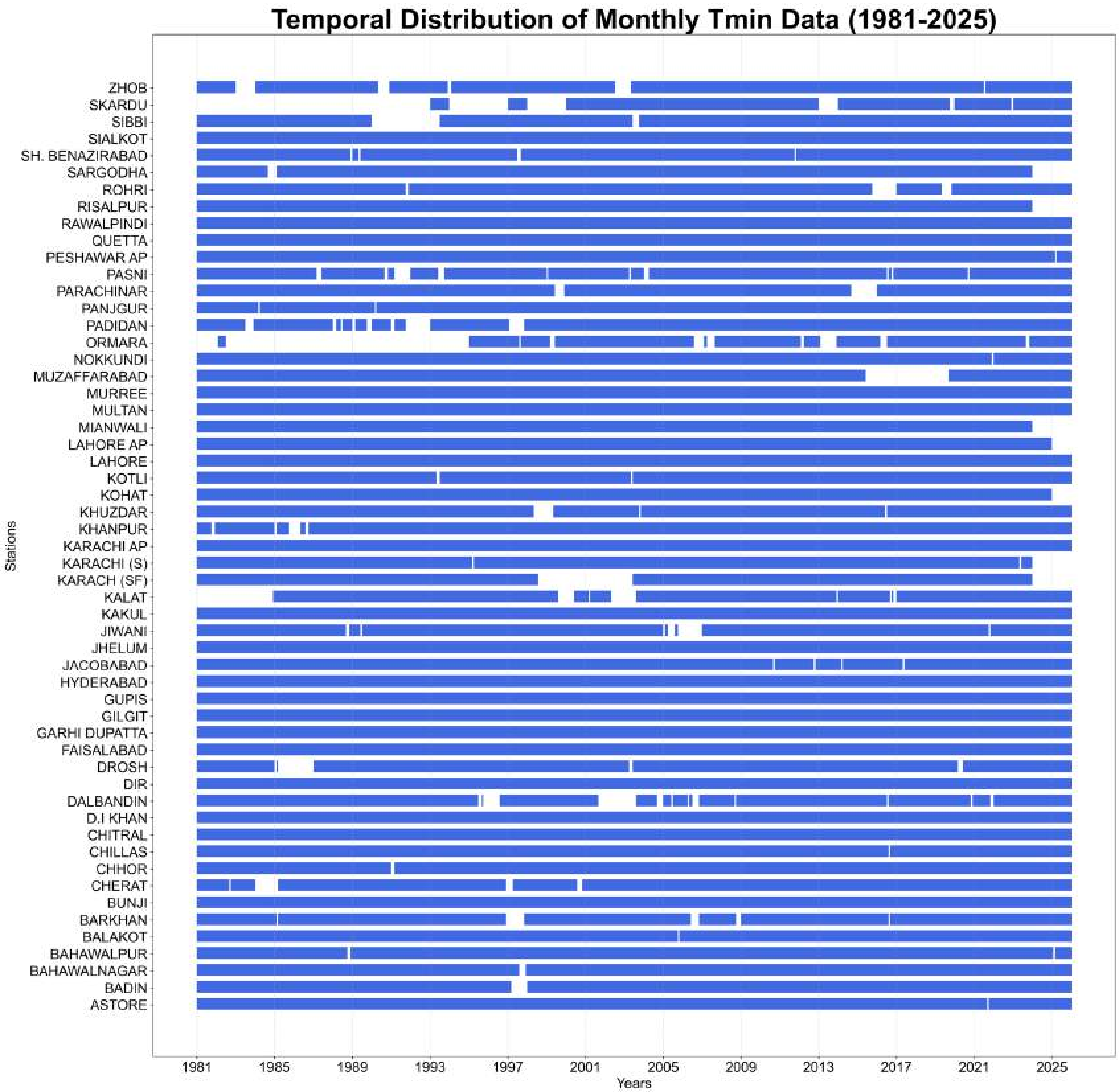
33 Khan, A. A., Aqsa, T., & Shahid, M. A. (2024). Flood pattern variation in Pakistan: a comprehensive study on water quantity and rainfall data from 1992 to 2022. Pakistan Research Journal of Social Sciences, 3(2).

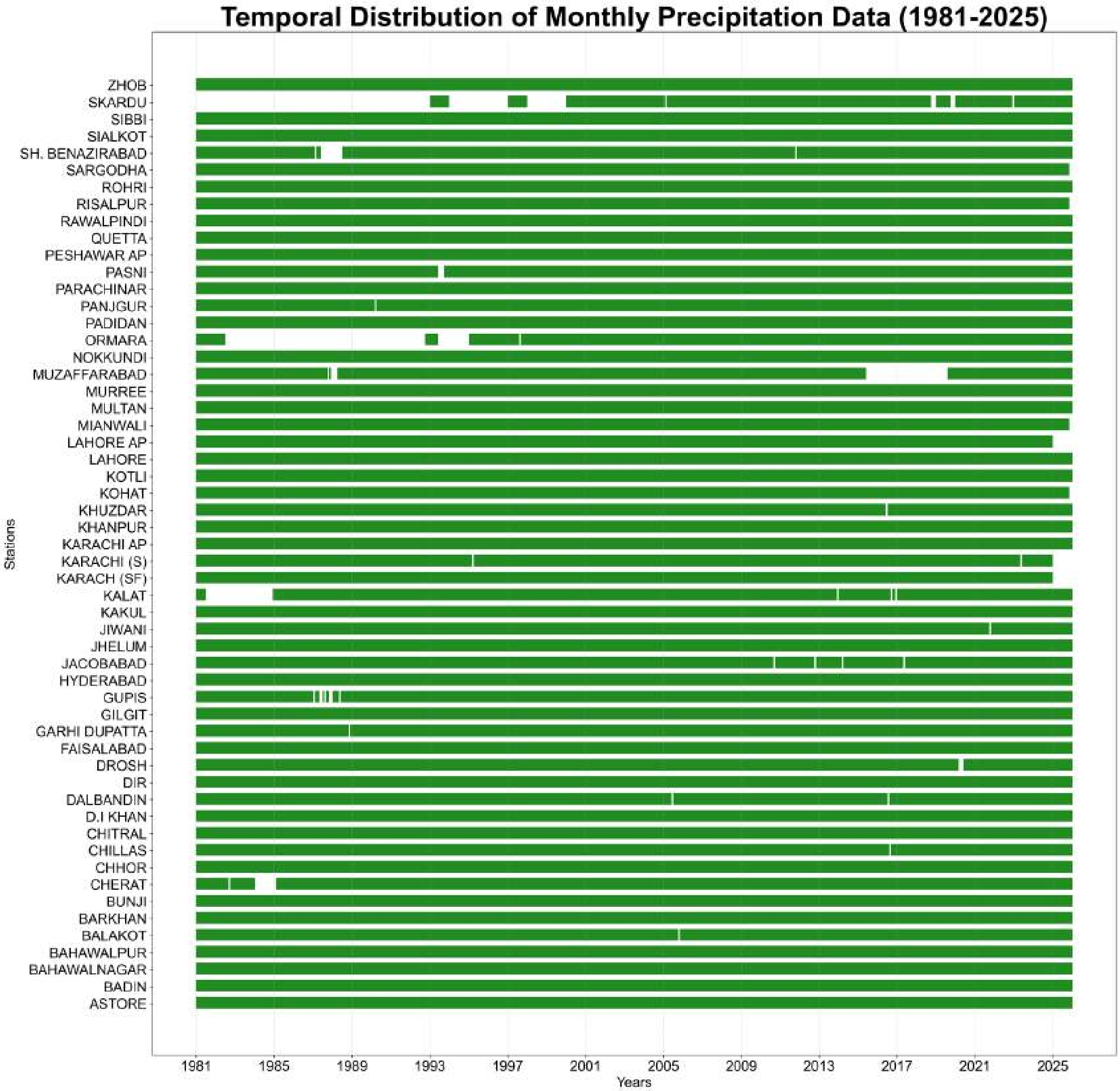
# 5. ANNEXURES

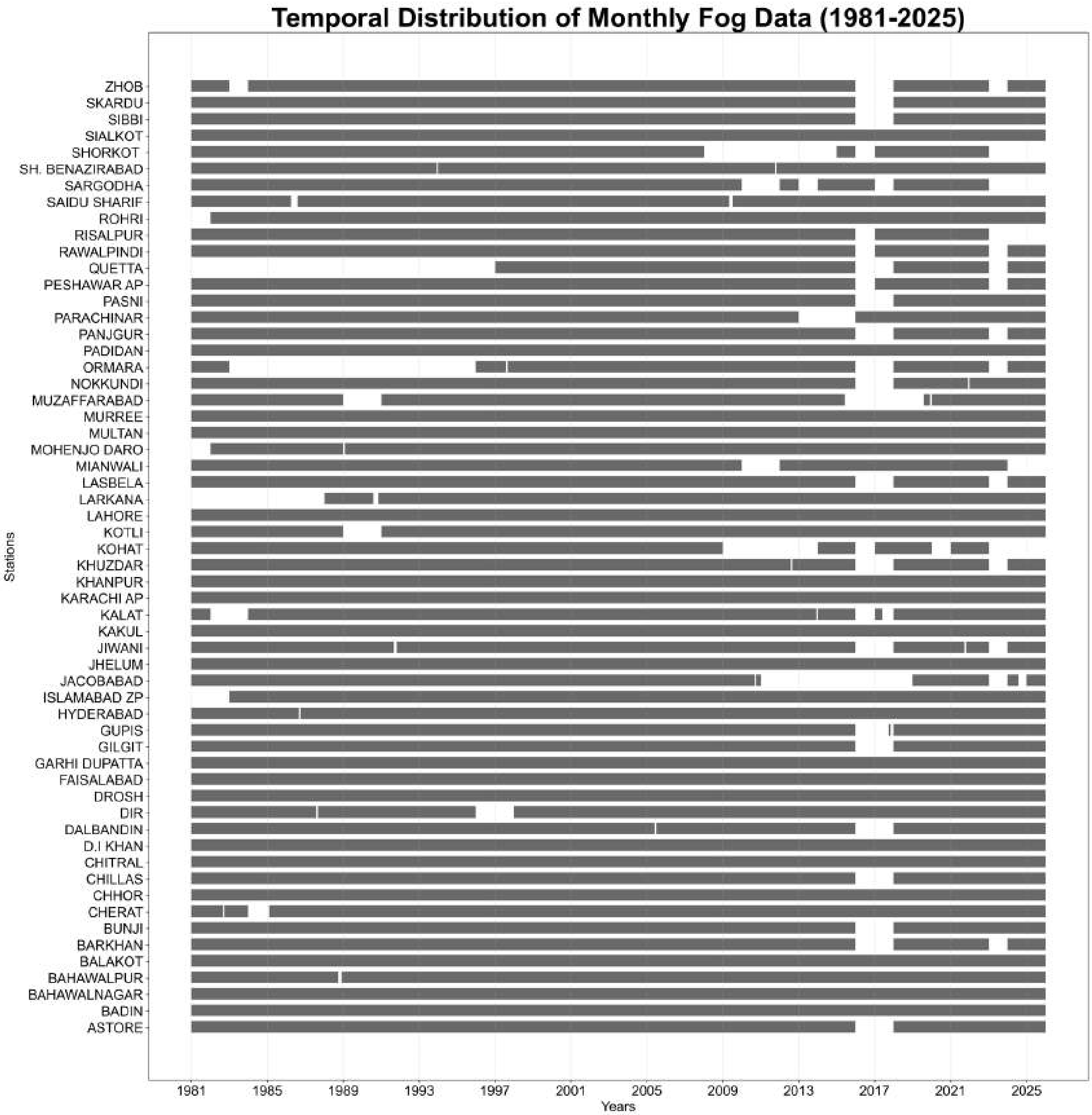
## Annexure-I

Data availability of climatic variables used in the study.




Temporal Distribution of Monthly Tmin Data (1981-2025)
ZHOB
SKARDU
SIBBI
SIALKOT
SH. BENAZIRABAD
SARGODHA
ROHRI
RISALPUR
RAWALPINDI
QUETTA
PESHAWAR AP
PASNI
PARACHINAR
PANJGUR
PADIDAN
ORMARA
NOKKUNDI
MUZAFFARABAD
MURREE
MULTAN
MIANWALI
LAHORE AP
LAHORE
KOTLI
KOHAT
KHUZDAR
KHANPUR
KARACHI AP
KARACHI (S)
KARACH (SF)
KALAT
KAKUL
JIWANI
JHELUM
JACOBABAD
HYDERABAD
GUPIS
GILGIT
GARHI DUPATTA
FAISALABAD
DROSH
DIR
DALBANDIN
D.I KHAN
CHITRAL
CHILLAS
CHHOR
CHERAT
BUNJI
BARKHAN
BALAKOT
BAHAWALPUR
BAHAWALNAGAR
BADIN
ASTORE
Stations
1981
1985
1989
1993
1997
2001
2005
2009
2013
2017
2021
2025
Years


Temporal Distribution of Monthly Precipitation Data (1981-2025)
ZHOB
SKARDU
SIBBI
SIALKOT
SH. BENAZIRABAD
SARGODHA
ROHRI
RISALPUR
RAWALPINDI
QUETTA
PESHAWAR AP
PASNI
PARACHINAR
PANJGUR
PADIDAN
ORMARA
NOKKUNDI
MUZAFFARABAD
MURREE
MULTAN
MIANWALI
LAHORE AP
LAHORE
KOTLI
KOHAT
KHUZDAR
KHANPUR
KARACHI AP
KARACHI (S)
KARACH (SF)
KALAT
KAKUL
JIWANI
JHELUM
JACOBABAD
HYDERABAD
GUPIS
GILGIT
GARHI DUPATTA
FAISALABAD
DROSH
DIR
DALBANDIN
D.I KHAN
CHITRAL
CHILLAS
CHHOR
CHERAT
BUNJI
BARKHAN
BALAKOT
BAHAWALPUR
BAHAWALNAGAR
BADIN
ASTORE
Stations
1981
1985
1989
1993
1997
2001
2005
2009
2013
2017
2021
2025
Years


Temporal Distribution of Monthly Fog Data (1981-2025)
Stations
ZHOB
SKARDU
SIBBI
SIALKOT
SHORKOT
SH. BENAZIRABAD
SARGODHA
SAIDU SHARIF
ROHRI
RISALPUR
RAWALPINDI
QUETTA
PESHAWAR AP
PASNI
PARACHINAR
PANJGUR
PADIDAN
ORMARA
NOKKUNDI
MUZAFFARABAD
MURREE
MULTAN
MOHENJO DARO
MIANWALI
LASBELA
LARKANA
LAHORE
KOTLI
KOHAT
KHUZDAR
KHANPUR
KARACHI AP
KALAT
KAKUL
JIWANI
JHELUM
JACOBABAD
ISLAMABAD ZP
HYDERABAD
GUPIS
GILGIT
GARHI DUPATTA
FAISALABAD
DROSH
DIR
DALBANDIN
D.I KHAN
CHITRAL
CHILLAS
CHHOR
CHERAT
BUNJI
BARKHAN
BALAKOT
BAHAWALPUR
BAHAWALNAGAR
BADIN
ASTORE
1981
1985
1989
1993
1997
2001
2005
2009
2013
2017
2021
2025
Years

# Annexure-II

## Table AI. Trends (per decade) of extreme climate indices of some particular stations.

| Station\Index | DTR | HW | CDD | CODED | CWD | R150 | SU40 | SDII | TR30 | Rx5day |
|---|---|---|---|---|---|---|---|---|---|---|
| Badin | **-0.27*** | 0.00 | 2.14 | 53.10 | 0.00 | 0.00 | 2.22 | -0.24 | 0.00 | 5.64 |
| Bahawalnagar | -0.09 | 0.00 | 0.59 | **81.09*** | **0.32*** | 0.00 | **3.75*** | **0.64*** | -0.53 | **10.81*** |
| Barkhan | 0.19 | 0.00 | 1.30 | 43.41 | 0.00 | 0.00 | -0.65 | **0.74*** | 0.00 | 3.06 |
| Cherat | 0.04 | 0.00 | 1.15 | 8.57 | 0.00 | 0.00 | **-1.43*** | **0.38*** | 0.00 | **11.94*** |
| Chhor | **-0.48*** | 0.00 | 4.00 | **57.68*** | **0.29*** | 0.00 | 3.79 | -0.18 | 0.00 | 6.27 |
| D.I.Khan A/P | -0.05 | 0.00 | 0.00 | **69.66*** | 0.00 | 0.00 | 2.50 | 0.38 | 0.00 | 4.30 |
| Dalbandin | **0.33*** | **2.06*** | -3.20 | **147.23*** | 0.00 | 0.00 | **7.06*** | 0.12 | 0.00 | 0.57 |
| Dir | **0.44*** | **3.91*** | 0.48 | **114.07*** | 0.00 | 0.00 | 0.00 | **-1.22*** | 0.00 | -7.29 |
| Gilgit | 0.02 | 1.88 | -3.55 | 41.85 | 0.00 | 0.00 | -1.11 | -0.20 | 0.00 | -1.54 |
| Gupis | **0.69*** | 0.00 | **-12.89*** | 33.28 | 0.00 | 0.00 | 0.00 | **-0.75*** | 0.00 | -3.30 |
| Islamabad A/P | -0.14 | 0.00 | 1.36 | -10.96 | 0.00 | 0.00 | **-1.90*** | -0.36 | 0.00 | -5.32 |
| Jiwani | **0.34*** | 0.00 | 5.00 | **115.06*** | 0.00 | 0.00 | 0.00 | **0.70*** | 0.00 | 0.00 |
| Karachi A/P | **-0.31*** | 0.00 | -3.75 | **98.92*** | 0.00 | 0.00 | 0.71 | 0.44 | 0.00 | 7.82 |
| Khanpur | **-0.52*** | 0.00 | -1.00 | 51.88 | 0.00 | 0.00 | -0.37 | 0.63 | **2.96*** | 4.62 |
| Khuzdar | -0.13 | 0.00 | -1.88 | **65.28*** | 0.00 | 0.00 | 0.00 | 0.19 | 0.00 | 1.80 |
| Kotli | 0.02 | 0.00 | **4.38*** | **65.39*** | **-0.50*** | 0.00 | 0.00 | **0.98*** | 0.00 | -2.36 |
| Lahore A/P | **-0.36*** | 0.00 | 4.62 | -22.87 | 0.00 | 0.00 | **-2.69*** | **0.47*** | 0.30 | **21.28*** |
| Mianwali A/B | **-0.51*** | 0.00 | 1.36 | -41.50 | **-0.28*** | 0.00 | **-4.21*** | 0.13 | 0.00 | -1.14 |
| Multan A/P | **-0.70*** | 0.00 | -1.36 | **-78.62*** | 0.00 | 0.00 | **-5.38*** | 0.19 | **4.00*** | -0.03 |
| Muzaffarabad A/P | **0.30*** | 0.00 | 1.67 | 23.52 | **-0.77*** | 0.00 | -1.00 | **1.29*** | 0.00 | 3.82 |
| Nokkundi | -0.10 | **1.76*** | 0.00 | **102.22*** | 0.00 | 0.00 | **3.33*** | -0.07 | **3.75*** | -0.41 |
| Padidan | **-0.56*** | 0.00 | -5.19 | 21.10 | 0.00 | 0.00 | 3.33 | 0.43 | 0.29 | 3.18 |
| Panjgur | 0.07 | 0.00 | -2.22 | **117.88*** | 0.00 | 0.00 | 2.50 | -0.09 | 0.00 | -1.10 |
| Parachinar | **0.63*** | **3.60*** | 2.14 | **61.08*** | 0.00 | 0.00 | 0.00 | **0.78*** | 0.00 | 0.00 |
| Peshawar A/B | **-0.39*** | 0.00 | -0.53 | -8.20 | 0.00 | 0.00 | **-2.86*** | -0.05 | 0.00 | -2.17 |
| Quetta (Samungli) | **-0.12** | **1.43*** | -2.50 | **77.67*** | 0.00 | 0.00 | 0.00 | **-0.50*** | 0.00 | -3.85 |
| Rohri | **-0.50*** | 0.00 | -6.67 | 55.84 | 0.00 | 0.00 | **3.33*** | 0.35 | **5.00*** | 4.47 |
| Sargodha A/B | **-0.56*** | 0.00 | -0.74 | -40.57 | 0.00 | 0.00 | **-4.40*** | 0.17 | 0.77 | 0.50 |
| Sialkot A/P | **-0.24*** | 0.00 | 2.67 | 50.59 | 0.00 | 0.00 | -0.67 | 0.49 | 0.00 | 7.26 |
| Skardu | 0.17 | 0.00 | -5.00 | -16.79 | 0.00 | 0.00 | 0.00 | 0.09 | 0.00 | -0.41 |
| Zhob | 0.11 | **1.00*** | -3.64 | 54.80 | 0.00 | 0.00 | 0.23 | 0.11 | 0.00 | -0.99 |

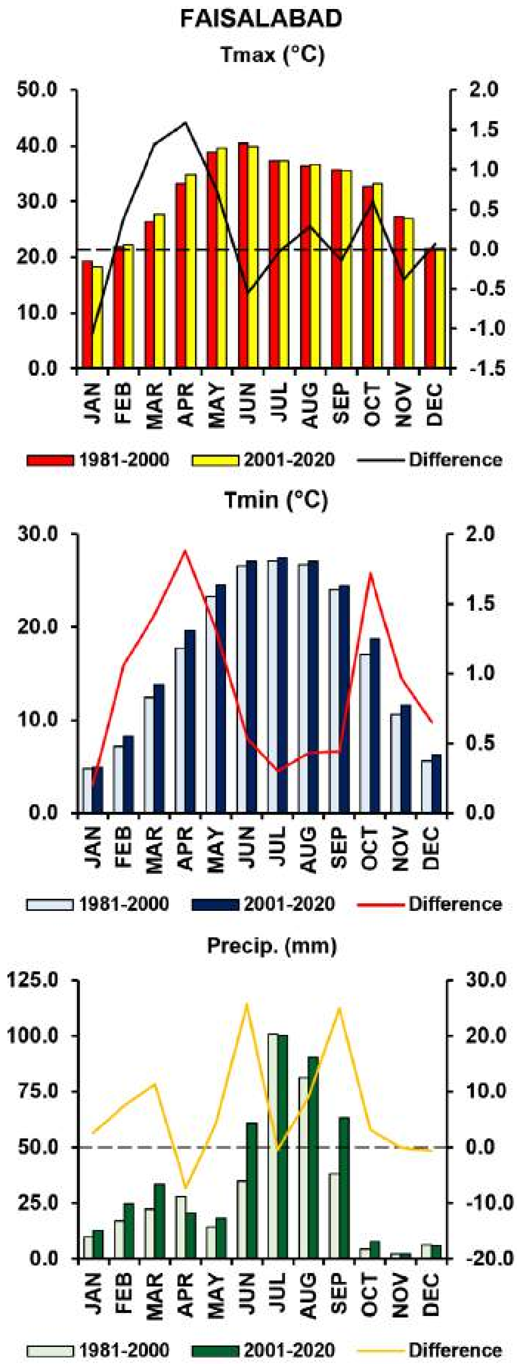
The results with asterisk "*" are significant at the 95% confidence level. Orange cells represent increasing while blue cells represent decreasing trends.

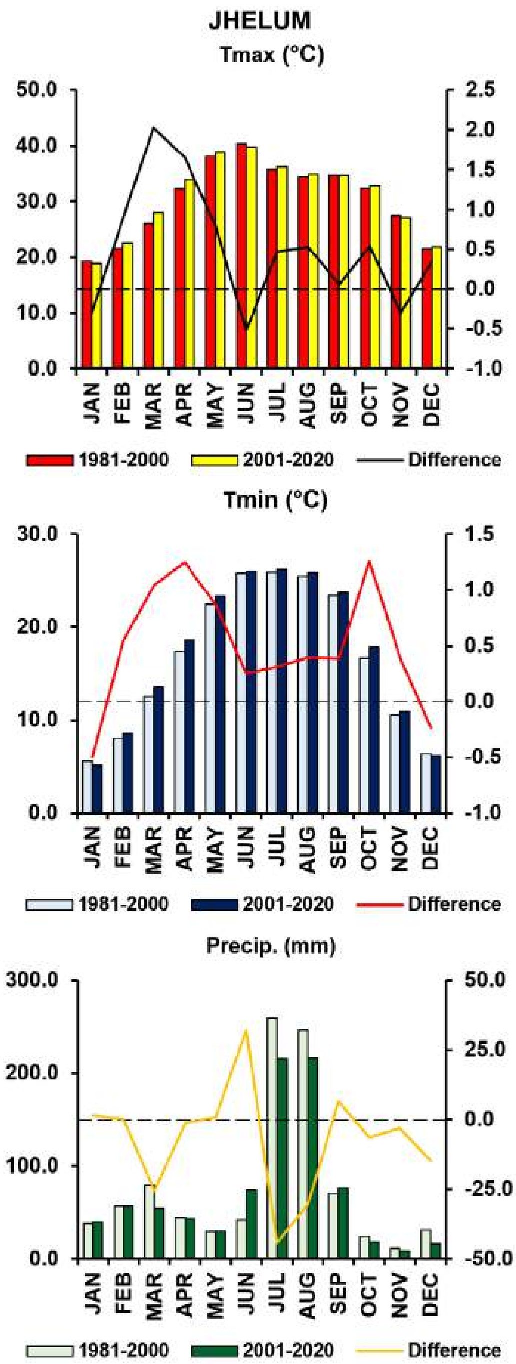
# Annexure-III

Station-wise annual cycles of maximum temperature (Tmax), minimum temperature (Tmin) and precipitation (Precip.) for the 1981-2000 and 2001-2020 periods. The lines show the difference (2001-2020 minus 1981-2000) between these periods.

## Punjab

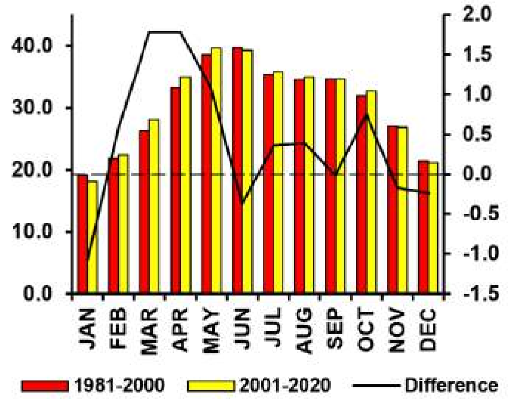
### North Punjab



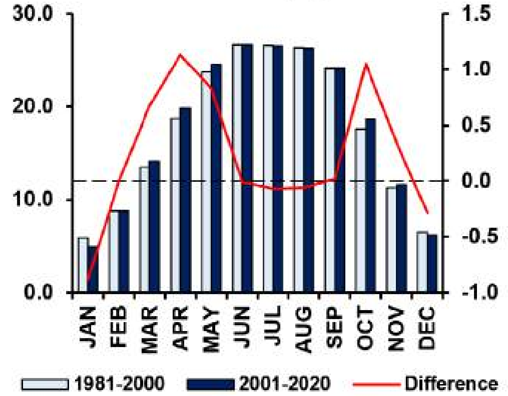



## LAHORE AIRPORT

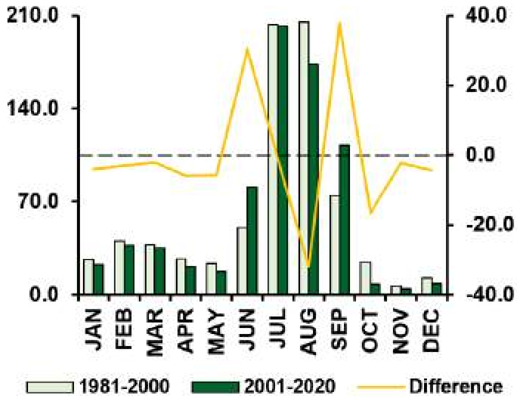
Tmax (°C)




Tmin (°C)

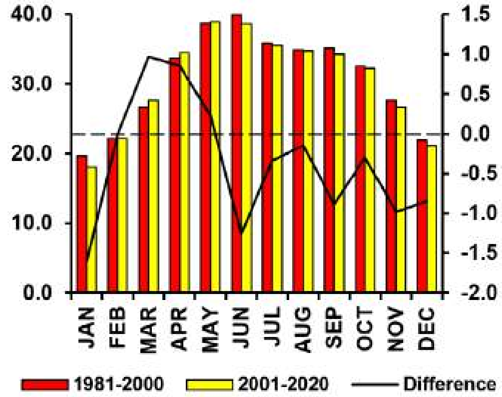



Precip. (mm)

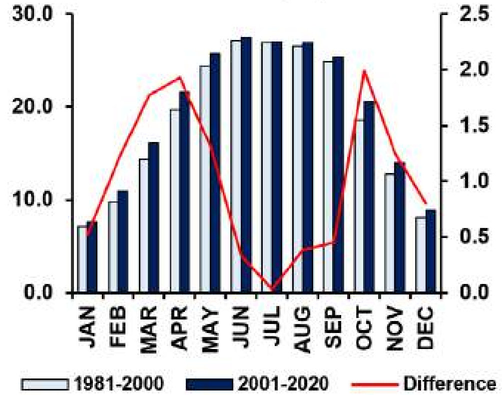



## LAHORE

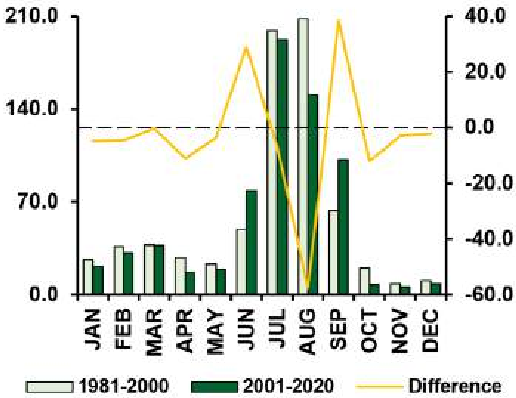
Tmax (°C)



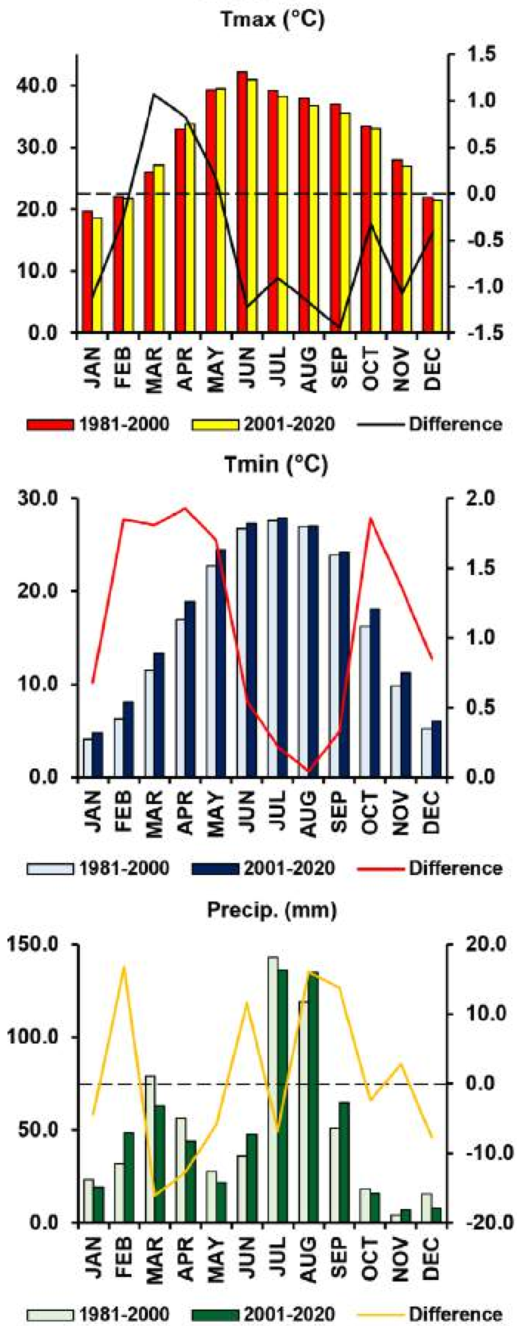

Tmin (°C)



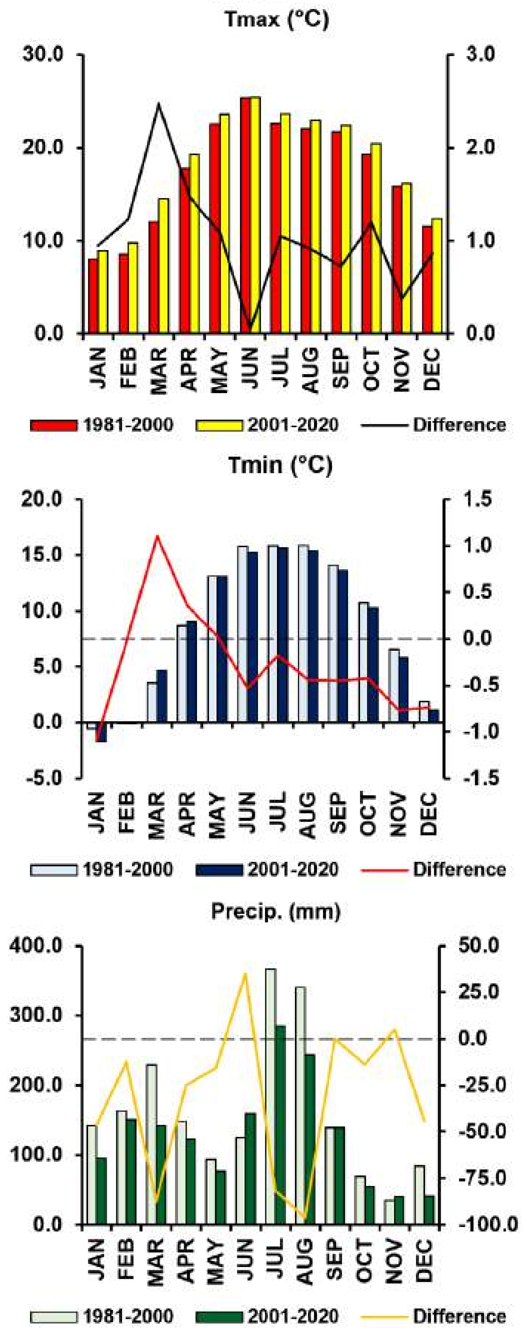

Precip. (mm)

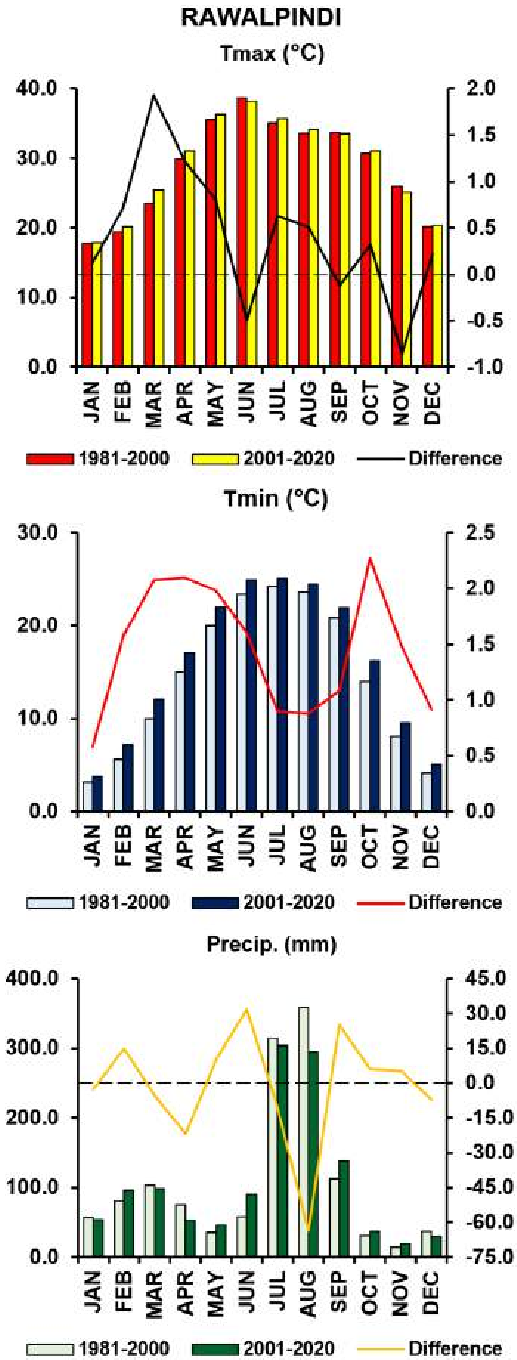


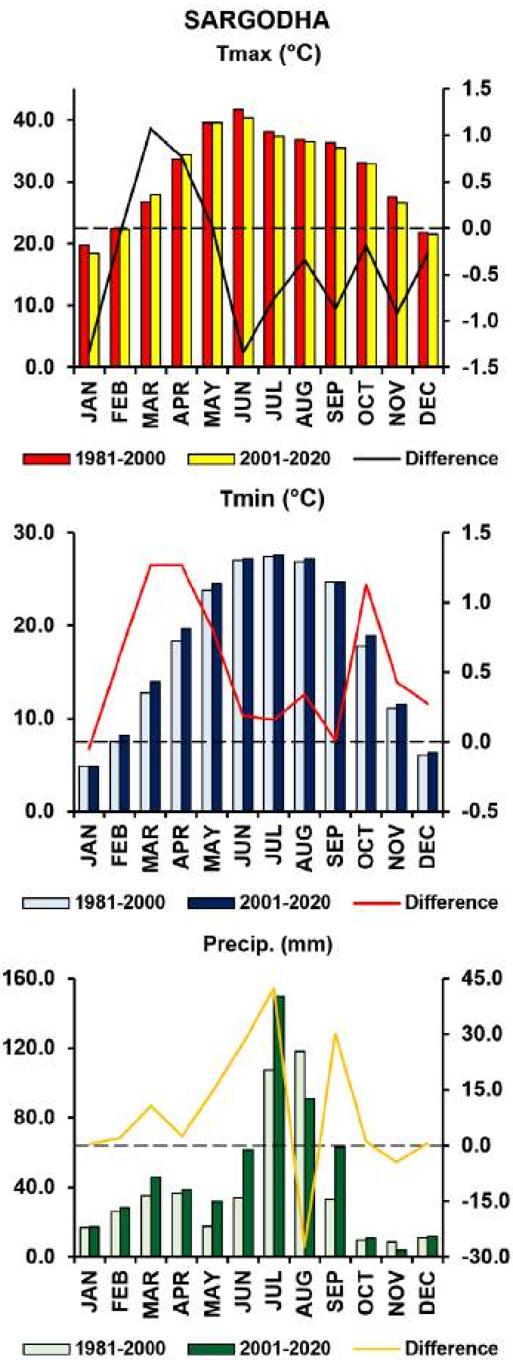
**MIANWALI**

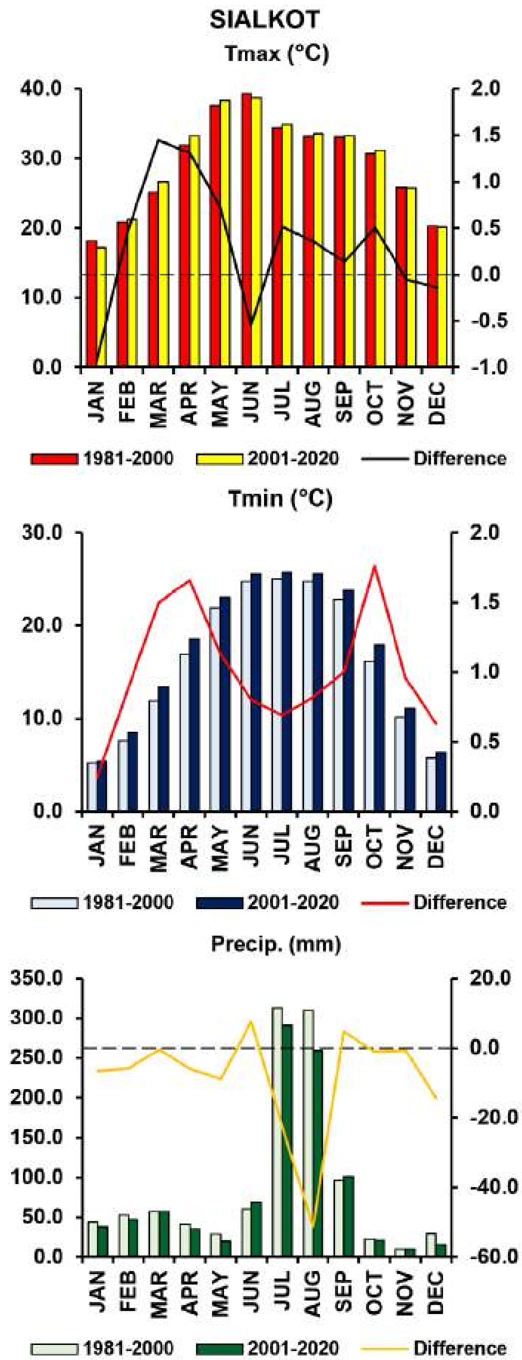



**MURREE**

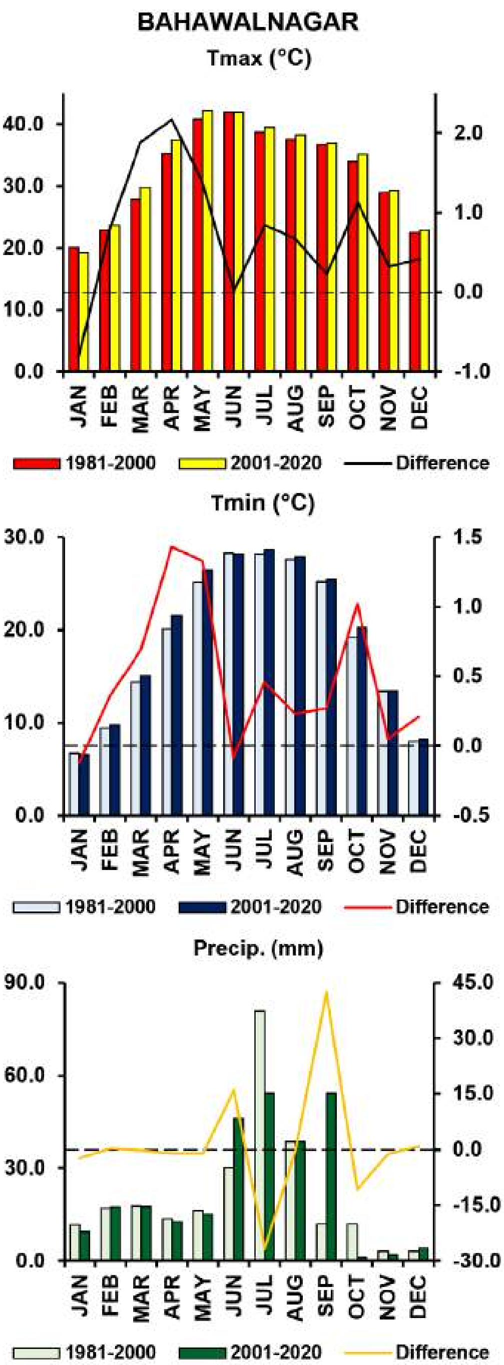


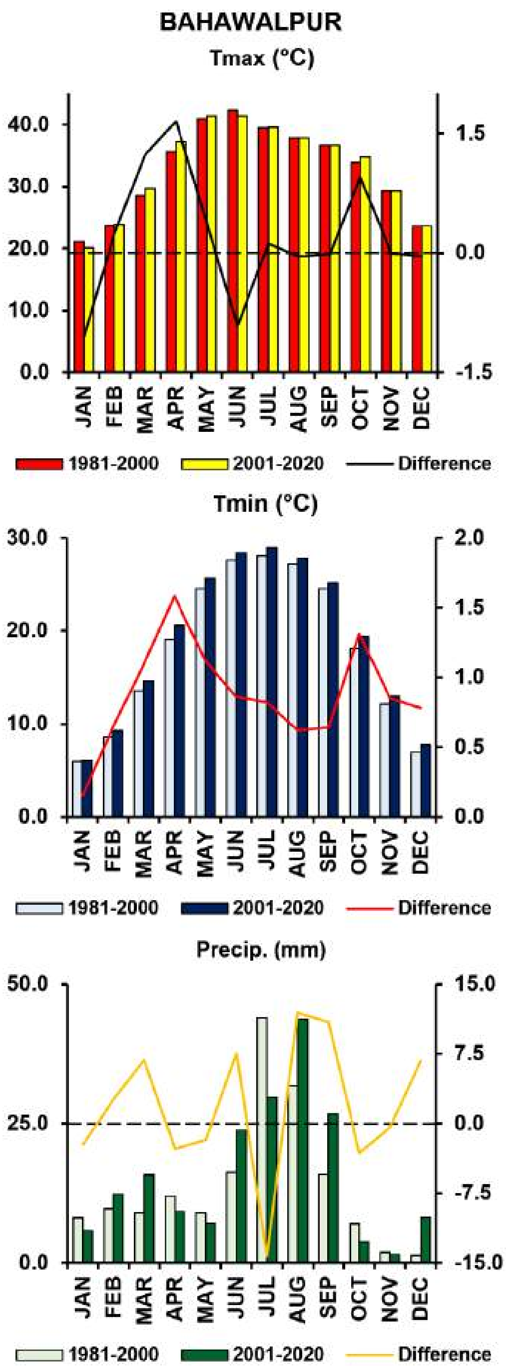

RAWALPINDI
Tmax (°C)
1981-2000
2001-2020
Difference
Tmin (°C)
1981-2000
2001-2020
Difference
Precip. (mm)
1981-2000
2001-2020
Difference
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC


SARGODHA
Tmax (°C)
1981-2000
2001-2020
Difference
Tmin (°C)
1981-2000
2001-2020
Difference
Precip. (mm)
1981-2000
2001-2020
Difference
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

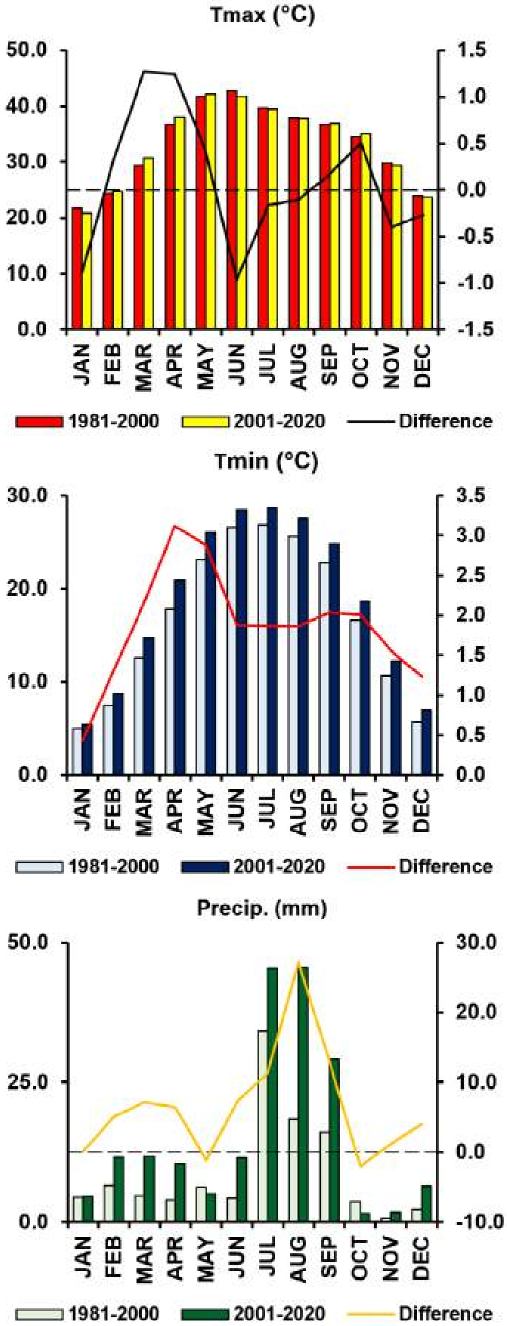

SIALKOT
Tmax (°C)
1981-2000
2001-2020
Difference
Tmin (°C)
1981-2000
2001-2020
Difference
Precip. (mm)
1981-2000
2001-2020
Difference
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

## South Punjab

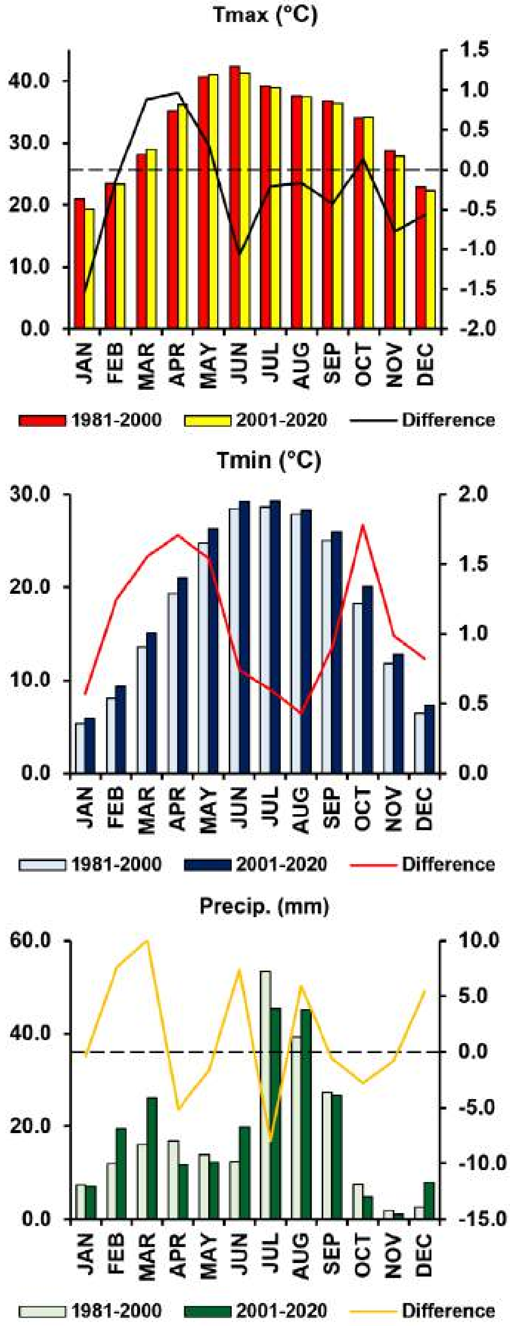


## KHANPUR

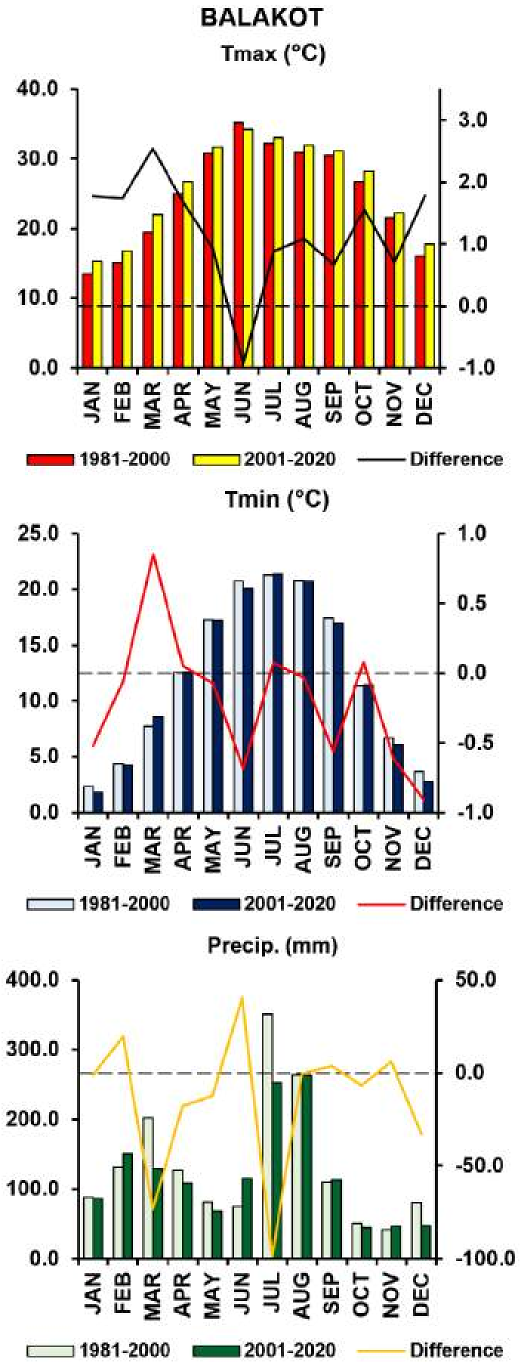


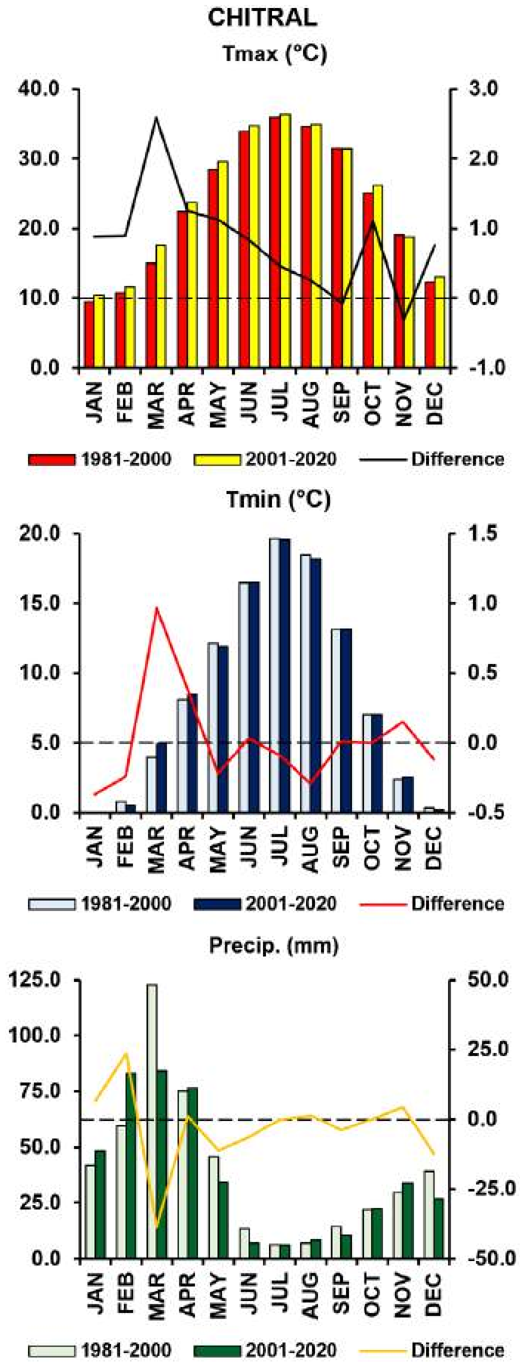

## MULTAN



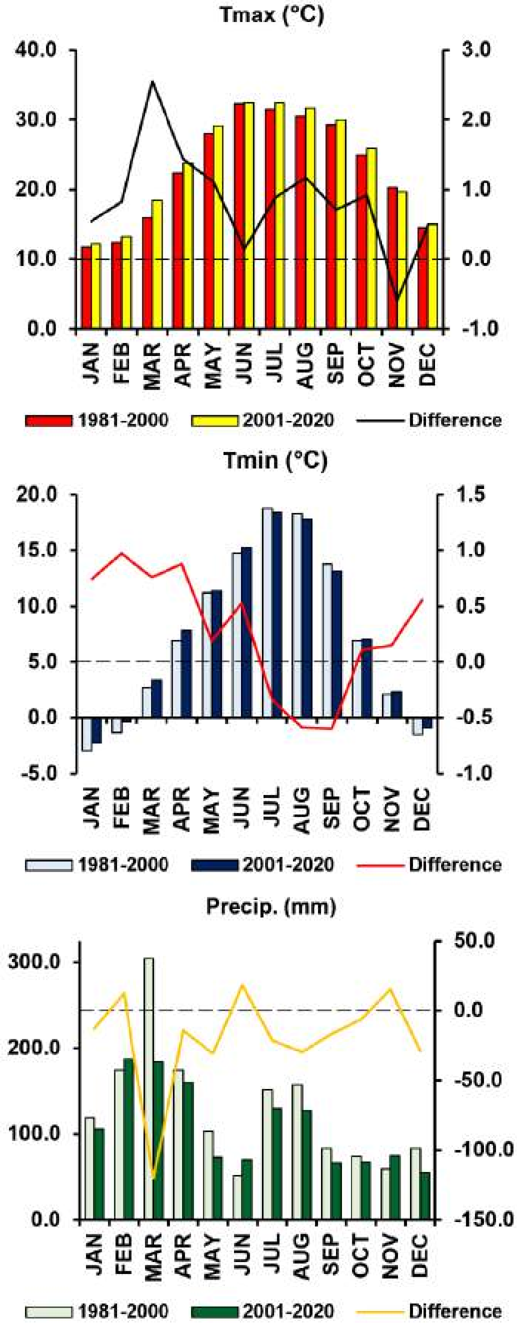
# Khyber Pakhtunkhwa

## North Khyber Pakhtunkhwa

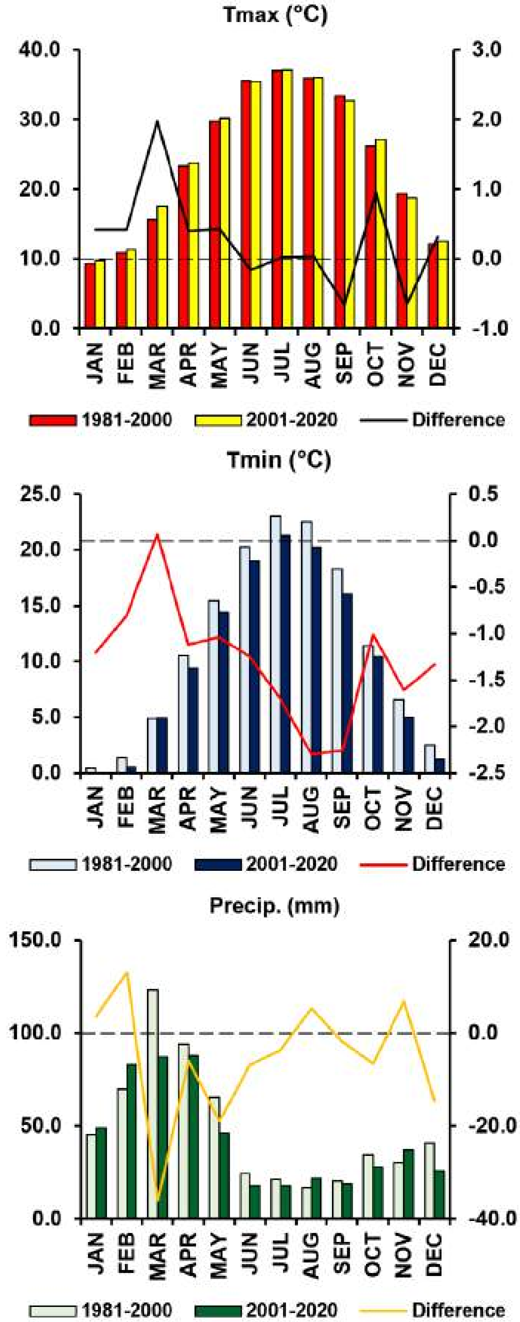


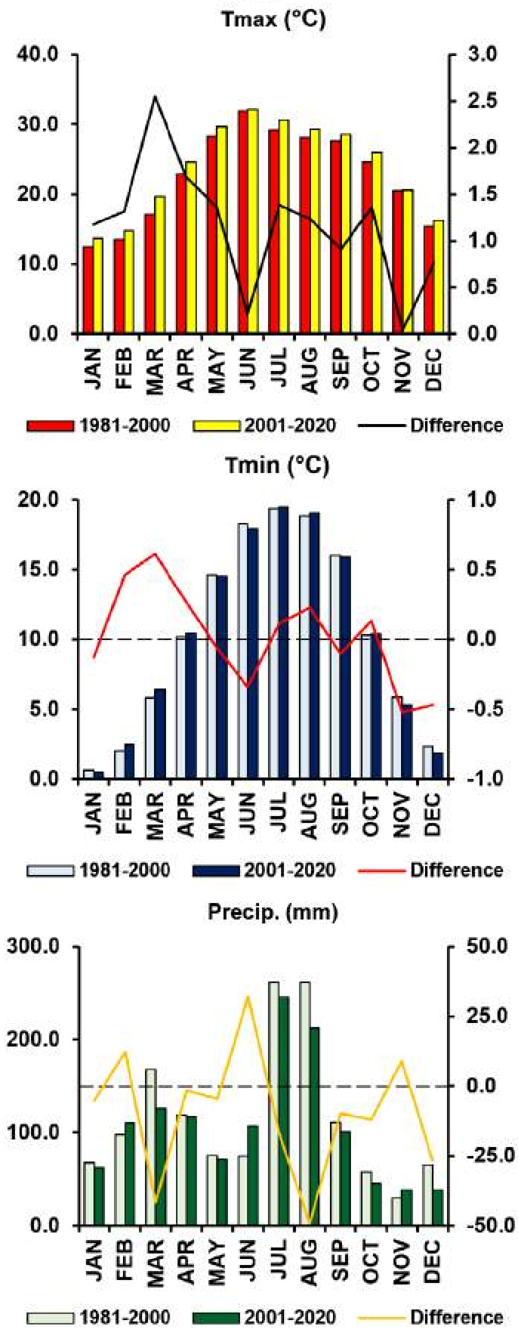
## DIR


Tmax (°C)
40.0
30.0
20.0
10.0
0.0
3.0
2.0
1.0
0.0
-1.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1981-2000
2001-2020
Difference
Tmin (°C)
20.0
15.0
10.0
5.0
0.0
-5.0
1.5
1.0
0.5
0.0
-0.5
-1.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1981-2000
2001-2020
Difference
Precip. (mm)
300.0
200.0
100.0
0.0
50.0
0.0
-50.0
-100.0
-150.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1981-2000
2001-2020
Difference

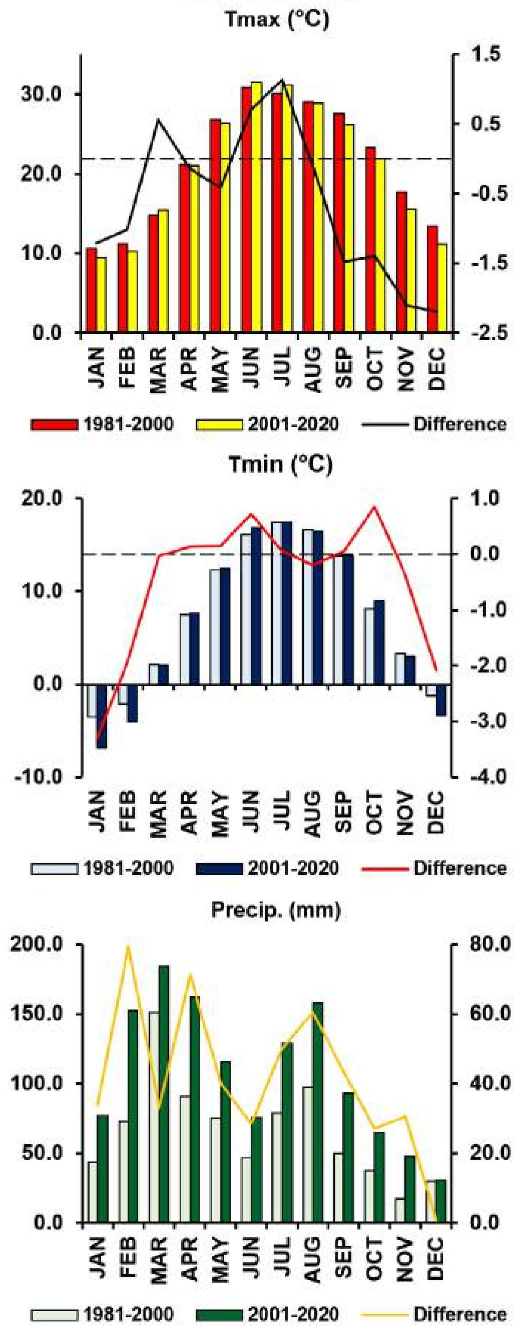
## DROSH


Tmax (°C)
40.0
30.0
20.0
10.0
0.0
3.0
2.0
1.0
0.0
-1.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1981-2000
2001-2020
Difference
Tmin (°C)
25.0
20.0
15.0
10.0
5.0
0.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1981-2000
2001-2020
Difference
Precip. (mm)
150.0
100.0
50.0
0.0
20.0
0.0
-20.0
-40.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1981-2000
2001-2020
Difference

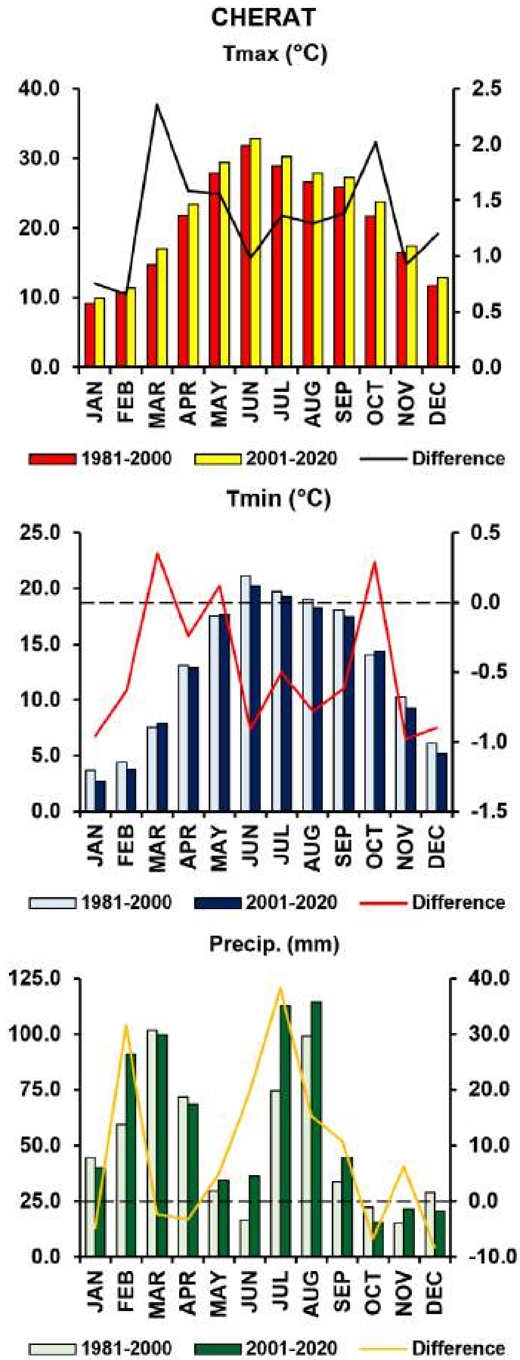
## KAKUL

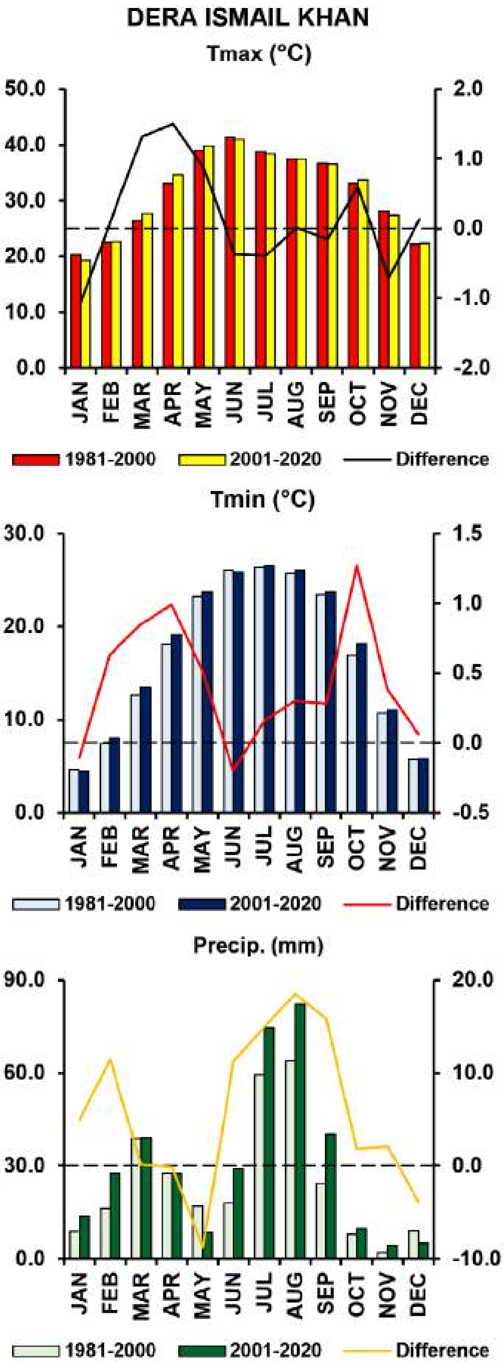


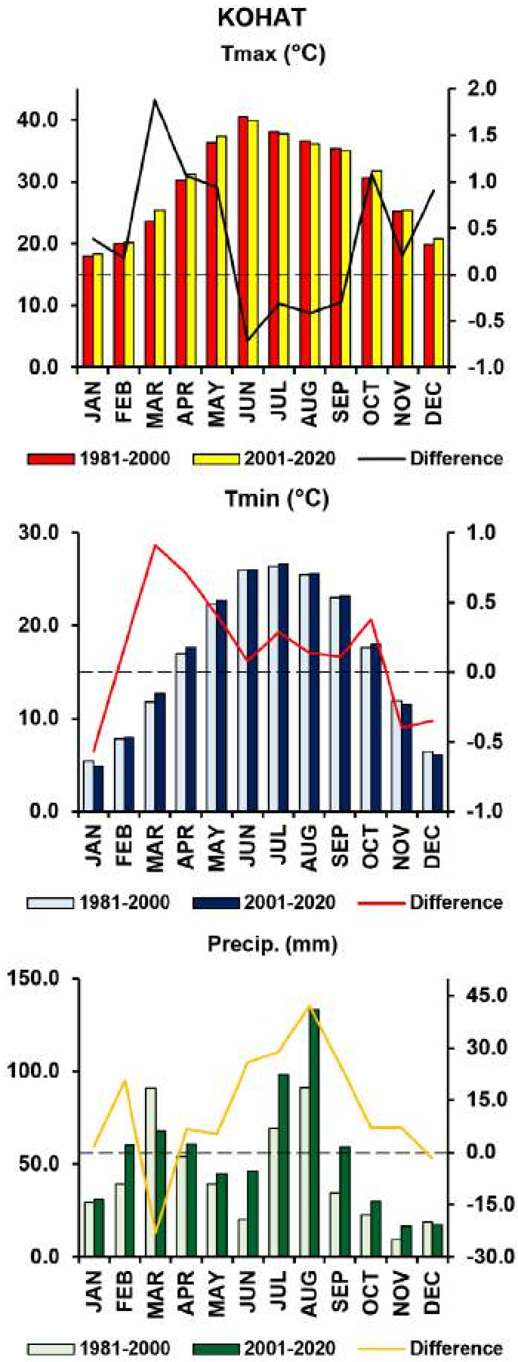

## PARACHINAR

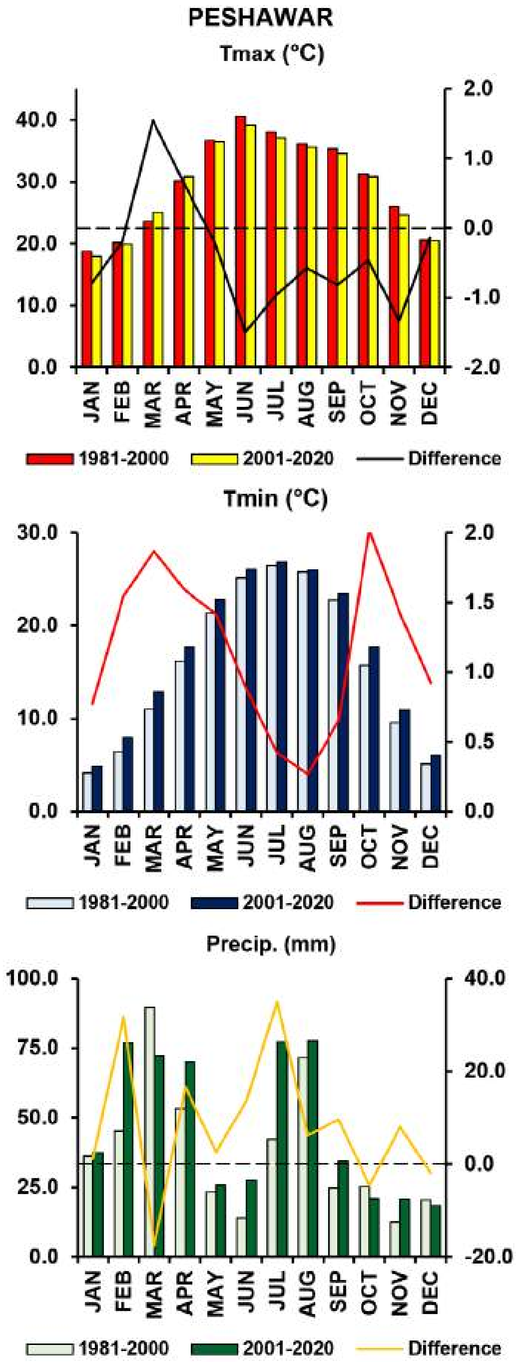


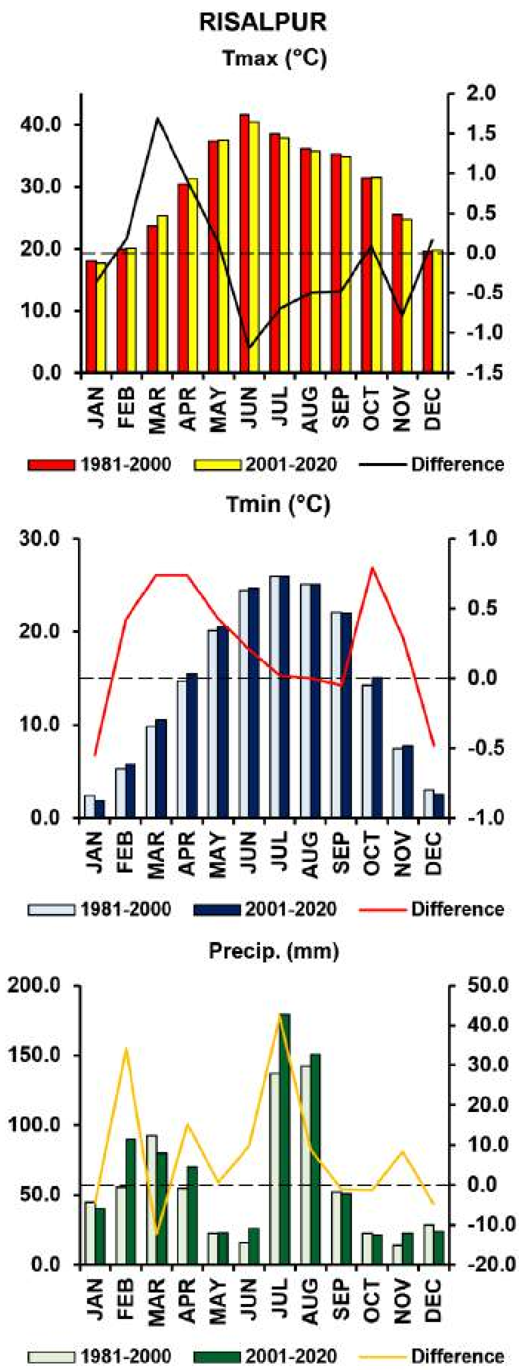
## South Khyber Pakhtunkhwa



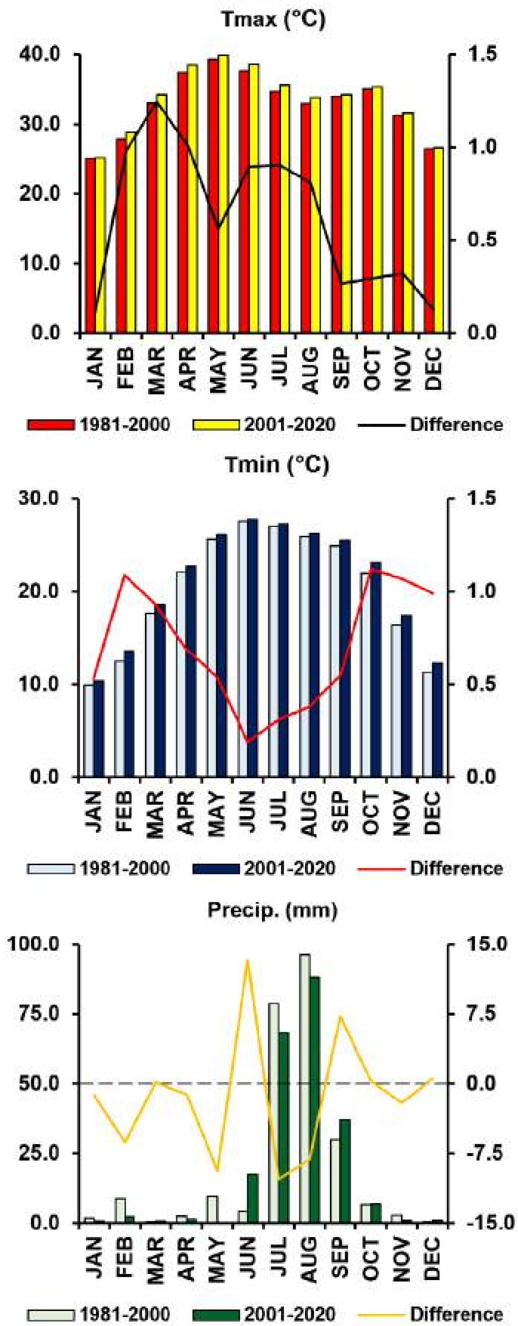

KOHAT
Tmax (°C)
1981-2000
2001-2020
Difference
Tmin (°C)
1981-2000
2001-2020
Difference
Precip. (mm)
1981-2000
2001-2020
Difference
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC


PESHAWAR
Tmax (°C)
1981-2000
2001-2020
Difference
Tmin (°C)
1981-2000
2001-2020
Difference
Precip. (mm)
1981-2000
2001-2020
Difference
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

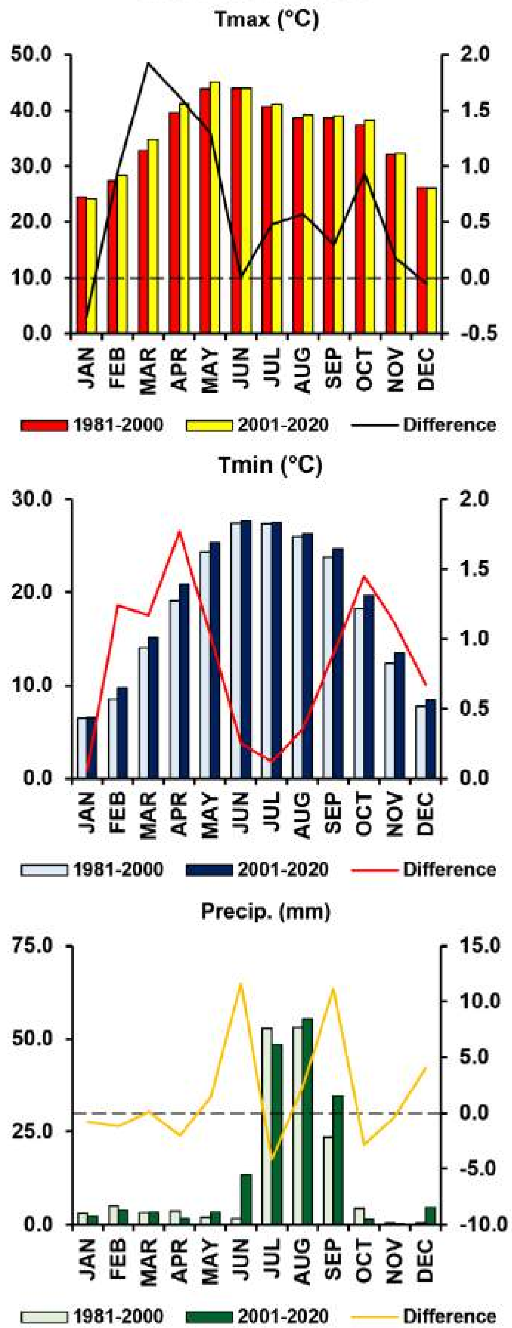

RISALPUR
Tmax (°C)
40.0
30.0
20.0
10.0
0.0
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1981-2000
2001-2020
Difference
Tmin (°C)
30.0
20.0
10.0
0.0
1.0
0.5
0.0
-0.5
-1.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1981-2000
2001-2020
Difference
Precip. (mm)
200.0
150.0
100.0
50.0
0.0
50.0
40.0
30.0
20.0
10.0
0.0
-10.0
-20.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1981-2000
2001-2020
Difference

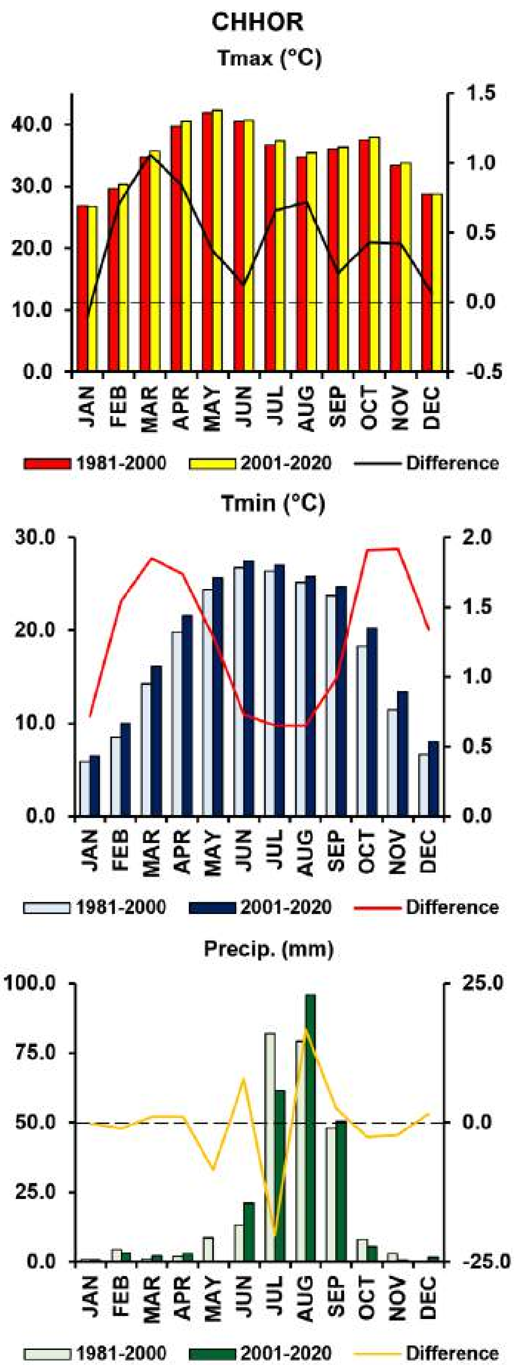
# Sindh

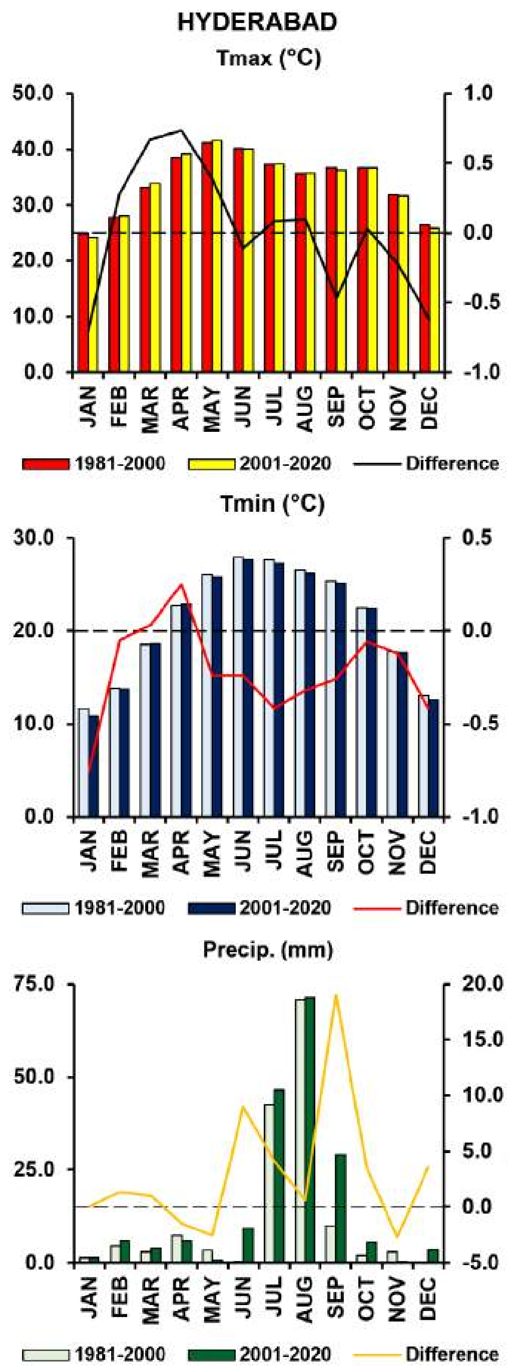
## BADIN



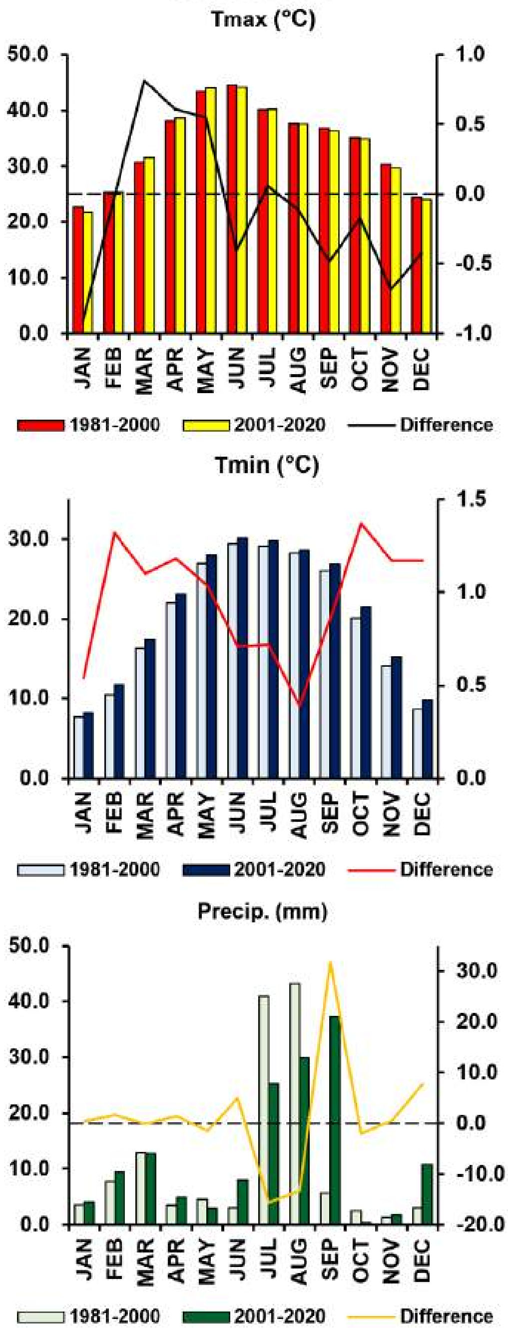

## SH. BENAZIRABAD



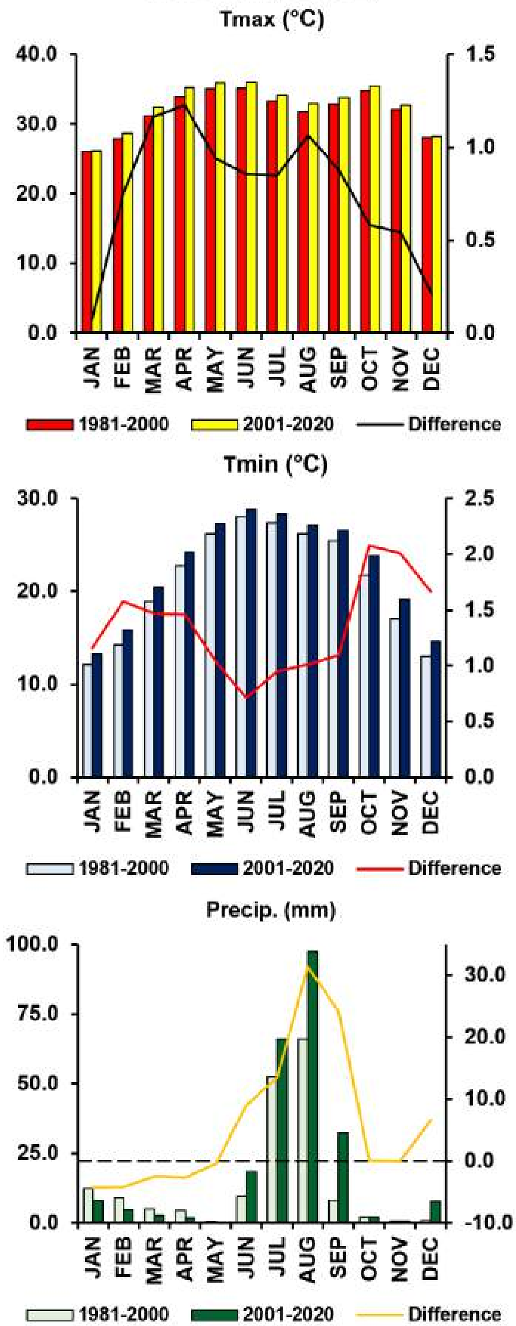

CHHOR
Tmax (°C)
40.0
30.0
20.0
10.0
0.0
1.5
1.0
0.5
0.0
-0.5
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1981-2000
2001-2020
Difference
Tmin (°C)
30.0
20.0
10.0
0.0
2.0
1.5
1.0
0.5
0.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1981-2000
2001-2020
Difference
Precip. (mm)
100.0
75.0
50.0
25.0
0.0
25.0
0.0
-25.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1981-2000
2001-2020
Difference


HYDERABAD
Tmax (°C)
50.0
40.0
30.0
20.0
10.0
0.0
1.0
0.5
0.0
-0.5
-1.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1981-2000
2001-2020
Difference
Tmin (°C)
30.0
20.0
10.0
0.0
0.5
0.0
-0.5
-1.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1981-2000
2001-2020
Difference
Precip. (mm)
75.0
50.0
25.0
0.0
20.0
15.0
10.0
5.0
0.0
-5.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1981-2000
2001-2020
Difference

## JACOBABAD

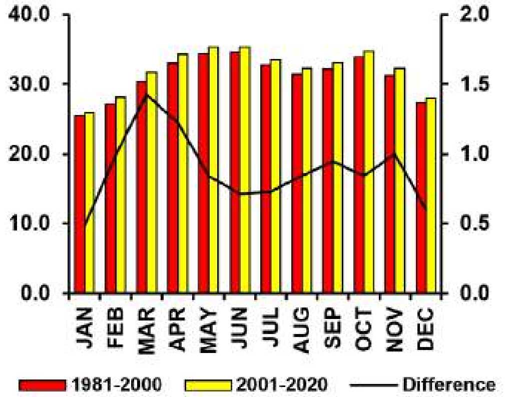



## KARACHI (FAISAL)

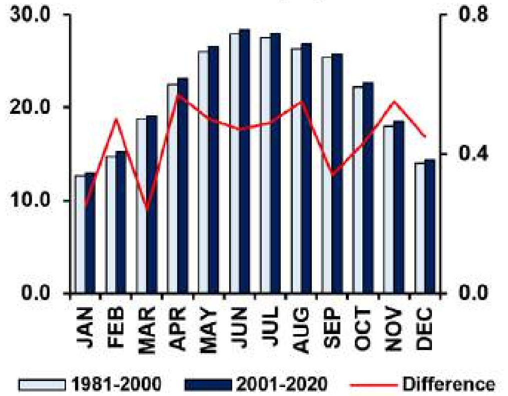


## KARACHI (SOUTH)

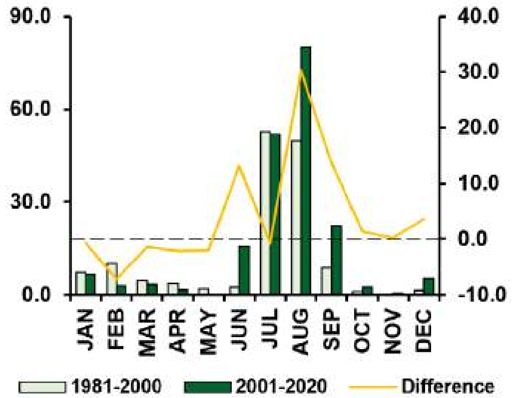
Tmax (°C)




Tmin (°C)

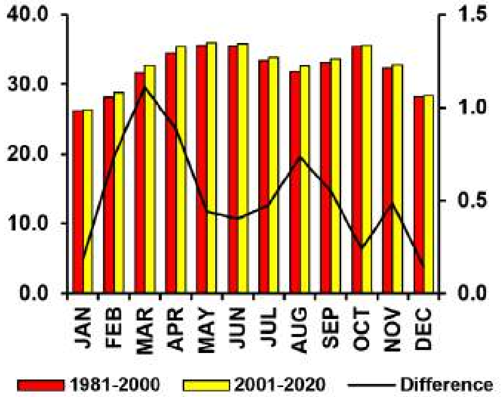



Precip. (mm)

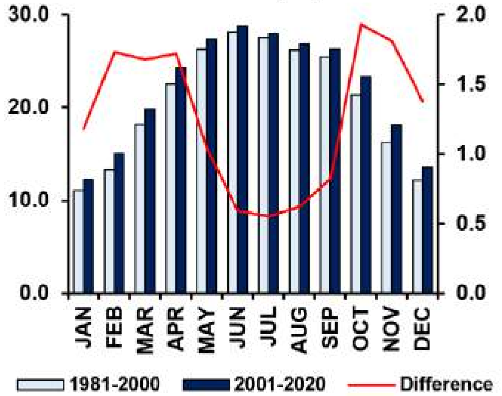



## KARACHI AIRPORT

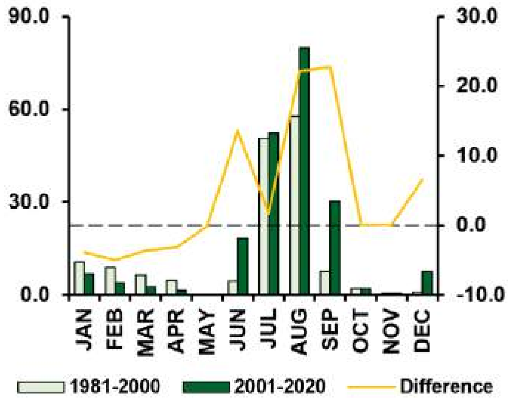
Tmax (°C)

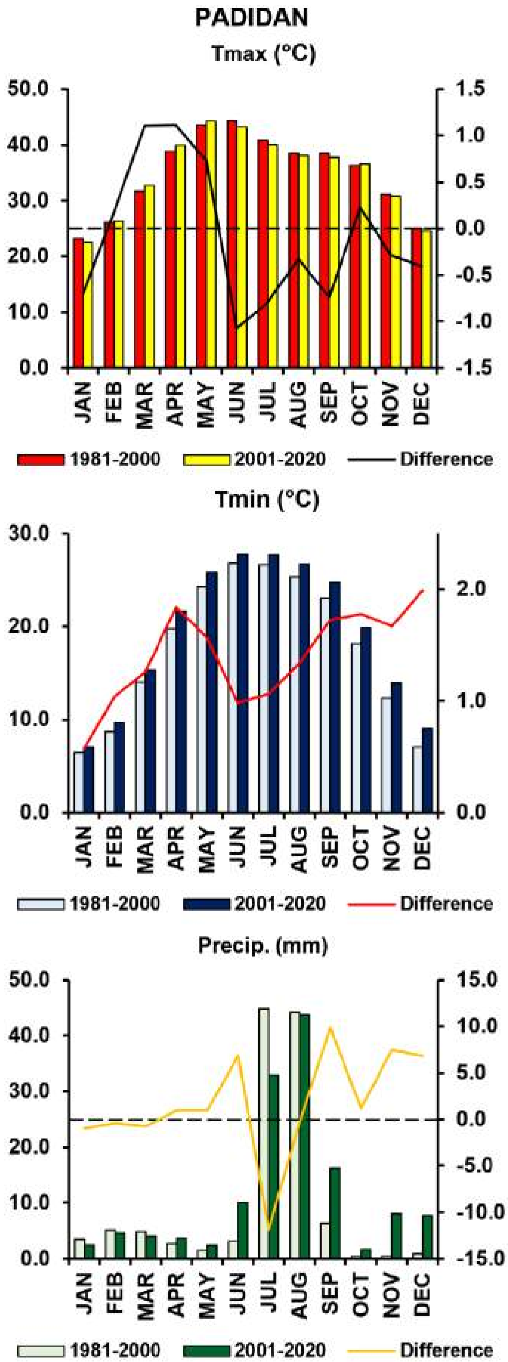


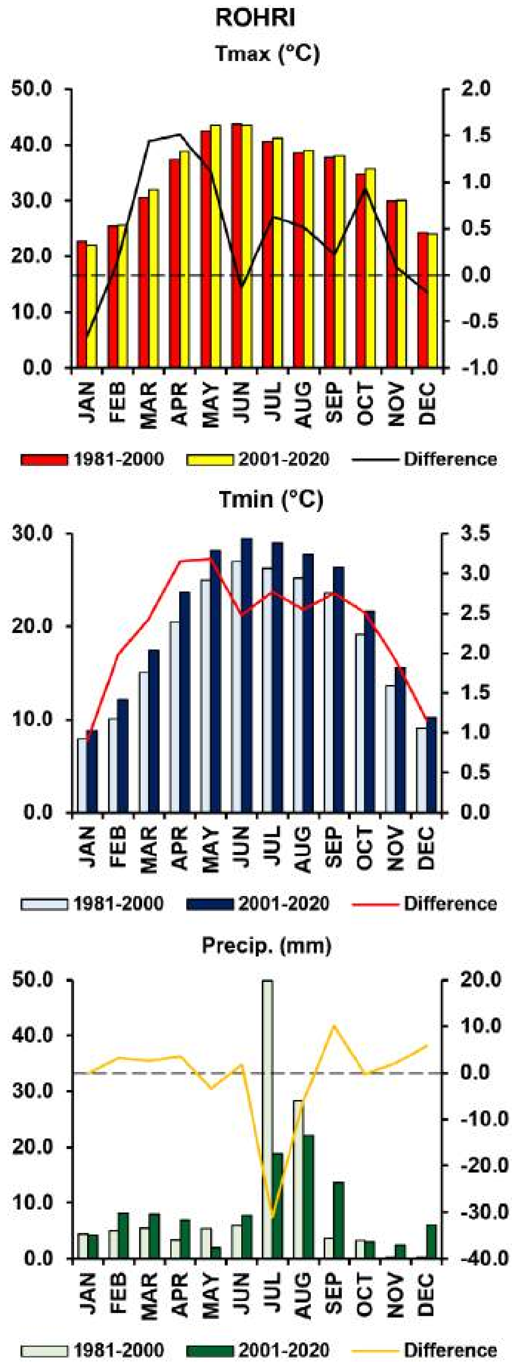

Tmin (°C)



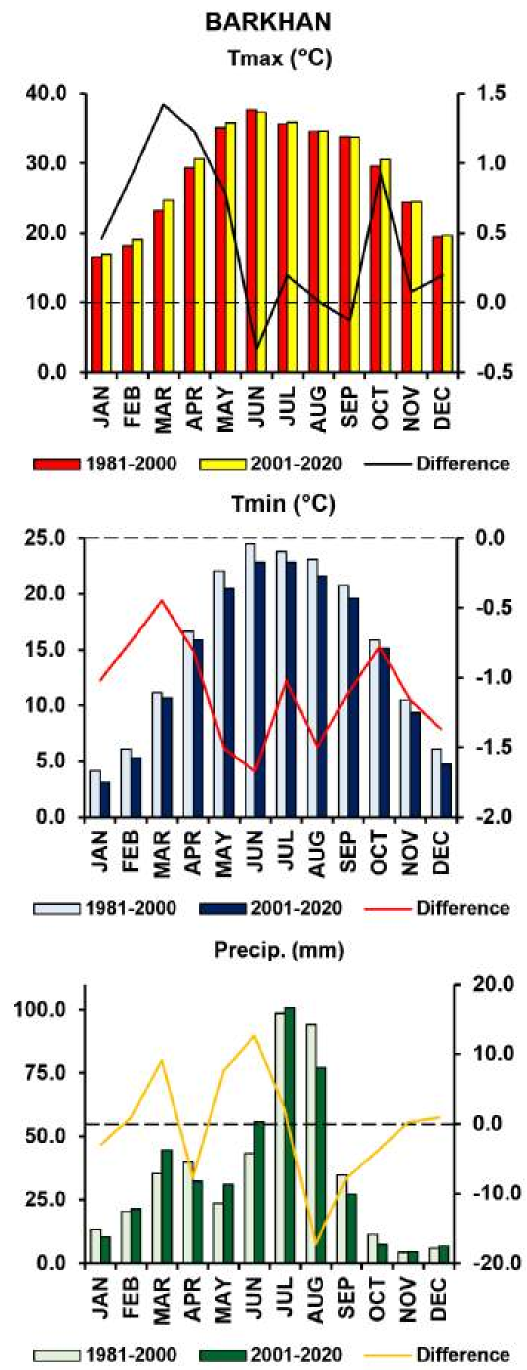

Precip. (mm)

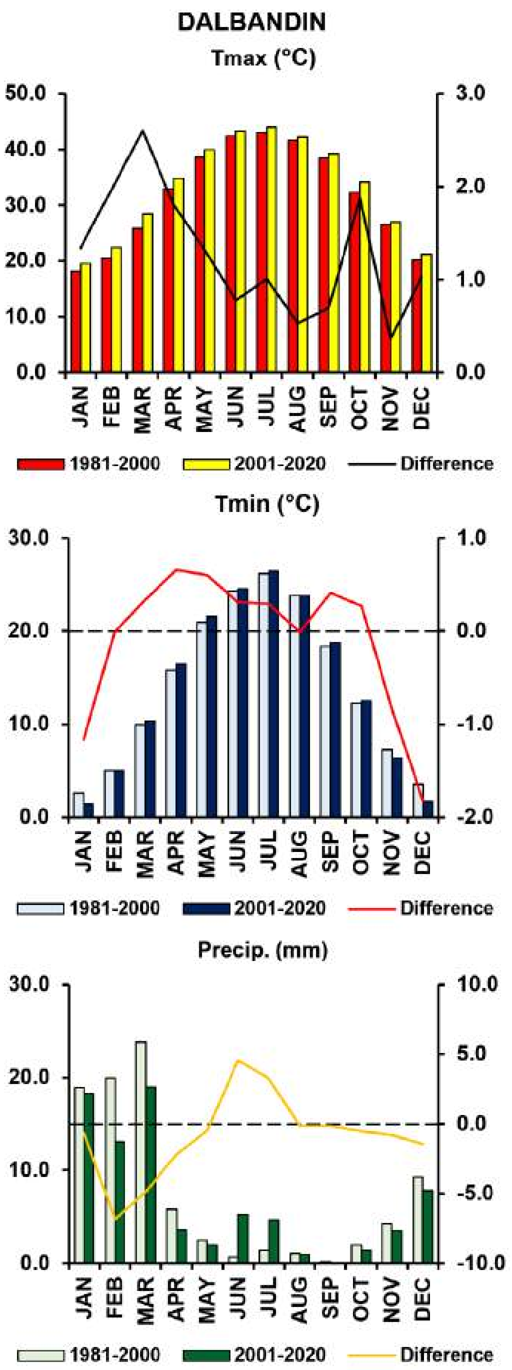


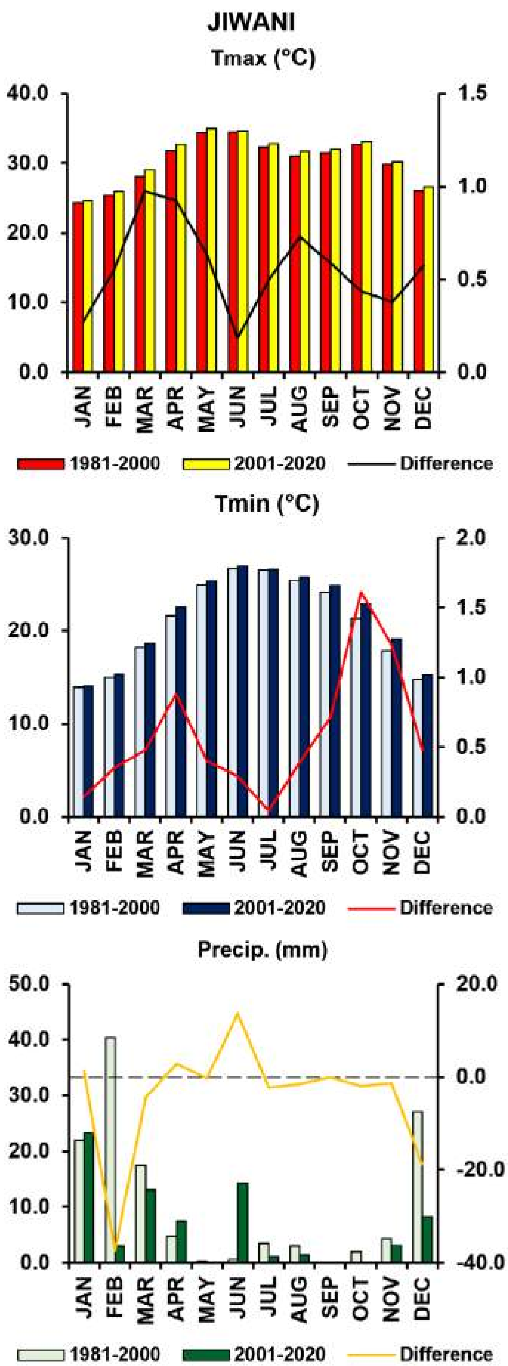

PADIDAN
Tmax (°C)
1981-2000
2001-2020
Difference
Tmin (°C)
1981-2000
2001-2020
Difference
Precip. (mm)
1981-2000
2001-2020
Difference

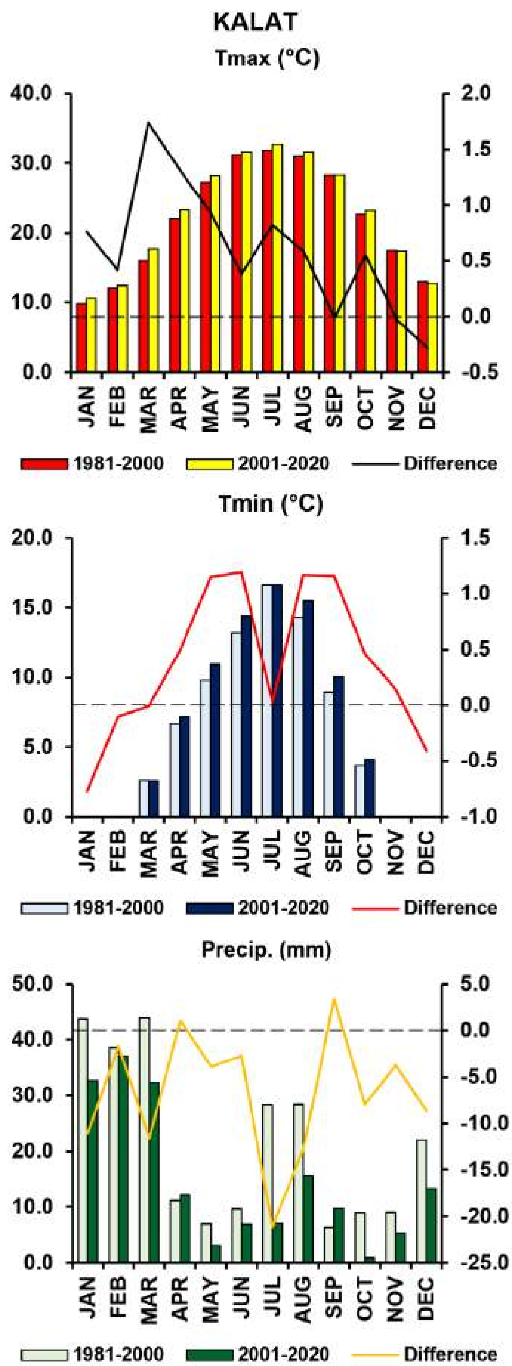

ROHRI
Tmax (°C)
1981-2000
2001-2020
Difference
Tmin (°C)
1981-2000
2001-2020
Difference
Precip. (mm)
1981-2000
2001-2020
Difference

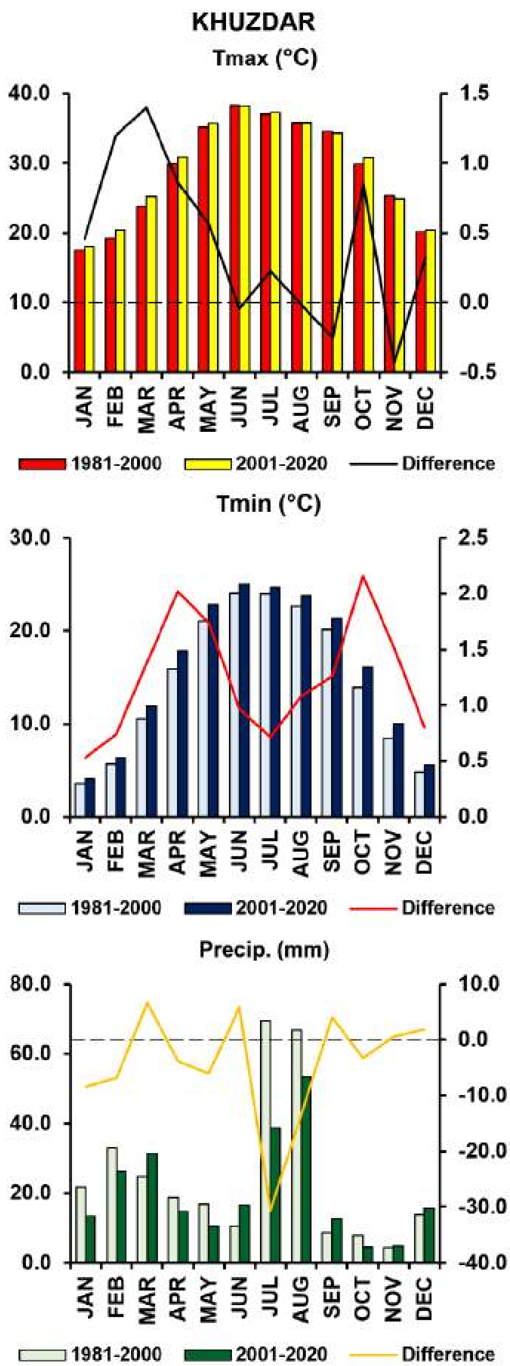
# Balochistan

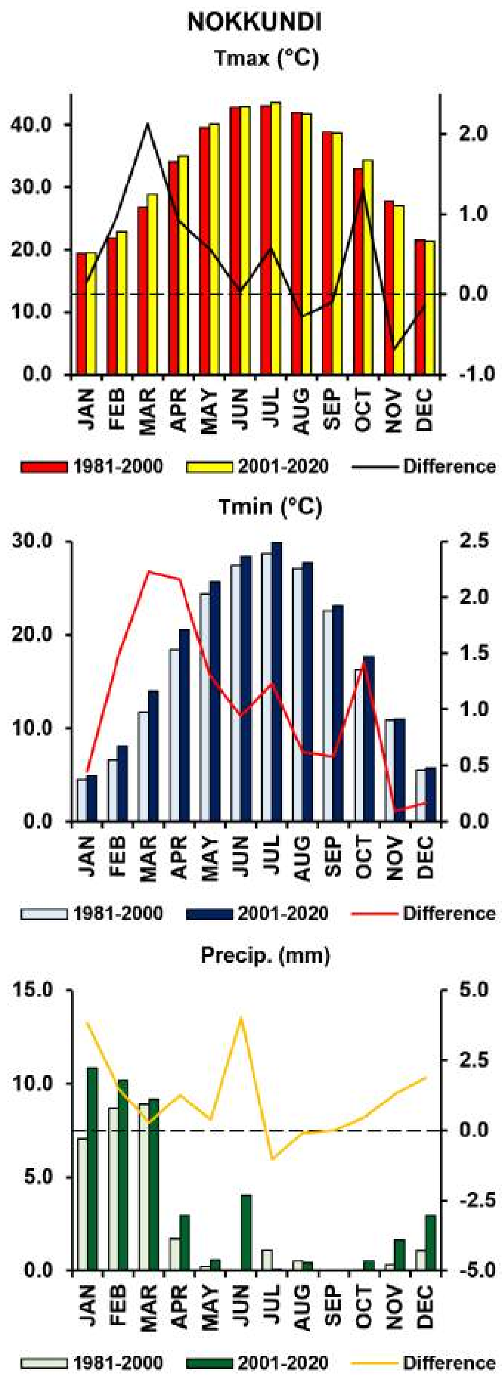


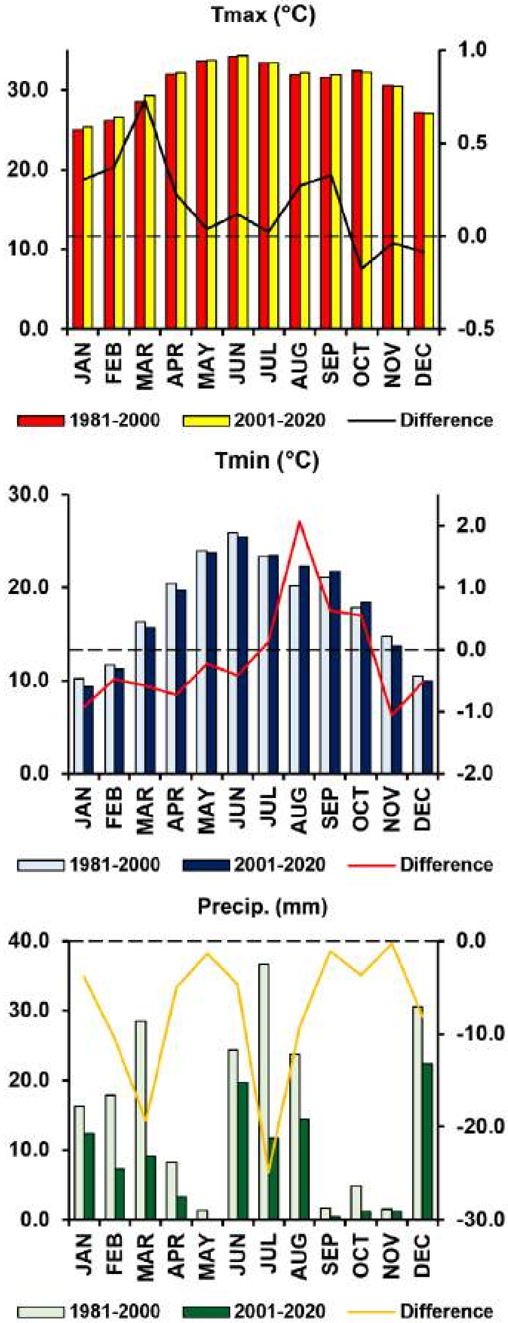

JIWANI
Tmax (°C)
1981-2000
2001-2020
Difference
Tmin (°C)
1981-2000
2001-2020
Difference
Precip. (mm)
1981-2000
2001-2020
Difference
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC


KALAT
Tmax (°C)
1981-2000
2001-2020
Difference
Tmin (°C)
1981-2000
2001-2020
Difference
Precip. (mm)
1981-2000
2001-2020
Difference
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

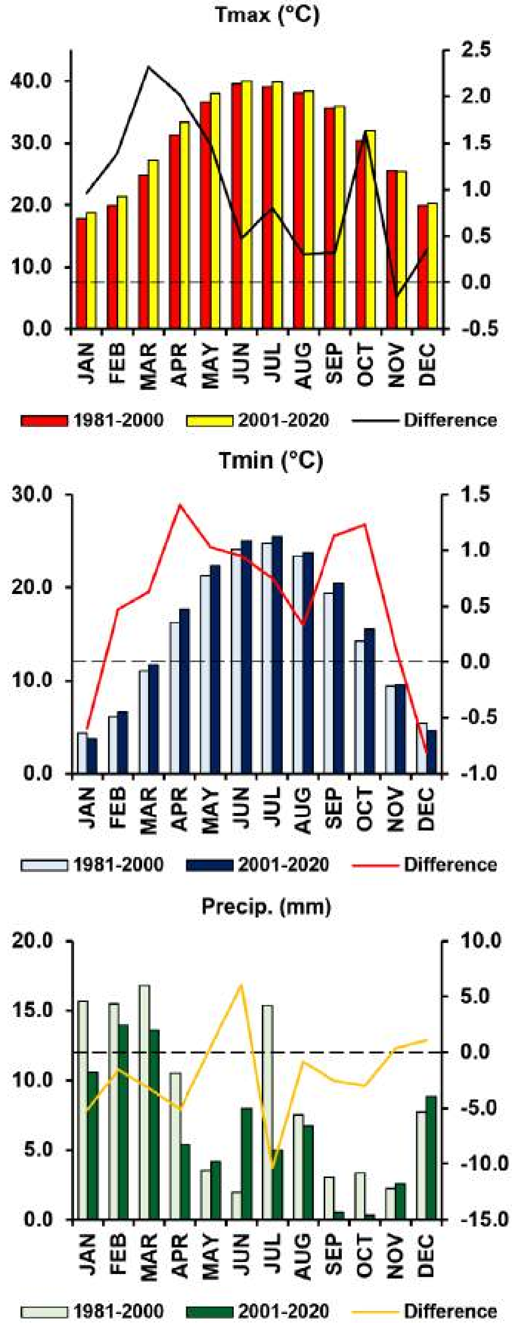

KHUZDAR
Tmax (°C)
40.0
30.0
20.0
10.0
0.0
1.5
1.0
0.5
0.0
-0.5
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
1981-2000
2001-2020
Difference
Tmin (°C)
30.0
20.0
10.0
0.0
2.5
2.0
1.5
1.0
0.5
0.0
1981-2000
2001-2020
Difference
Precip. (mm)
80.0
60.0
40.0
20.0
0.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
1981-2000
2001-2020
Difference


NOKKUNDI
Tmax (°C)
40.0
30.0
20.0
10.0
0.0
2.0
1.0
0.0
-1.0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
1981-2000
2001-2020
Difference
Tmin (°C)
30.0
20.0
10.0
0.0
2.5
2.0
1.5
1.0
0.5
0.0
1981-2000
2001-2020
Difference
Precip. (mm)
15.0
10.0
5.0
0.0
5.0
2.5
0.0
-2.5
-5.0
1981-2000
2001-2020
Difference

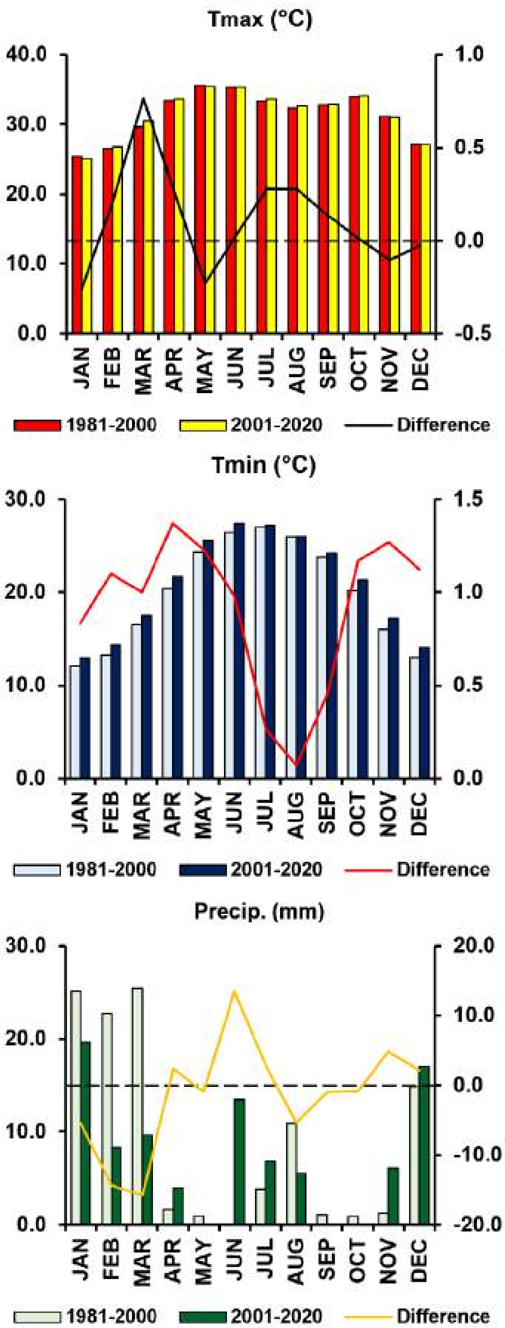
ORMARA



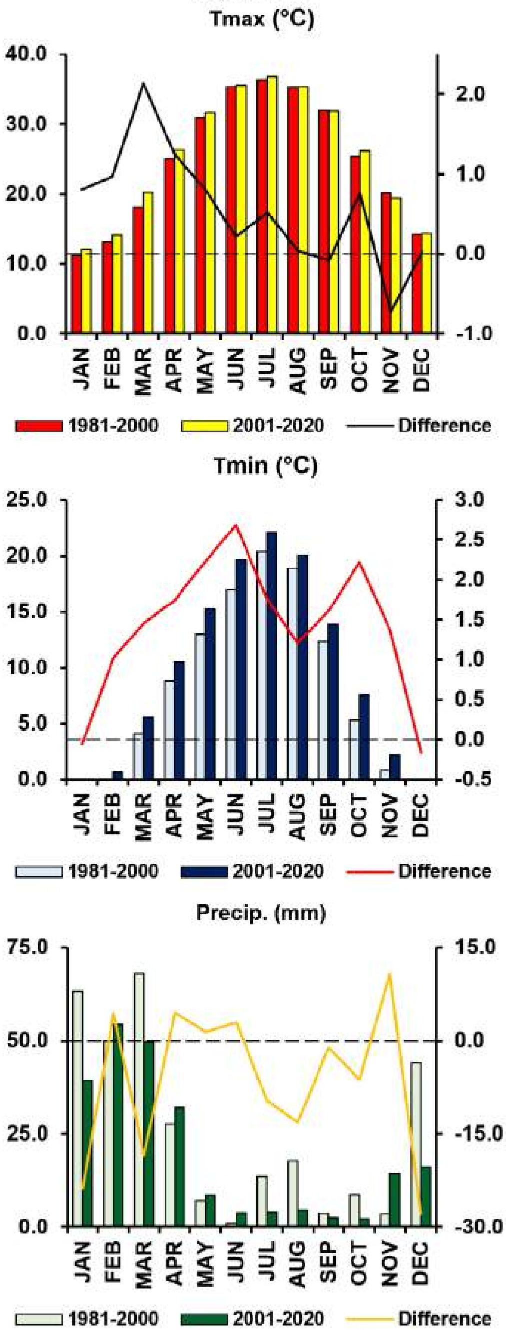

PANJGUR



PASNI

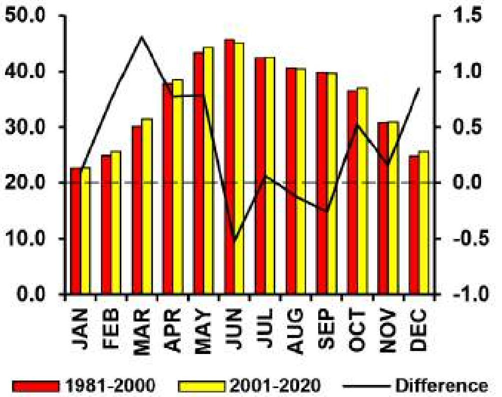



QUETTA

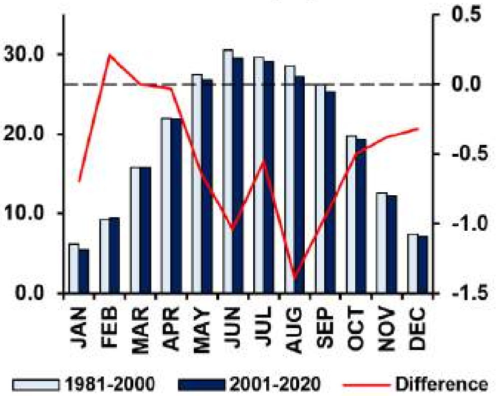


## SIBI

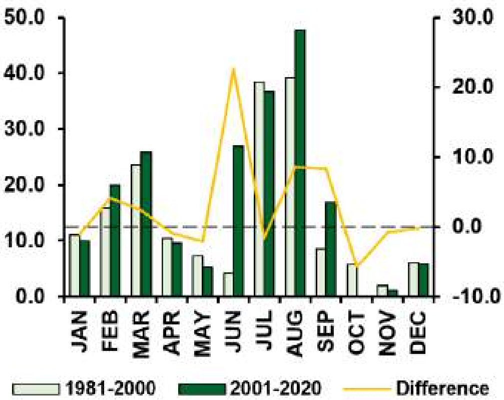
Tmax (°C)




Tmin (°C)

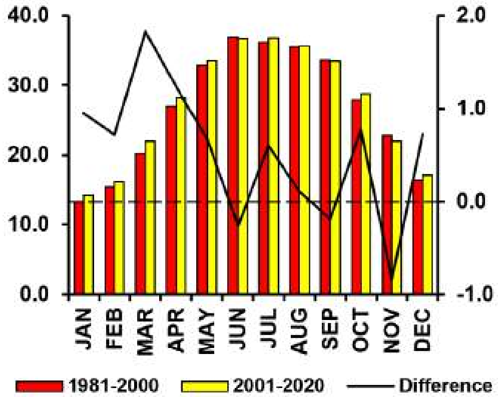



Precip. (mm)

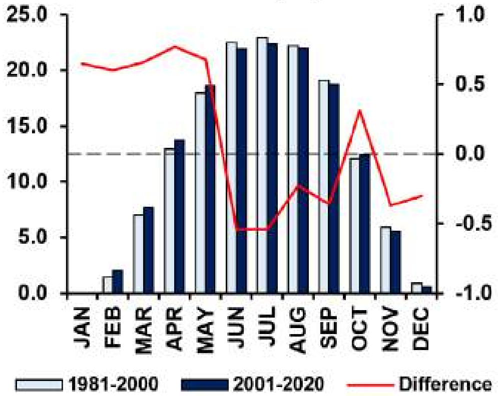



## ZHOB

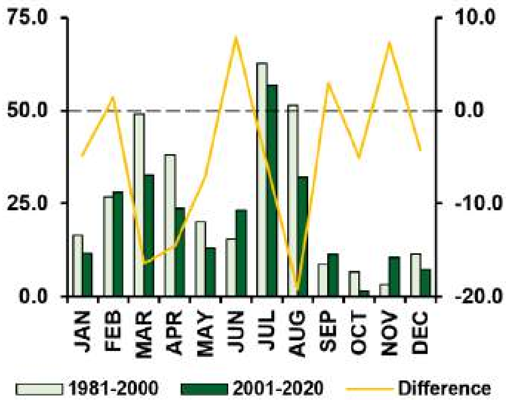
Tmax (°C)



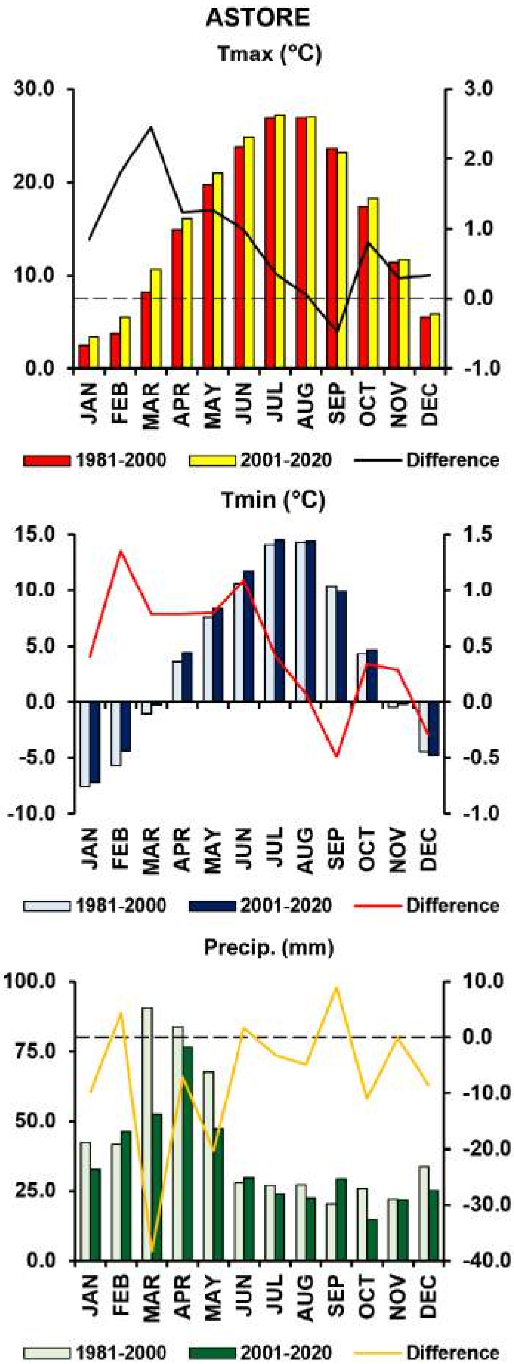

Tmin (°C)

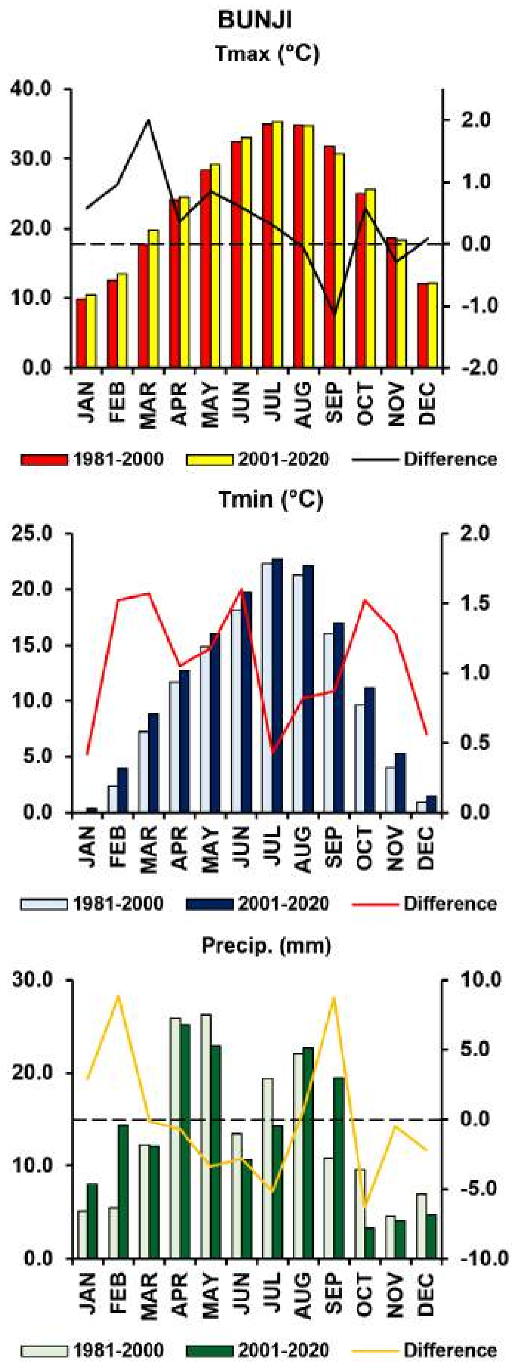



Precip. (mm)

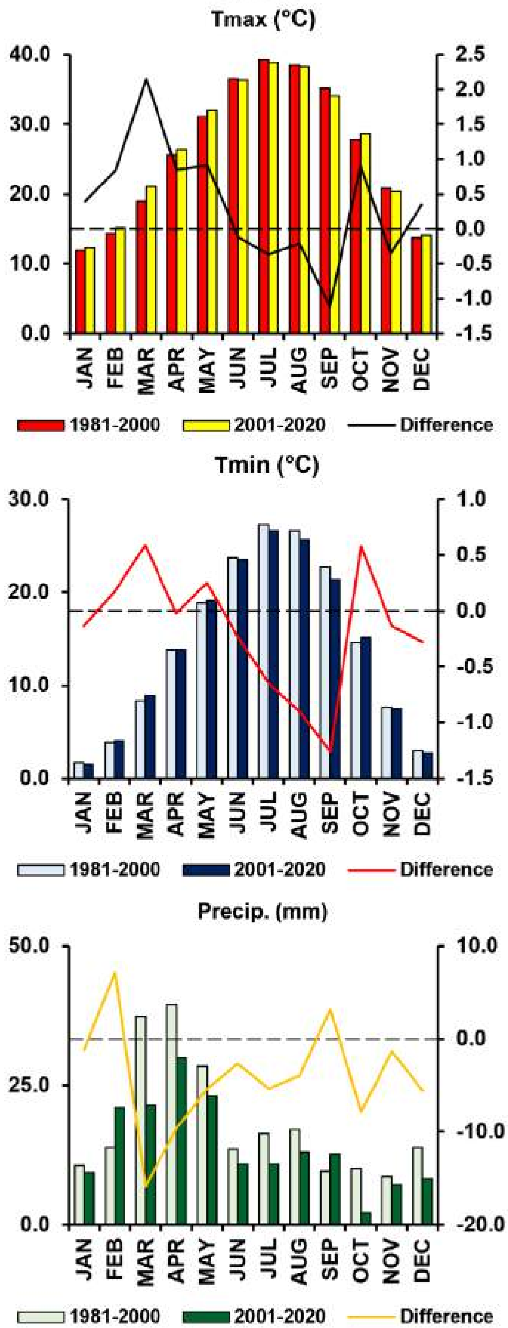


## Gilgit Baltistan

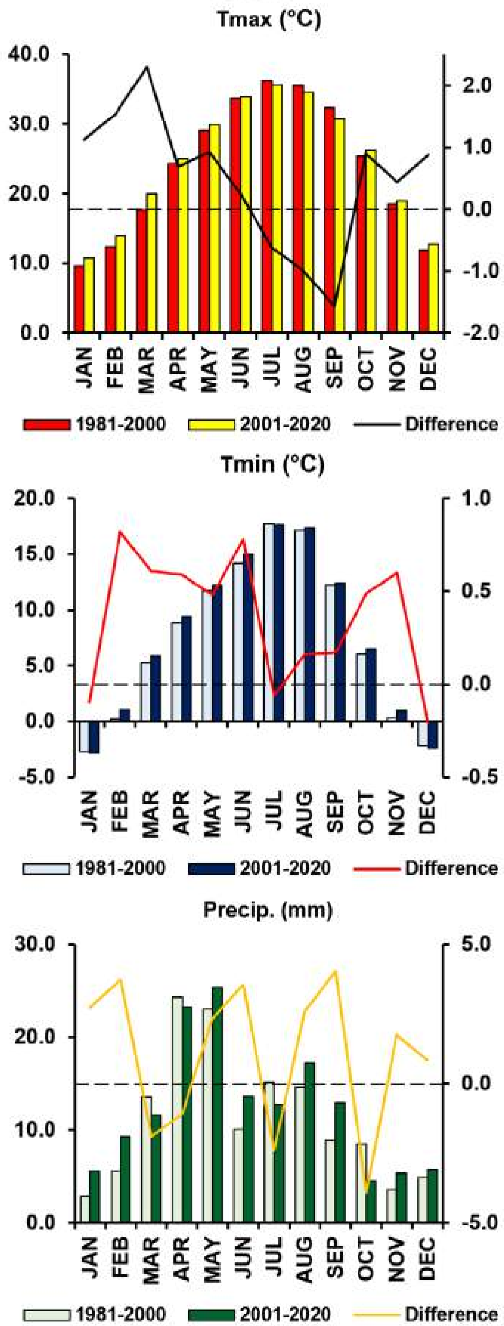


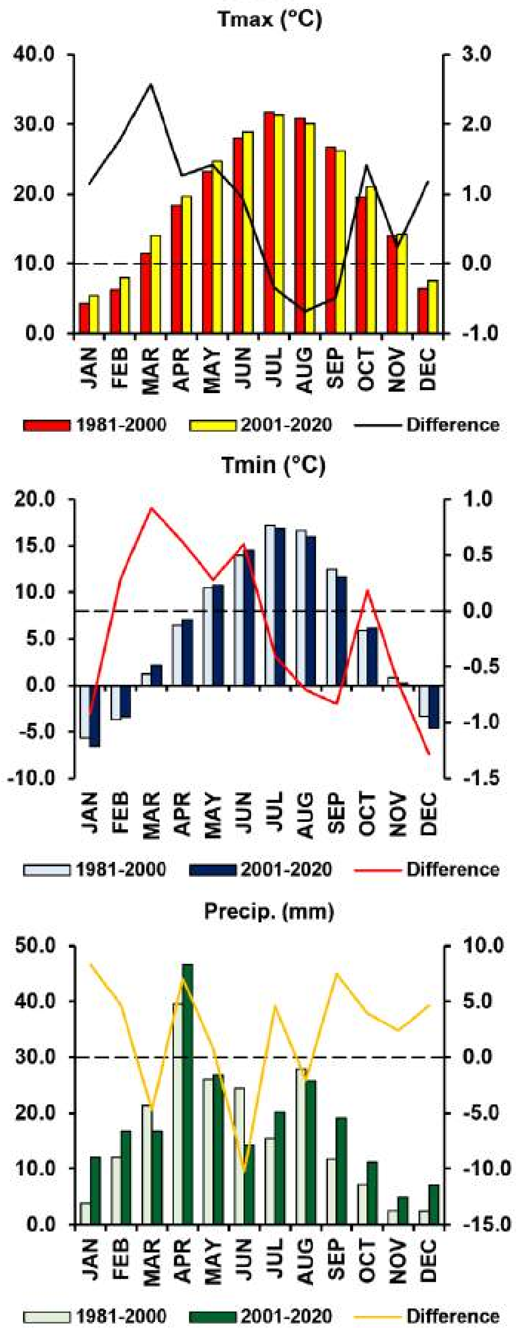
## CHILAS



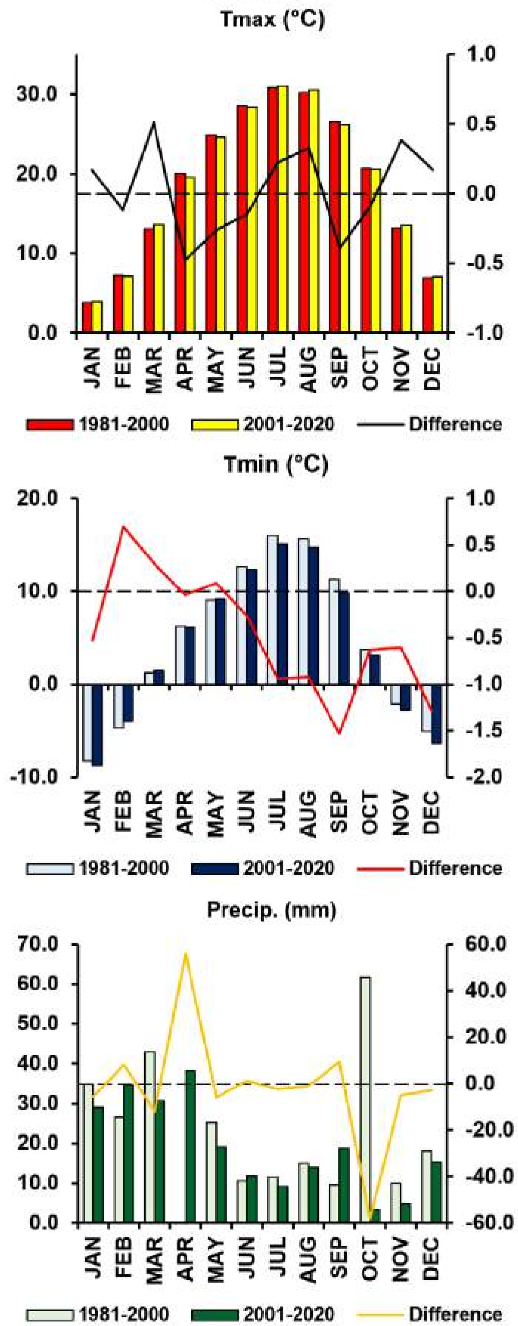

## GILGIT



GUPIS

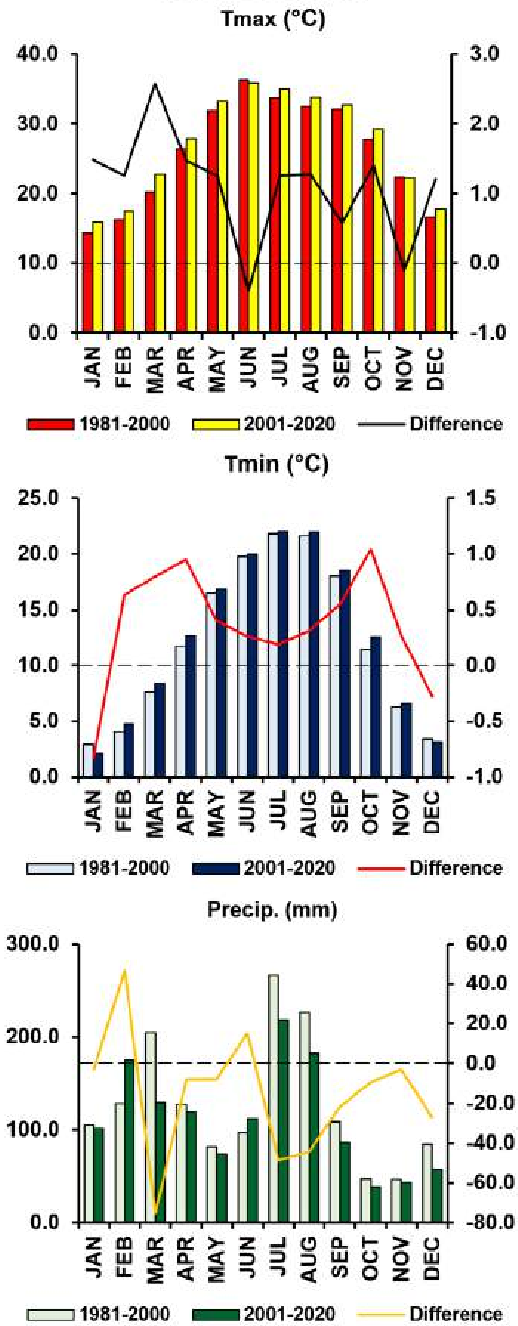



SKARDU

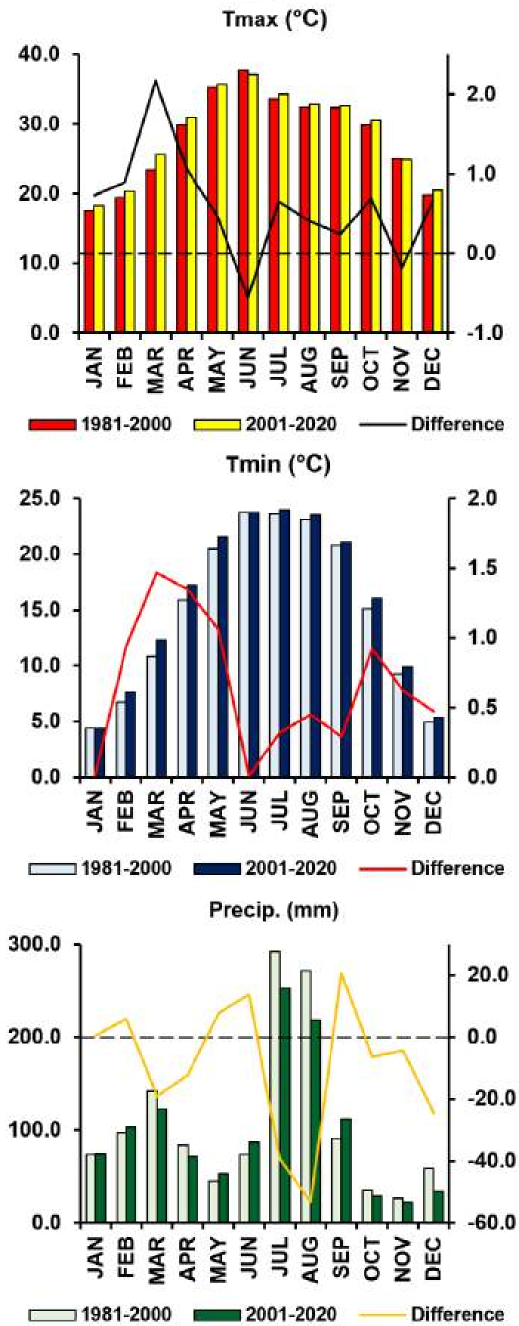


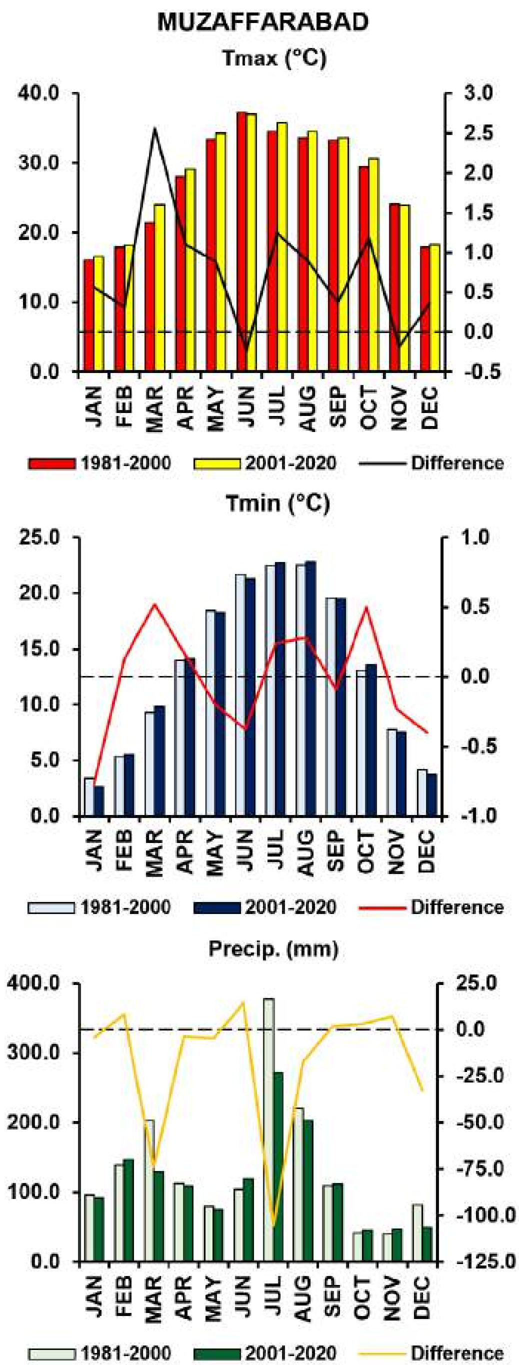
# Azad Jammu and Kashmir

## GARHI DUPATTA




## KOTLI




MUZAFFARABAD
Tmax (°C)
40.0
30.0
20.0
10.0
0.0
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1981-2000
2001-2020
Difference
Tmin (°C)
25.0
20.0
15.0
10.0
5.0
0.0
1.0
0.5
0.0
-0.5
-1.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1981-2000
2001-2020
Difference
Precip. (mm)
400.0
300.0
200.0
100.0
0.0
25.0
0.0
-25.0
-50.0
-75.0
-100.0
-125.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
1981-2000
2001-2020
Difference


## Dr. Faisal Saeed Syed (Lead Author)

Chief Meteorologist, Pakistan Meteorological Department


Dr. Faisal Saeed Syed is a climate scientist and meteorologist with more than 25 years of experience in operational meteorology, atmospheric and climate research. He holds a PhD in Atmospheric Science and Oceanography from Stockholm University, Sweden, where his doctoral research examined intra-seasonal to decadal climate variability over South Asia and the dynamics of the South Asian monsoon.

He currently serves as Chief Meteorologist at PMD. His international assignments included working as a consultant in the National Centre for Meteorology, Jeddah and visiting appointments at the International Centre for Theoretical Physics (ICTP, Italy) and the International Meteorological Institute (Sweden). He has published widely in high-impact international journals. His honours include the SAARC Young Scientist Award (2006) and appointment as an ICTP Associate Scientist (2005-2020).


Contact: faisal.met@gmail.com


## OTHER AUTHORS

Burhan Ahmed is a Senior Meteorologist and a PhD scholar at COMSATS University Islamabad. He has authored a number of publications in international journals focusing on climate variability and climate change. Sultan Muhammad Zaheer Ud Din is a Meteorological Assistant. He holds BS Geology with cum laude honours from Bahria University. He possesses extensive experience in drought monitoring and early warning, climate data analysis and geospatial data visualization. Shahzad Ali, Meteorologist, holds a Master's degree in Mathematics and has research interests in climate and data science. Currently he is undergoing training on weather modification at Chinese Academy of Sciences, Beijing. Lastly, Anwar Sadiq is working as a Data Entry Operator and has vast experience in data analysis.


PAKISTAN METEOROLOGICAL DEPARTMENT