



Ghana
Meteorological
Agency



GHANA CLIMATE ATLAS

FUTURE CHANGES IN CLIMATE OVER GHANA

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Group photo of the GMet and DMI teams during a training program in Denmark.

Authors

Ignatius Kweku Williams¹, Maureen Abla Ahiataku¹, David Tetteh¹, Hayford Asuako Yeboah¹, Joana Amavih¹, Christiana Foriwaa Aggrey¹, Etornam Godswill Kpodo¹, Adwoa Serwaa Gyasi¹, Quarshie Wordu¹, Peter-William Nii Amah¹, Stanley Annan¹, Stephen Amankwah¹, Shingirai Shepard Nangombe², and Julie Alexandra Stensballe²

Affiliations

¹ Ghana Meteorological Agency (GMet), Accra, Ghana

² Danish Meteorological Institute (DMI), Copenhagen, Denmark

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The Director General

Ghana Meteorological Agency (GMet)

37 Trinity Road, East Legon

Tel: 0307010019

P.O. Box LG 87, Legon

Email: info@meteo.gov.gh

Accra, Ghana.

GA-485-3581

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**Ghana Climate Atlas Report:
Future changes in climate over Ghana**

A publication of Ghana Meteorological Agency

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Foreword

Climate change is widely recognized as one of the most significant challenges of the 21st century, with far-reaching implications for sustainable development, natural ecosystems, and human well-being. In Ghana, observed increases in temperature and growing variability in rainfall patterns highlight the importance of strengthening climate information systems to support effective planning, risk management, and long-term resilience.

The Ghana Climate Atlas Report: Future Changes in Climate over Ghana provides an important scientific foundation for understanding how the country's climate may evolve throughout the 21st century. The report presents projections of key climate indicators including temperature, rainfall, and sea level rise under different greenhouse gas emission scenarios and across multiple future time periods. By examining these projections both at the national scale and across Ghana's agro-climatic zones, the report provides valuable insights into potential regional differences in future climate conditions.

The results presented in this report indicate a clear warming trend across Ghana under all emission scenarios, with the magnitude of warming increasing toward the end of the century. While projected changes in annual rainfall are generally minimal, the analysis highlights important seasonal variations and regional differences that may have implications for agriculture, water resources, infrastructure planning, and other climate-sensitive sectors. In addition, projected sea level rise poses increasing risks to Ghana's coastal ecosystems, communities, and infrastructure.

Access to credible and scientifically robust climate information is essential for strengthening national climate adaptation and resilience efforts. The Ghana Climate Atlas, therefore, represents an important contribution to Ghana's climate service framework, providing policymakers, planners, researchers, and development partners with reliable evidence to support climate risk assessments, development planning, and the design of effective adaptation strategies.

It is my sincere hope that this report will serve as a key reference for stakeholders across government, academia, the private sector, and civil society as Ghana continues to strengthen its preparedness for the impacts of climate variability and long-term climate change.

Preface

In recent years, the climate of Ghana has been experiencing shifts from what is generally considered as normal conditions and this is manifesting through rising temperatures, increased rainfall variability, rising sea levels, and high incidence of weather extremes such as flood and droughts. Information about the current and future climate is therefore critical to support informed decision-making.

In 2023, Ghana Meteorological Agency (GMet) successfully launched the National Framework for Climate Services (NFCS), an initiative that is built upon the World Meteorological Organization's (WMO) five pillars of the Global Framework for Climate Services (GFCS). It encompasses the generation and provision of a wide range of information on past, present and future climate and its impacts on natural and human systems.

To achieve the NFCS's objectives, GMet is collaborating with the Danish Meteorological Institute (DMI) and the Danish Embassy in Accra under the Strategic Sector Cooperation (SSC) project to develop a maiden GMet-centric Ghana Climate Atlas. This partnership exemplifies how international cooperation can foster local capacity building while addressing the global challenge of climate change. The collaboration is designed to propel GMet towards its vision of becoming the leading meteorological service provider in the sub-region.

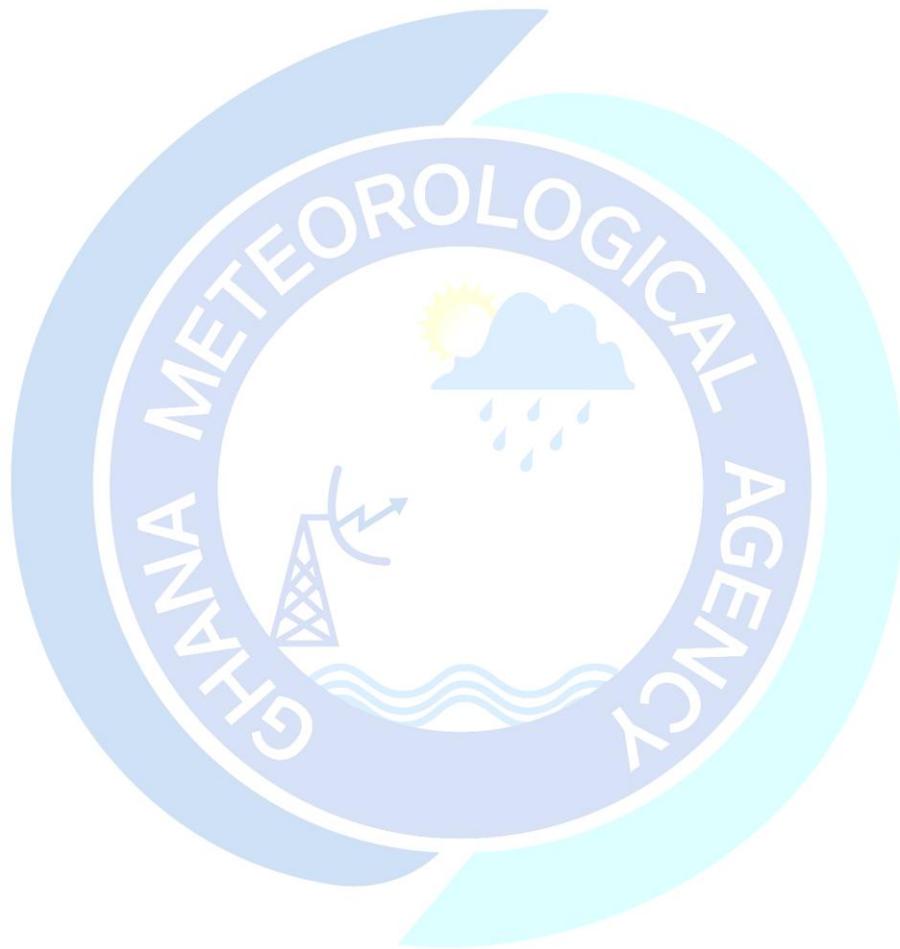
To achieve co-production, stakeholders in the climate sensitive sectors were presented with the initial results where inputs and feedback received were incorporated into generating the first version of the Ghana Climate Atlas. This report serves as a foundation for the first version of the Ghana Climate Atlas. It focuses on future changes in temperature, rainfall, and sea level rise. at the national level and across the various agro-climatic zones of Ghana.

This publication presents projections of key climate indicators, including average annual and seasonal temperature, total annual and seasonal rainfall, and mean sea level. These projections are analyzed across three future time periods; the near term (2021–2040), middle of the century herein referred to as mid century (2041–2060), and the end of the century (2081–2100) and are examined at both the national scale and across Ghana's five agro-climatic zones: Coastal, Forest, Transition, Guinea Savannah, and Sudan Savannah. This agro-climatic zones perspective provides important insights into potential regional variations in future climate conditions.

The analysis presented in this report draws on both observational datasets and regional climate model simulations. Historical climate conditions are represented using a high-resolution gridded dataset developed by the Ghana Meteorological Agency, which integrates station observations with reanalysis temperature data and satellite-based rainfall estimates to produce climate information at approximately 4 km spatial resolution, thereby improving spatial coverage and reliability across the country. Future climate projections are derived from an ensemble of approximately 39 Regional Climate Model simulations from the CORDEX-Africa suite.

Recognizing the inherent uncertainties associated with climate modelling, the report adopts a multi-model ensemble approach to capture a range of possible future climate outcomes. This approach allows the Atlas to present both central projections and the spread of model results, thereby providing a more robust basis for assessing potential climate risks.

The Ghana Meteorological Agency hopes that the information presented in this report will support policymakers, researchers, and practitioners in integrating climate considerations into development planning and sectoral decision-making. By strengthening the scientific foundation for climate services in Ghana, the Climate Atlas contributes to the country's broader efforts to enhance resilience to climate variability and long-term climate change.

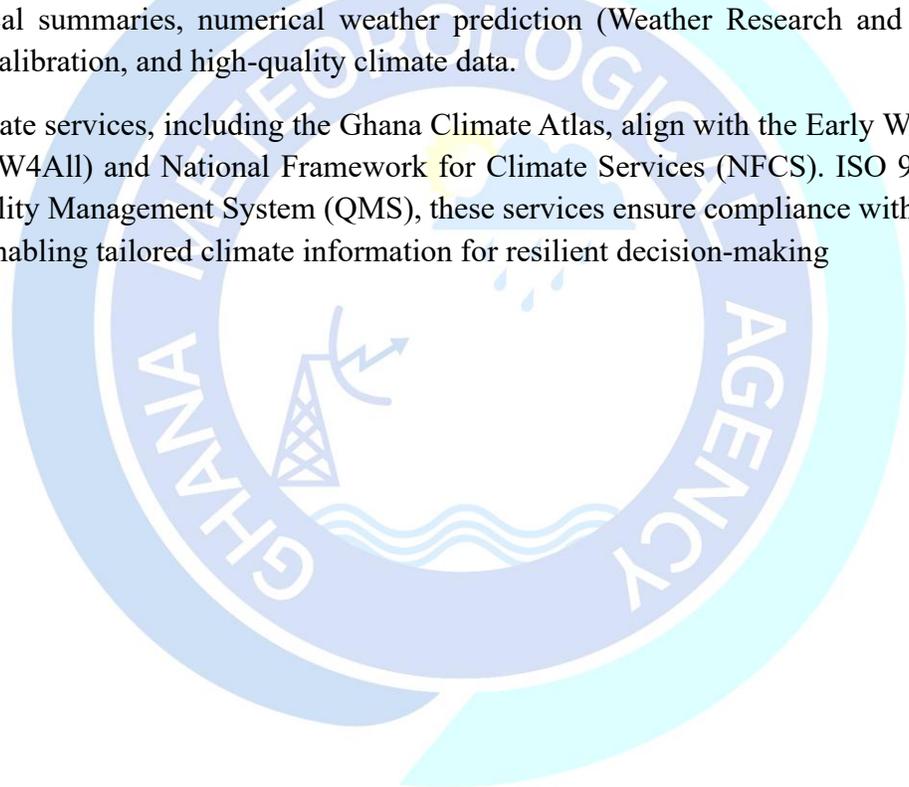


About GMet

The Ghana Meteorological Agency (GMet) established under Act 682 (2004), is mandated to provide meteorological services and ensure the operation and maintenance of international standards and practices in meteorology in the country. The Agency advises the government on weather and climate matters while issuing forecasts for aviation, maritime operations, oil rigs, and socio-economic sectors. GMet's information, advisories, and warnings support agriculture, aviation, transport, hydrology, energy, and water resource management, mitigating natural hazards like floods, storms, and droughts to safeguard socio-economic development.

With a vision to lead meteorological services in the sub-region, GMet's mission is to provide efficient weather and climate services for Ghana's sustainable growth. Key climate services span nowcasts, public weather forecasts, aeronautical and marine/inland water forecasts, sub-seasonal to seasonal (S2S) predictions, climate projections, flood/drought bulletins, agrometeorological and climatological summaries, numerical weather prediction (Weather Research and Forecasting), equipment calibration, and high-quality climate data.

GMet's climate services, including the Ghana Climate Atlas, align with the Early Warning for All initiative (EW4All) and National Framework for Climate Services (NFCS). ISO 9001:Certified under a Quality Management System (QMS), these services ensure compliance with international standards, enabling tailored climate information for resilient decision-making



Acknowledgement

The Ghana Meteorological Agency extends profound gratitude to the Danish Government particularly the Ministry of Foreign Affairs represented by the Embassy of Denmark in Ghana and the Danish Meteorological Institute for their invaluable collaboration in developing this maiden edition of the Ghana Climate Atlas. Their expertise, unwavering support, and continual commitment were pivotal to this achievement. This partnership reflects a shared dedication to advancing climate knowledge and promoting climate resilience in Ghana.



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Summary

By the end of the century (2081-2100), in a medium emission scenario, the best estimate of Ghana's future climate compared to the 1991-2020 reference period will be characterized by the following climatic changes:

Annual Temperature

Ghana's average annual temperature is projected to increase by about 1.5°C, reaching approximately 29.3°C. The Coastal, Forest, and Transition zones are each expected to warm by around 1.4°C, while the Guinea Savannah is projected to warm by about 1.5°C, and the Sudan Savannah is expected to experience the highest increase of approximately 1.7°C.

Seasonal Temperature

Across Ghana, seasonal temperatures are projected to increase most during the December-January-February (DJF) dry season, with a national average rise of about 1.6°C, while the smallest increase of about 1.3°C is expected during the July-August-September (JAS).

Below are the temperature projections for the Agro-climatic zones:

- **Coastal Zone:** Relatively spatially uniform warming, with increases ranging between 1.3°C and 1.4°C across all seasons.
- **Forest Zone:** Highest increases of about 1.5°C during AMJ and DJF; lowest of 1.3°C during JAS and SON.
- **Transition Zone:** Highest increase of 1.5°C during DJF; lowest of 1.3°C during SON.
- **Guinea Savannah:** Highest increases of 1.6°C during AMJ and DJF; lowest of 1.3°C during JAS.
- **Sudan Savannah:** Highest increases of 1.8°C during AMJ and DJF; lowest of 1.3°C during JAS.

Annual Rainfall

Total annual rainfall for Ghana is projected to increase by 22mm (1.8%) relative to the reference period value of 1221mm. These projected changes are very small, and year-to-year variations fall within the models' uncertainty range, indicating that only minimal changes in annual rainfall are expected nationally.

Seasonal Rainfall

Among the rainy seasons, July-August-September (JAS) will experience the most increase nationally, with an increase of about 18mm (3.9%) followed by September- October-November (SON) with about 13mm (3.6%). However, April-May-June is expected to have a decline in rainfall of about 8mm (1.7%).

Below are the rainfall projections for the Agro-climatic zones:

- **Coastal Zone:** Annual rainfall decreases slightly by 6mm (0.6%). The SON season is expected to have the largest increase of 18mm (7.0%), while the AMJ major rainy season declines sharply by 16mm (3.5%).
- **Forest Zone:** Annual rainfall increases slightly by 20mm (1.4%). The JAS season is expected to have the largest increase of 24mm (6.2%), while AMJ declines by 9mm (1.7%).
- **Transition Zone:** Annual rainfall increases by 15mm (1.3%). The JAS season is expected to have the largest increase of 20mm (5.2%), while AMJ declines by 8mm (1.7%).
- **Guinea Savannah:** Annual rainfall increases by 26mm (2.3%). The SON season is expected to have the largest increase of 9mm (2.7%), while AMJ declines by 6mm (1.6%).
- **Sudan Savannah:** Annual rainfall increases slightly by 31mm (3.2%). The SON peak rainy season is expected to have the largest increase of 10mm (4.7%), while AMJ declines by 6mm (2.2%).

These projected changes in future rainfall are very small, and the year-to-year variations fall within the models' uncertainty range. This means we can communicate that only minimal changes in rainfall are expected

Sea-level rise

- A continuous rise in mean sea level ranging from 0.4 to 0.7m is expected.

1.0 Introduction

1.1 Ghana Climate Atlas

The issue of climate change has gained a lot of traction on the world stage, especially since the start of the 21st century. Climate change affects the environment in different ways, including rising temperatures, sea level rise, heatwaves, strong winds, drought, and extreme rainfall events among many others (IPCC, 2021). These hazards are experienced differently from region to region, and some places are more vulnerable than others (IPCC, 2018). This report is part of the Ghana Climate Atlas showing results of how the climate in Ghana is projected to change in the 21st century under multiple future scenarios both annually and seasonally. This report shows climate change results focusing on a few selected key indicators; average annual temperature, average seasonal temperature, total annual rainfall, total seasonal rainfall, and average annual sea level rise (SLR) both at the national level and across Ghana's various agro-climatic zones (SLR only applies to the coastal areas).

1.2 Ghana's Observed Climate

Ghana is located along the southern coast of West Africa and is bordered by Togo to the east, Côte d'Ivoire to the west, Burkina Faso to the north, and the Atlantic Ocean (Gulf of Guinea) to the south. The country lies approximately between latitudes 4.5°N and 11.5°N and longitudes 1.5°E and 3.5°W.

Ghana's climate is strongly influenced by its location within the tropical West African region and by the seasonal movement of the Inter-Tropical Discontinuity (ITD), which separates moist south-westerly winds from the Atlantic Ocean and dry north-easterly winds from the Sahara Desert. As the ITD moves northward and southward throughout the year, it determines the onset, intensity, and duration of rainfall across the country. Consequently, the rainfall patterns differ between the southern and northern parts of Ghana.

In recent decades, however, Ghana's climate has shown signs of gradual change consistent with global climate change trends. Observational records indicate rising temperatures, increasing variability in rainfall patterns, and a growing frequency of extreme weather events such as floods and droughts. These changes pose significant risks to key sectors including agriculture, water resources, energy, infrastructure, and public health.

Understanding how Ghana's climate is changing over time is crucial for planning effective adaptation and resilience strategies. The Ghana Climate Atlas, therefore, offers a comprehensive assessment of the country's future climate relative to historical conditions under different emission scenarios

Rainfall and Temperature Patterns

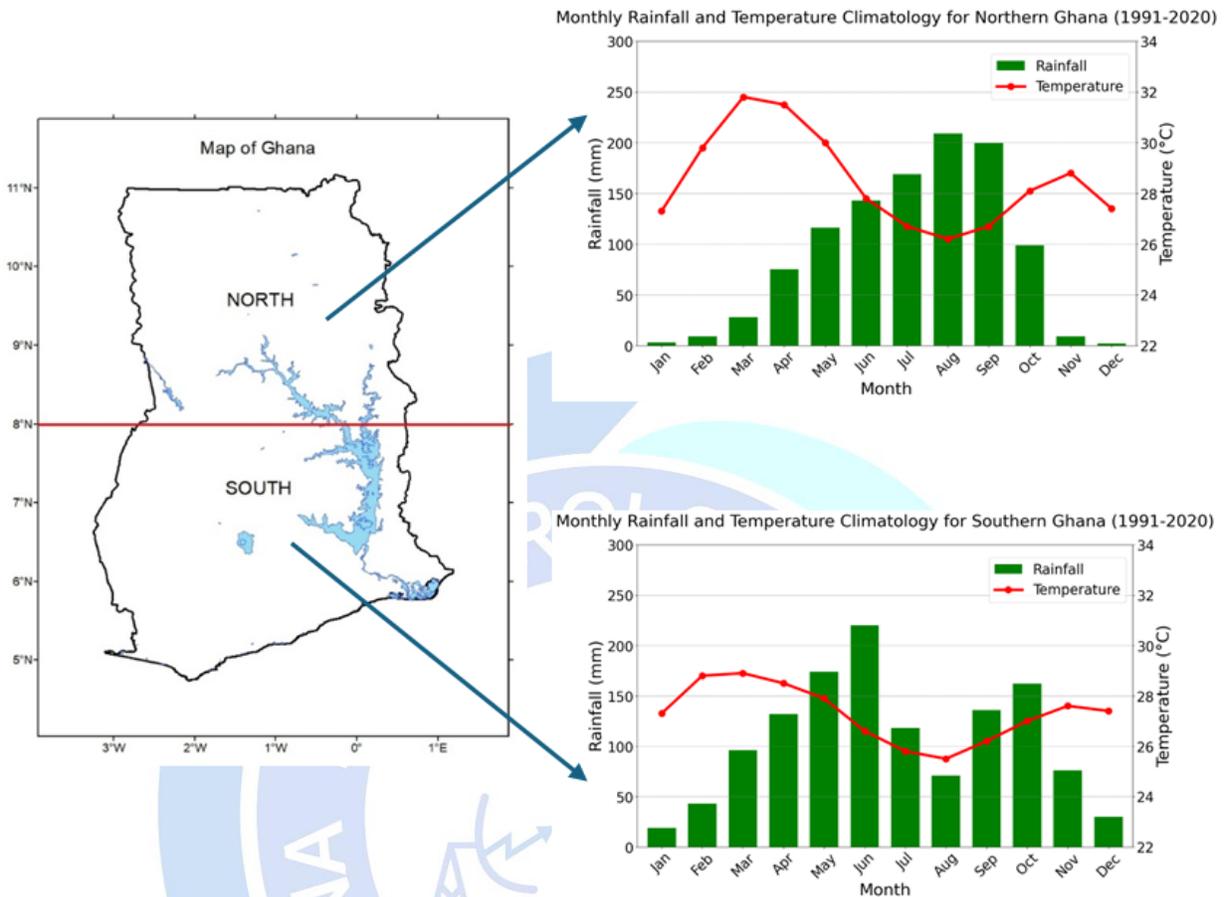


Figure 1 Rainfall and Temperature climatology of Ghana (1991 -2020)

In the southern sector of Ghana (south of 8°N), rainfall follows a bimodal pattern, meaning two distinct rainy seasons occur within the year. The major rainy season typically extends from March to July, while the minor rainy season occurs between September and November. Between these two seasons, rainfall temporarily reduces during August; a period commonly referred to as the “little dry season”. Average monthly temperatures typically range between 25°C and 30°C, with relatively small seasonal variations but noticeable differences across regions.

In contrast, the northern sector of Ghana (north of 8°N) experiences a unimodal rainfall pattern, that is, a single rainy season that typically begins around April and lasts until October. Average monthly temperatures are generally high throughout the year, typically ranging between 26°C and 32°C, reflecting the region’s location within the tropical savannah belt and its stronger exposure to dry continental air mass during the dry season (December-January-February).

Trends and Anomaly

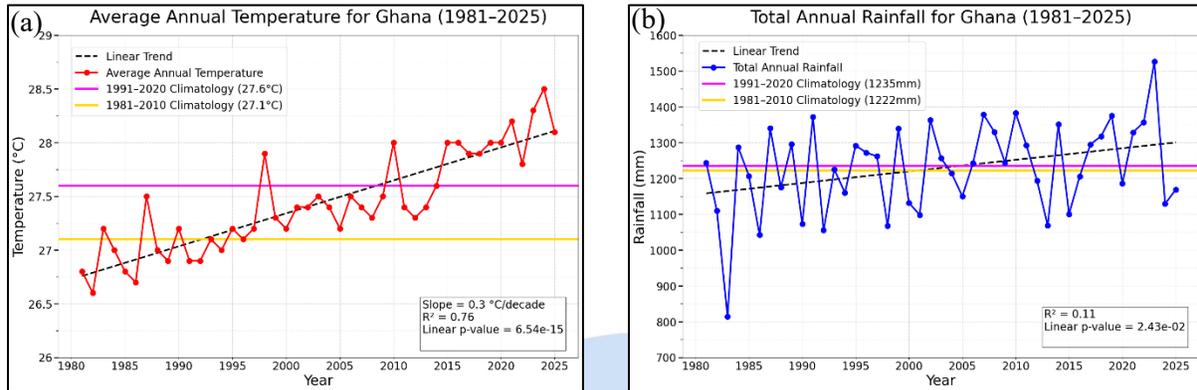


Figure 2. Average Annual Temperature and Rainfall Trend of Ghana (1981 - 2025)

Temperatures have gradually increased over the period as shown in the **figure 2(a)**, reflecting a steady warming of Ghana's climate over time. **Figure 2(b)** illustrates how rainfall in Ghana have changed over time. It shows that rainfall varies considerably from year to year, with some years experiencing higher totals and others noticeably lower. While there are periods with relatively high rainfall amounts, the overall pattern suggests that rainfall is highly variable.

In terms of anomalies, as shown in **Figure 3(a)**, temperature shows a clear shift over time. Earlier years were generally cooler than the long-term average, while more recent years are mostly warmer. The increasing number of positive temperature anomalies in recent years suggests that warmer than average conditions have become more common.

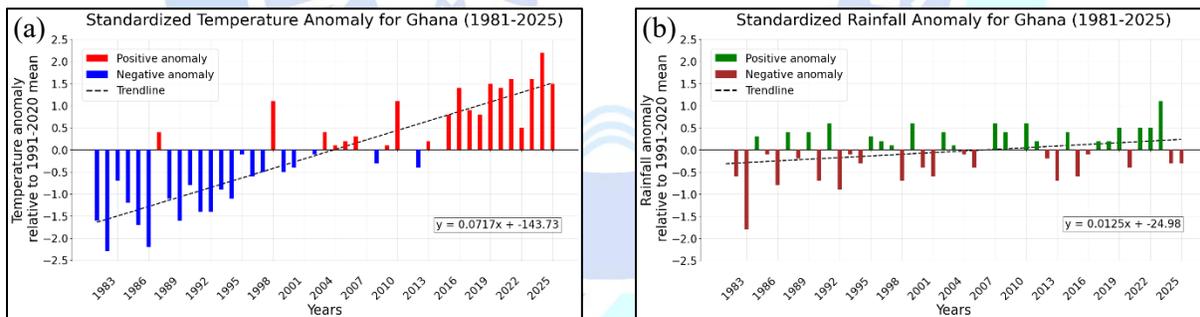


Figure 3. Standardized Rainfall and Temperature Anomaly for Ghana (1981 - 2025)

The rainfall anomalies shown in **Figure 3(b)**, on the other hand, show much greater variability. Some years experienced above normal rainfall, while other years were below normal. Unlike temperatures, rainfall does not show a strong or consistent long-term trend but rather fluctuates from year to year.

1.3 Emission scenarios

Long-term emission scenarios describe different possible pathways for how global greenhouse gas emissions may change in the future based on how the world might produce or reduce greenhouse gases in the future (Pedersen et al., 2021). Emission scenarios help understand what the climate

could look like under different choices made today. These scenarios guide much of today's climate research and provide governments with useful information when planning climate risks and solutions. The Ghana Climate Atlas provides the opportunity to see how the climate in Ghana is projected to change under different emission scenarios derived from the Intergovernmental Panel on Climate Change (IPCC) reports. The IPCC's fifth assessment report (AR5) and special reports from 2018 and 2019 used the so-called RCPs scenarios ("Representative Concentration Pathways"), while the sixth assessment report (AR6) and special reports from 2021 and 2022 used a new set of scenarios called SSPs ("Shared Socioeconomic Pathways"). The RCPs describe different levels of future greenhouse gas concentrations based on how much the world warms, whereas the SSPs describe possible socioeconomic futures such as population, development, and technology, combined with emission pathways to assess future climate outcomes (IPCC, 2021). The scenarios used in this report are a **low** (RCP2.6/SSP1-2.6), a **medium** (RCP4.5/SSP3-4.5), and a **high** (RCP8.5/SSP5-8.5) emission scenario.

A low emission scenario is representative of scenarios that lead to low greenhouse gas concentration levels due to decline in emissions of carbon dioxide (CO₂) by mid century, eventually becoming negative by the end of the century, which is in line with the Paris Agreement. A medium emission scenario has CO₂ emissions remaining around current levels until mid century, then declines towards the end of the century. A high emission scenario has CO₂ emissions rising steadily and roughly doubling from current levels by the end of the century, where global warming is likely to be 2°C (Van Vuuren et al., 2011).

1.4 Data sources, time periods and uncertainty levels

The Atlas relies on a station gridded merged dataset developed by GMet, which integrates station observations with reanalysis data for temperature and satellite-based estimates for rainfall. By blending spatially continuous, high-resolution reanalysis and satellite datasets with accurate ground-based gauge measurements, this generates a refined gridded dataset at approximately 4km that improves both spatial coverage and reliability.

For future projections, the Atlas uses simulations from CORDEX-Africa. These regional climate models, at approximately 25 to 50km grid spatial resolution, downscaled global climate models to provide region-specific information for Africa. An ensemble of about 39 Regional Climate Model combinations is used for Ghana to capture a broad spectrum of possible climate futures.

Since climate models do not perfectly reproduce observed conditions, the Ghana Climate Atlas applies Quantile Delta Mapping (QDM) to correct systematic biases. This statistical method aligns the distribution of model outputs with observed historical records while preserving the projected climate change signal. The calibration is based on the 1991–2020 reference period, which corresponds to the latest World Meteorological Organization climatological normal. The final product after calibration is a QDM bias-corrected and statistically downscaled climate data at 4 km spatial grid resolution.

The reference period used in the Ghana Climate Atlas is the 1991-2020 average inspired by the latest IPCC assessment report (AR6). Ghana Climate Atlas shows analysis of climate at four averaged time periods, i.e., reference period (1991-2020), near term (2021-2040), mid century (2041-2060) and end of century (2081-2100).

Since no single climate model can perfectly capture all aspects of the future climate, we need to communicate the uncertainty in the projections. The 10th and 90th percentiles around the median (50%) show the range of results produced by different climate models. This range represents model uncertainty, it helps us understand how confident we can be in the projections and reminds us that future climate outcomes are not a single fixed number but fall within a spread of possible values. In the Ghana Climate Atlas, the uncertainty is shown as 10th and 90th percentiles around the median value (50%). The climate models used were based on the climate model democracy approach (Knutti, 2010). This is an approach that refers to the practice of treating all climate models equally when analyzing future climate projections, rather than assigning different weights based on their perceived accuracy or reliability. This approach is widely adopted in multi-model ensembles used for estimating climate change signals, where outputs from multiple climate models are averaged to make climate projections.

1.5 Guide to figures

The report shows aggregated information in two different formats: maps and boxplot. How to read a boxplot is described in **Figure 4**. All figures show climate information in relation to emission scenarios and time periods. The graphs and boxplots also indicate the uncertainty intervals. It is most likely that the change is around the median, but the upper and lower bounds give an idea of how large the uncertainty is.

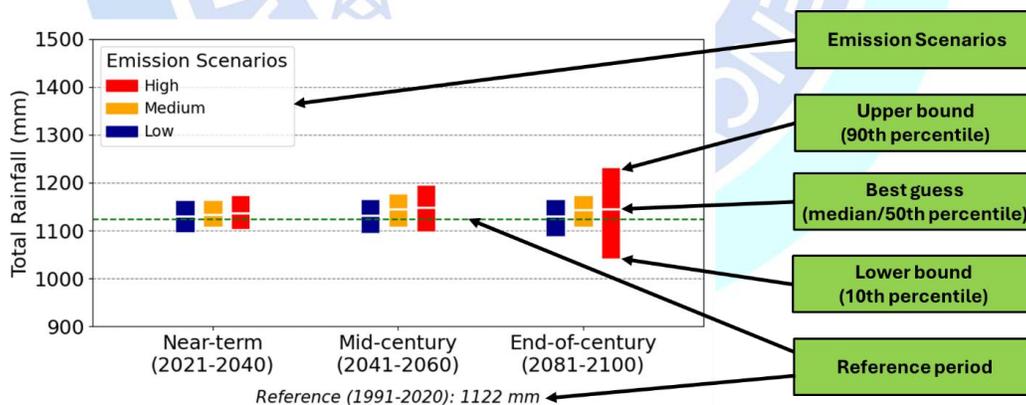


Figure 4. Interpreting the boxplot figures. Example of change in average annual rainfall across Ghana.

In this hypothetical example showing average annual rainfall across Ghana, the best guess (the median shown by a solid line) at the end of the century under a high emissions scenario is 1145mm, an increase of 23mm compared to the reference value of 1122mm. The lower bound (10th percentile of the models) is 1042mm, indicating a decrease of 80mm and the upper bound (90th percentile of the models) is 1231mm, indicating an increase of 109mm.

2.0 Climate Projections

This section examines key climate indicators; average temperature, total rainfall and sea level rise (SLR), critical to understanding climate change in Ghana. Rising temperatures, shifting rainfall patterns, and possible coastal erosion due to SLR poses significant environmental and socio-economic challenges in the country. Analyzing trends of these indicators provides insight into current and future climate risks which may inform adaptation and mitigation strategies.

2.1 Average Annual Temperature

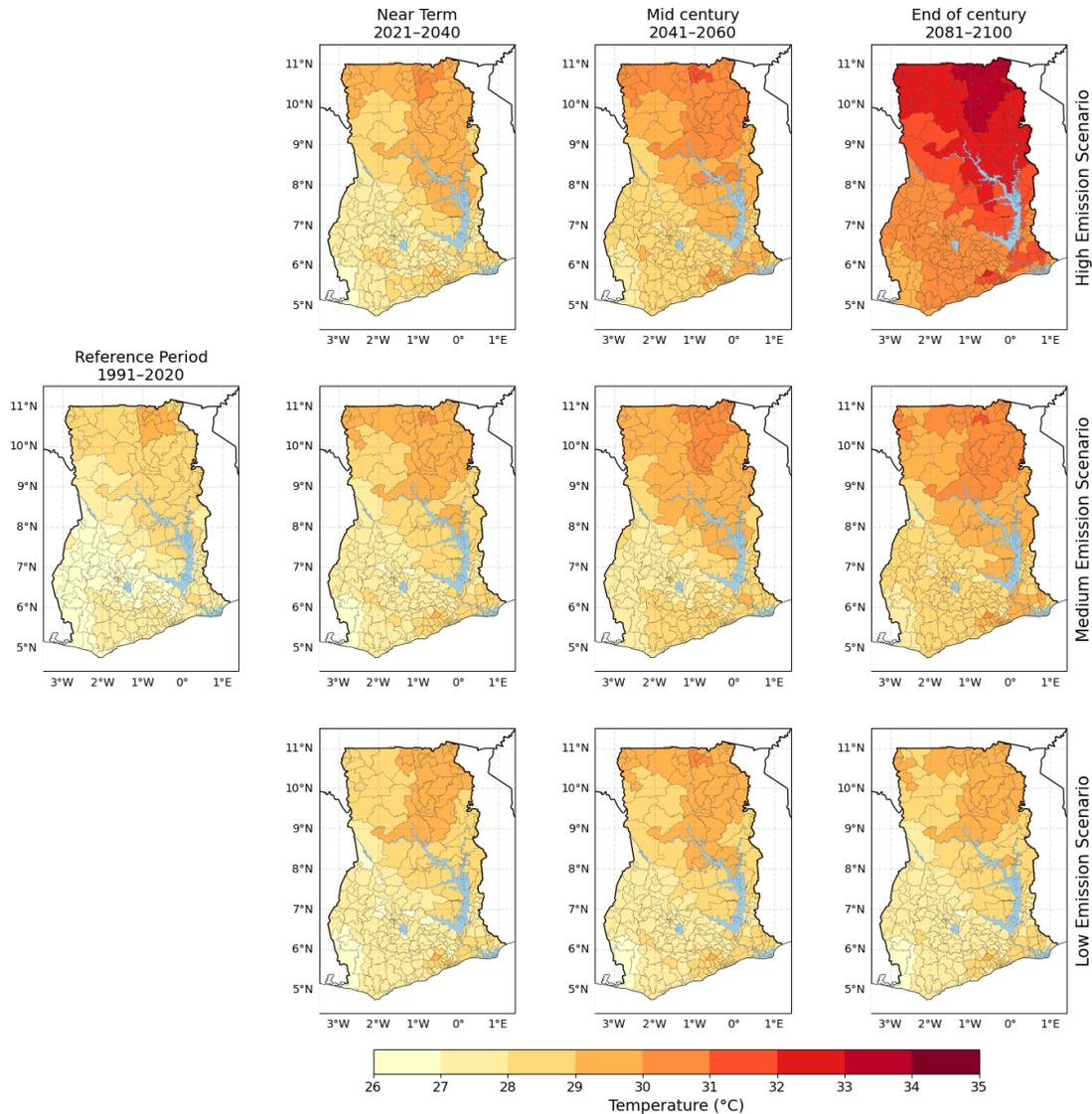


Figure 5. Variations in average annual temperature (50th percentile) in Ghana under low, medium and high emission scenarios for the near term (2021-2040), mid century (2041-2060) and end of century (2081-2100) periods. The stand-alone plot on the far left shows the reference period (1991-2020)

The projections for average annual temperature over the entire country show a general increase under all three emission scenarios: low, medium, and high for the near term, mid century and end of century. The medium and high emission scenarios show a higher increase towards the end of century especially in the northern part of the country, middle belt through to the south-eastern portion of the country. As expected, annual temperatures in Ghana are highest under the high-emission scenario toward the end of the century, reflecting the stronger global warming projected under this pathway.

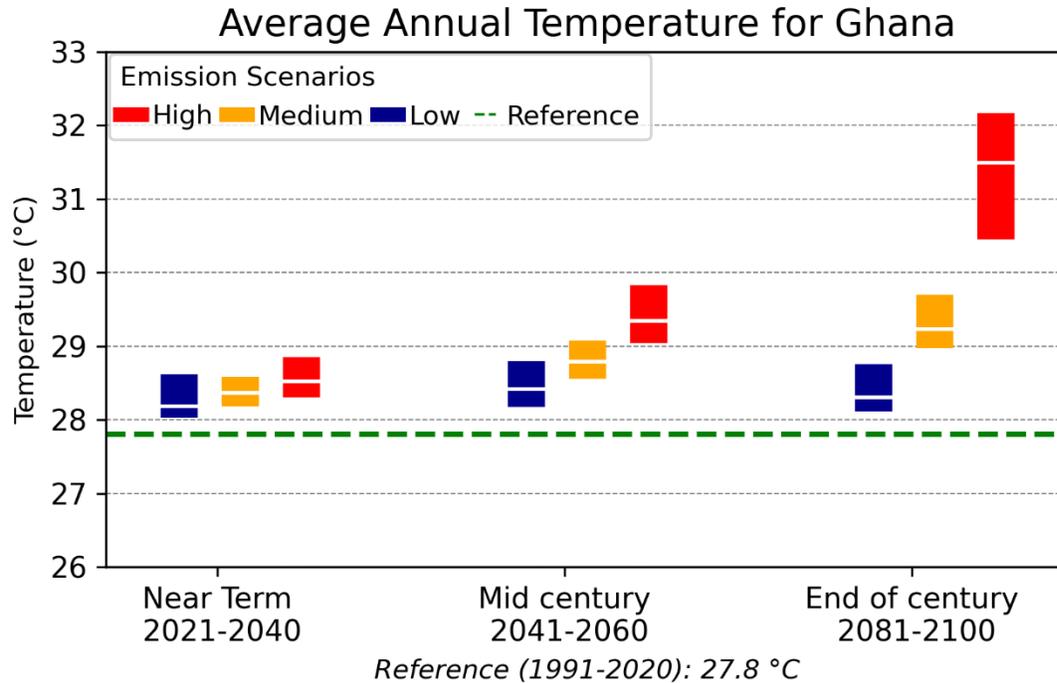


Figure 6. Average annual temperature boxplot under three emission scenarios in Ghana. The figure shows temperature projection for the time periods 2021-2040, 2041-2060 and 2081-2100. The low, medium and high emission scenarios are represented by blue, orange and red colored bars respectively. The uncertainty bounds shown on the plot are the 10th to 90th percentiles of the models.

Average annual temperature projection for Ghana shows a general increase in temperature above the 27.8°C reference period average under all three emission scenarios from the near term to the end of century as shown in **Figure 6**. Projections for a low emission scenario show a modest increase of about 0.4°C, 0.6°C, and 0.5°C for the near term, mid century and end of century respectively. A medium emission scenario indicates an increase of 0.6°C, 1.0°C and 1.5°C for the near term, mid century and end of century, respectively. For a high emission scenario, the average temperature increase towards the end of century is 3.7°C whereas the near term and mid century are projected to increase by 0.7°C and 1.6°C respectively. Average annual temperature is therefore expected to be 29.3°C with uncertainty range between 28.8°C and 29.5°C at the end of century under a medium emission scenario.

2.2 Average Seasonal Temperature

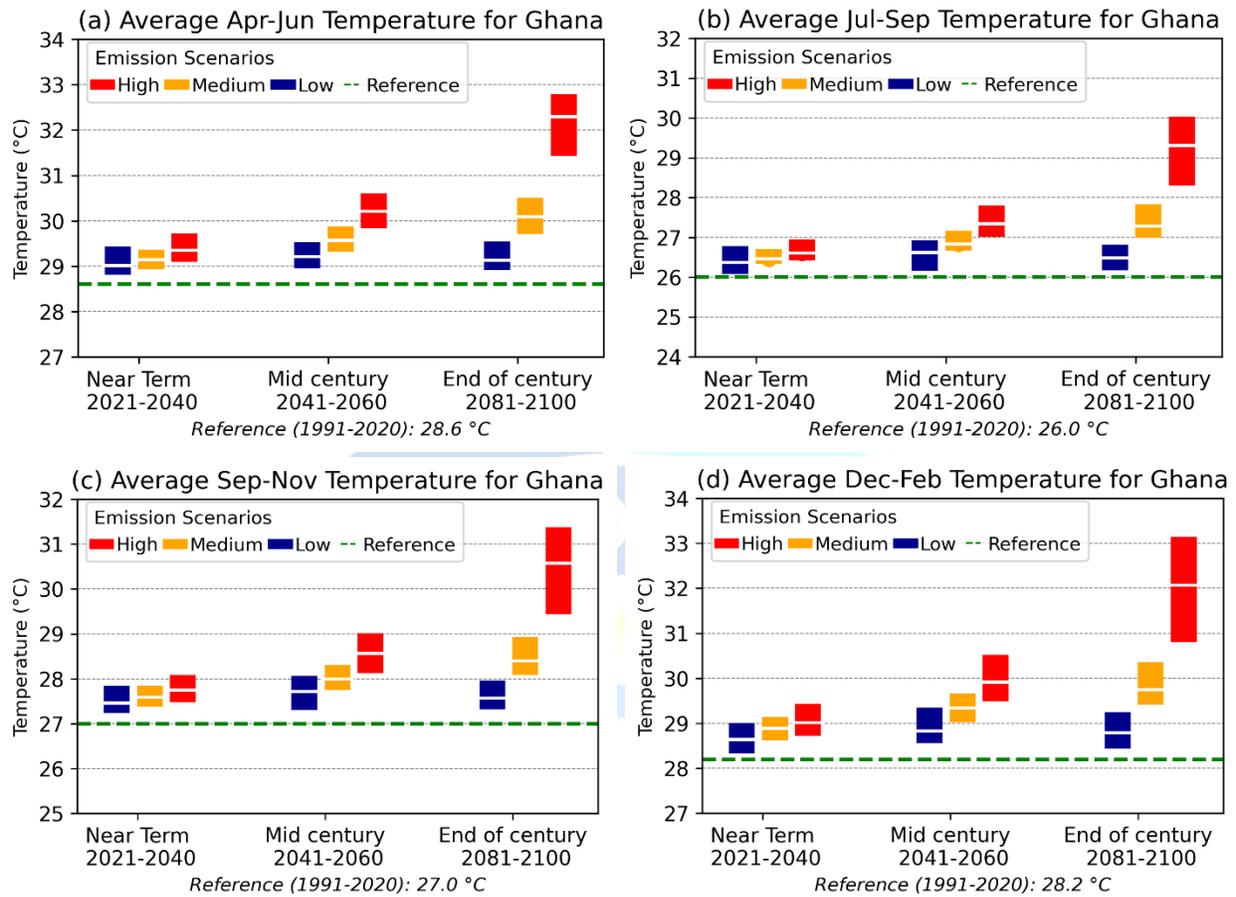


Figure 7. Average seasonal temperature boxplots for (a) Apr-Jun (AMJ), (b) Jul-Sep (JAS), (c) Sep-Nov (SON) and (d) Dec-Feb (DJF) seasons under three emission scenarios in Ghana. The figures show the temperature average in the time periods 2021-2040, 2041-2060 and 2081-2100. The low, medium and high emission scenarios are represented by blue, orange and red colored bars respectively. The uncertainty bounds shown on the plot are the 10th to 90th percentiles of the models. Note that the y-axis ranges differ between panels for clarity.

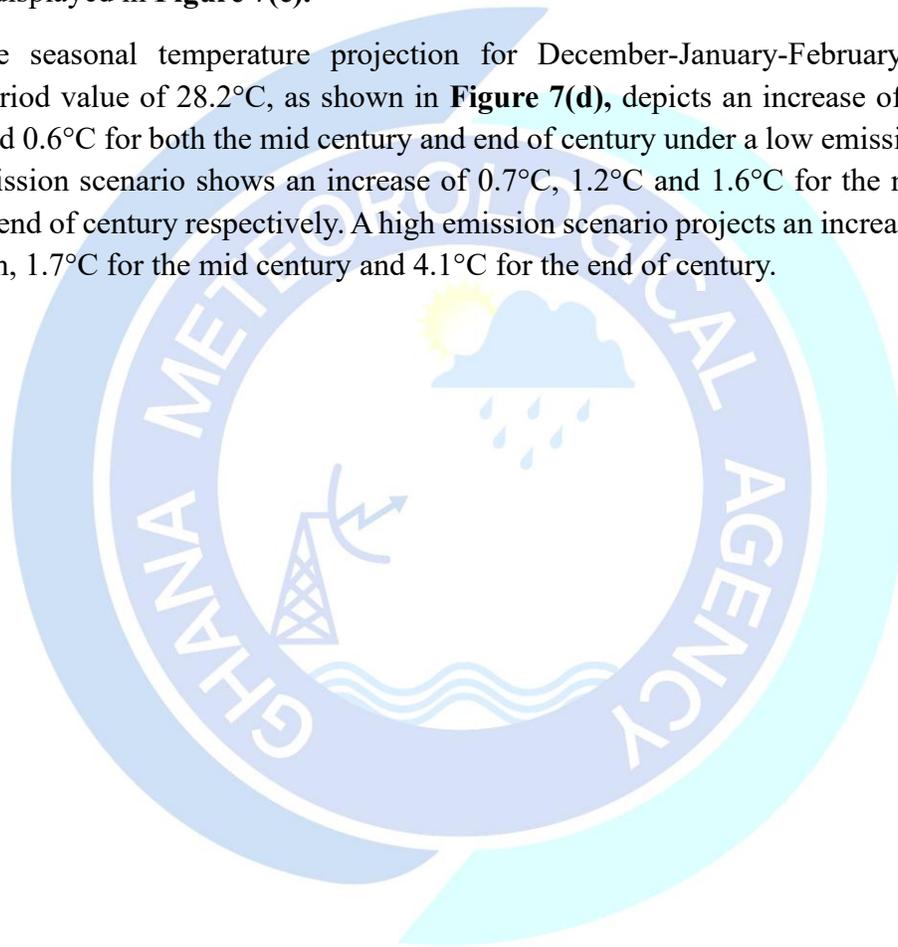
In **Figure 7(a)**, the average seasonal temperature for April-May-June (AMJ), with reference period value of 28.6°C, is projected to rise by 0.5°C, 0.6°C and 0.8°C under a low, medium and high emission scenarios respectively for the near term period. Temperature during the mid century is expected to increase by 0.7°C, 1.0°C and 1.7°C, for a low, medium and high emission scenario, respectively. The end of century projection shows an increase of 0.6°C for a low emission scenario, 1.5°C for a medium emission scenario and 3.7°C for a high emission scenario.

With an average seasonal temperature of 26.0°C for the reference period, the projection for July-August-September (JAS) as shown in **Figure 7(b)**, depicts an increase of 0.4°C for the near term, 0.7°C for mid century and 0.5°C at the end of century under a low emission scenario. A medium emission scenario shows an increase of 0.5°C, 0.9°C and 1.3°C for the near term, mid century and

end of century respectively. A high emission scenario projects an increase of 0.6°C, 1.4°C and 3.3°C for the near term, mid century and end of century respectively.

Projections for the average seasonal temperature for September-October-November (SON) relative to a reference period value of 27.0°C indicate an increase of 0.4°C for near term, 0.7°C for mid century and 0.5°C for end of century under a low emission scenario. A medium emission scenario projects an average temperature rise of 0.6°C, 1.0°C and 1.4°C for near term, mid century and end of century periods respectively. A high emission scenario shows an increase of 0.7°C and 1.5°C for the near term and mid century respectively while the end of century shows an increase of 3.6°C as displayed in **Figure 7(c)**.

The average seasonal temperature projection for December-January-February (DJF), with reference period value of 28.2°C, as shown in **Figure 7(d)**, depicts an increase of 0.5°C for the near term and 0.6°C for both the mid century and end of century under a low emission scenario. A medium emission scenario shows an increase of 0.7°C, 1.2°C and 1.6°C for the near term, mid century and end of century respectively. A high emission scenario projects an increase of 0.8°C for the near term, 1.7°C for the mid century and 4.1°C for the end of century.



2.3 Total Annual Rainfall

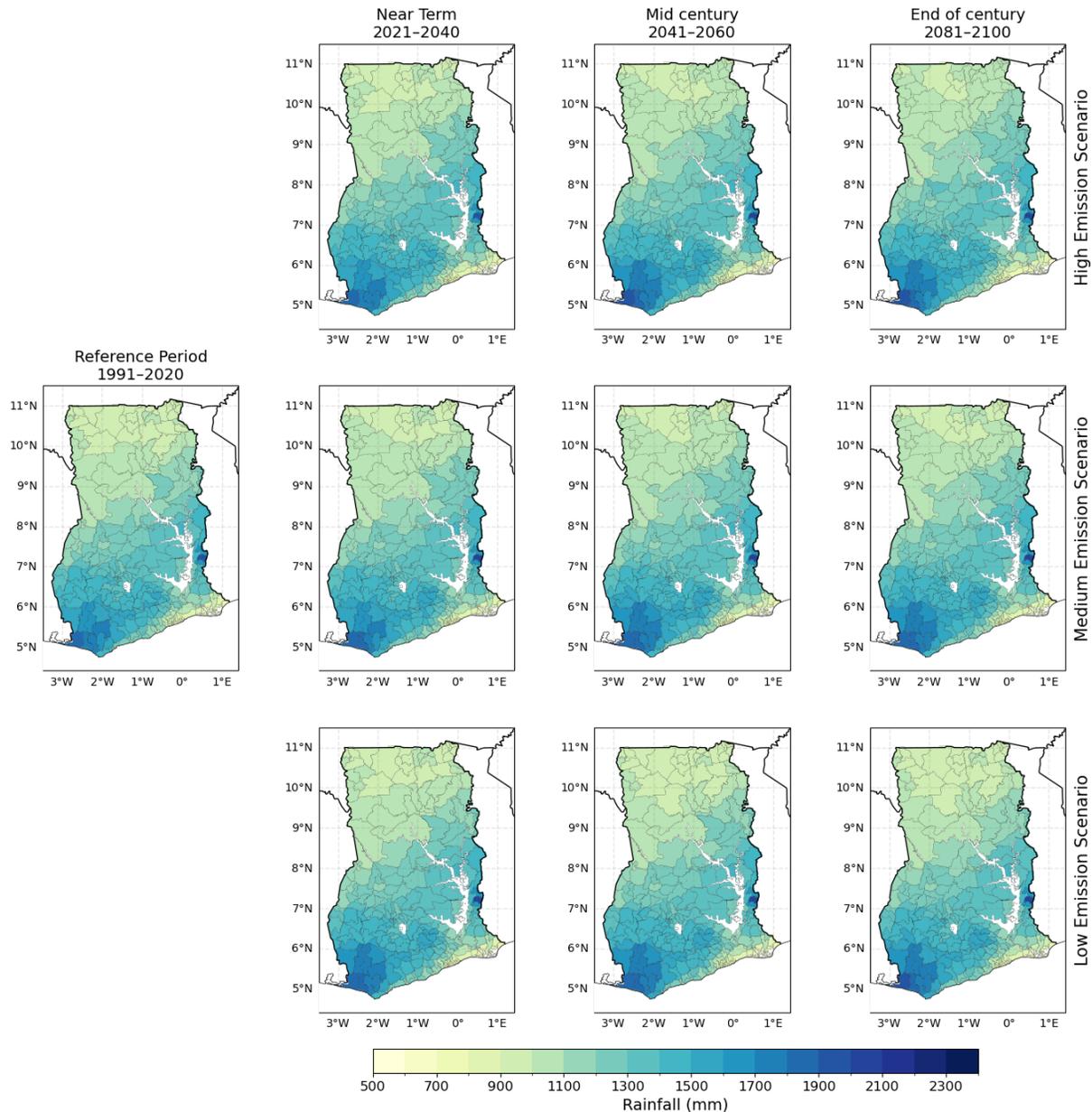


Figure 8. Variations in total annual rainfall (50th percentile) in Ghana under low, medium and high emission scenarios for the near term (2021-2040), mid century (2041-2060) and end of century (2081-2100). The stand-alone plot on the far-left shows for the reference period (1991-2020).

In **Figure 8**, the total annual rainfall projections for Ghana, for the near term, mid century and end of century as compared to the reference period show minimal increase under all the three emission scenarios (low, medium, and high). However, rainfall is highest in the southwest and far eastern parts of the country and decreases northwards. The variability in rainfall over Ghana is more pronounced when analyzed on a seasonal level.

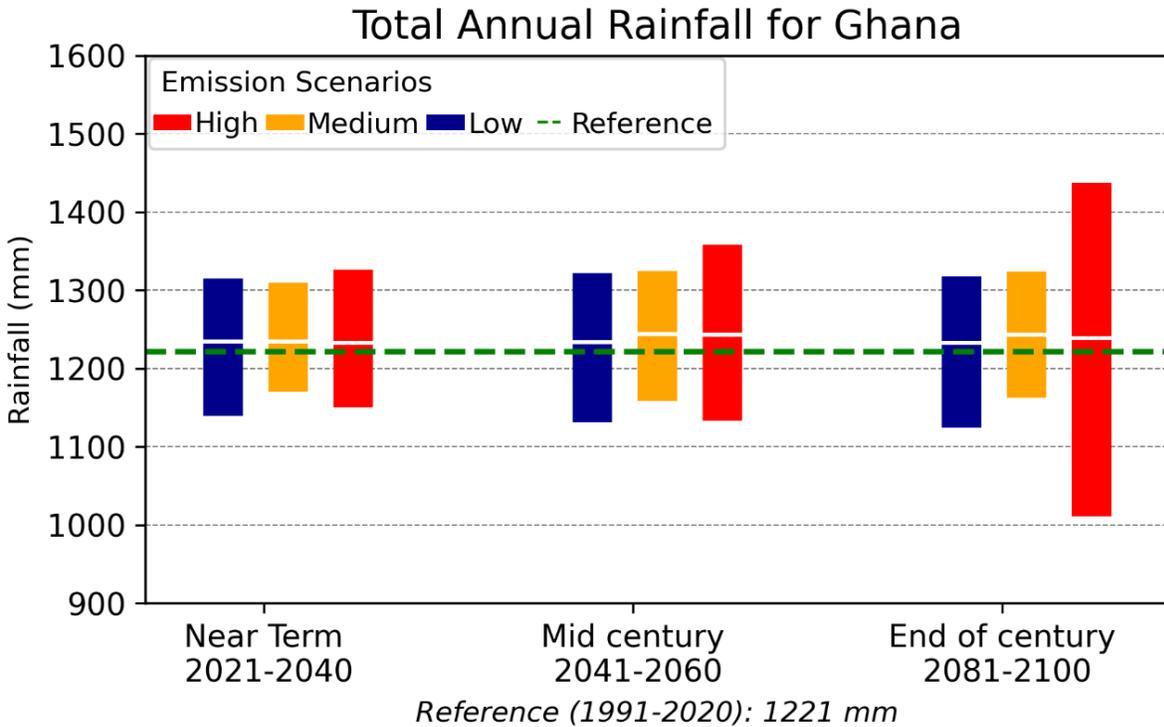


Figure 9. Total annual rainfall boxplot under three emission scenarios in Ghana. The figure shows rainfall projection for the time periods 2021-2040, 2041-2060 and 2081-2100. The low, medium and high emission scenarios are represented by blue, orange, and red colors respectively. The uncertainty bounds shown on the plot are the 10th to 90th percentiles of the models.

Total annual rainfall projection for Ghana shows a slight increase above the reference period value of 1221mm for all three emission scenarios from the near term to the end of century, as shown in **Figure 9**, albeit with wide uncertainties. On average, rainfall is projected to slightly increase by 13mm (1.1%) for near term, 12mm (1.0%) for both mid century and end of century under a low emission scenario. An increase of 13mm (1.1%), 23mm (1.9%) and 22mm (1.8%) is expected for the near term, mid century and end of century respectively under a medium emission scenario. Under a high emission scenario, rainfall is projected to increase by 12mm (0.9%) for the near term, 22mm (1.8%) for mid century and 17mm (1.4%) by end of century.

2.4 Total Seasonal Rainfall

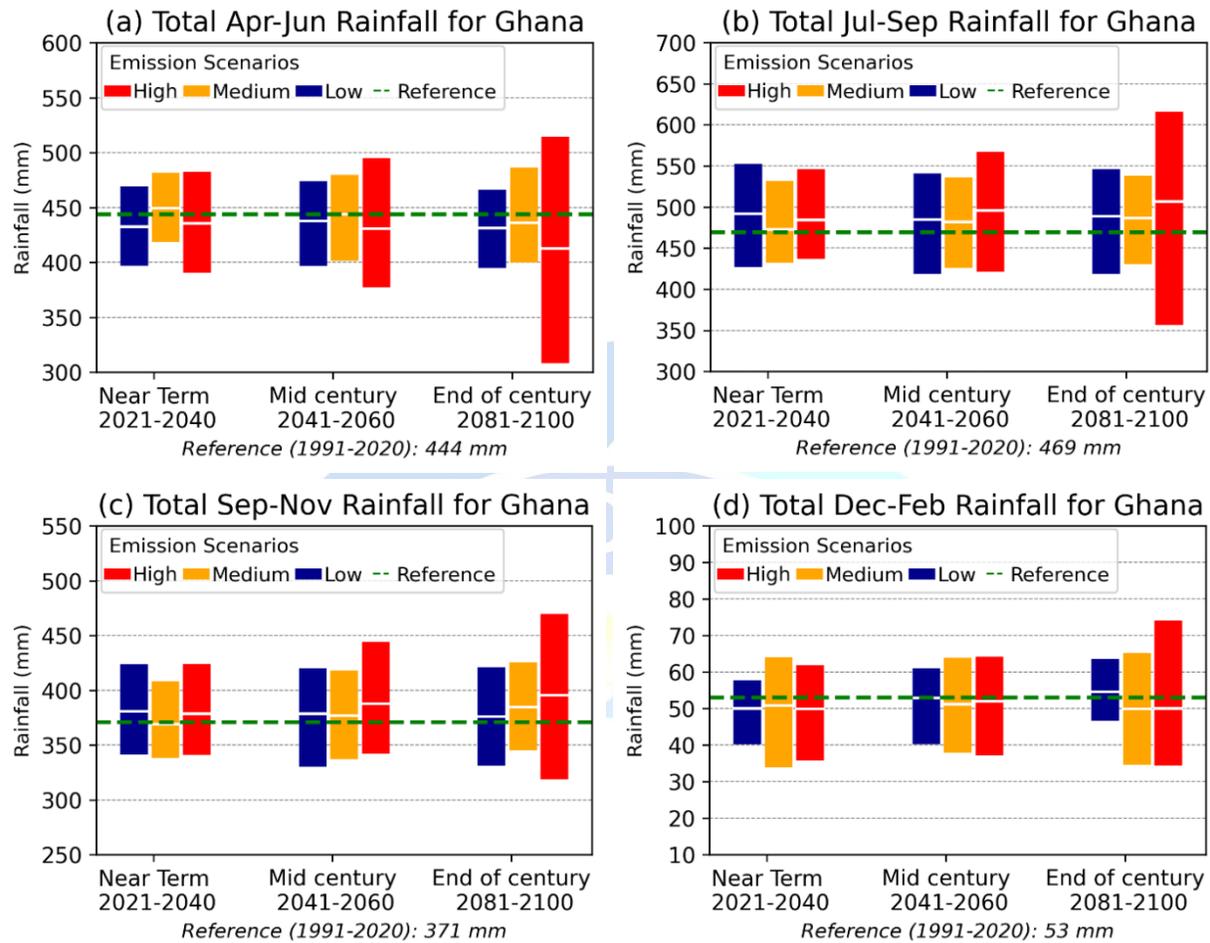


Figure 10. Total seasonal rainfall boxplots for (a) Apr-Jun (AMJ), (b) Jul-Sep (JAS), (c) Sep-Nov (SON) and (d) Dec-Feb (DJF) seasons under three emission scenarios in Ghana. The figures show the average rainfall in the time periods 2021-2040, 2041-2060 and 2081-2100. The low, medium and high emission scenarios are represented by blue, orange and red colors respectively. The uncertainty bounds shown on the plot are the 10th to 90th percentiles of the models. Note that the y-axis ranges differ between panels for clarity.

Rainfall projection for April-May-June (AMJ) season as depicted in **Figure 10(a)**, shows a decrease of 11mm (2.5%) for the near term, 6mm (1.4%) for the mid century, and 13mm (2.8%) for the end of century under a low emission scenario, compared to the reference period amount of 444mm. Under a medium emission scenario, rainfall is projected to increase by 6mm (1.3%) for the near term and 8mm (1.7%) for the end of century with no change expected during the mid century. Under a high emission scenario, rainfall is expected to decrease across all time periods by 8mm (1.8%) for the near term, 13mm (2.8%) for the mid century and 31mm (7.0%) for the end of century.

The projection for July-August-September (JAS) in comparison with the reference period value of 469mm as presented in **Figure 10(b)** shows an increase for all time periods. A low emission scenario depicts an increase of 23mm (5.0%) for the near term, 16mm (3.5%) for the mid century and 20mm (4.4%) for the end of century. Under a medium emission scenario, rainfall is projected to increase by 4mm (0.9%), 14mm (2.9%) and 18mm (3.9%) for the near term, mid century and end of century respectively. A high emission scenario projects an increase of 16mm (3.3%), 27mm (5.8%) and 38mm (8.1%) for the near term, mid century and end of century respectively.

Figure 10(c) shows projected changes in September-October-November (SON) seasonal rainfall relative to the reference period amount of 371mm. Under a low emission scenario, rainfall is projected to increase by 10mm (2.6%) for the near term, 7mm (2.0%) for the mid century and 5mm (1.2%) for the end of century. Under a medium emission scenario, a decrease of 2mm (0.6%) is projected for the near term whilst rainfall is projected to increase by 5mm (1.4%) for the mid century and 13mm (3.6%) for the end of century. A high emission scenario projects an increase of 7mm (1.9%) for near term, 17mm (4.4%) for mid century and 24mm (6.5%) for the end of century.

The projections for December-January-February (DJF), compared to the reference period value of 53mm as displayed in **Figure 10(d)**, show a decrease in rainfall for the medium and high emission scenarios for all time periods. Under a low emission scenario, a decrease of 3mm (4.9%) is projected for the near term and an increase of 2mm (3.8%) for the end of century whilst no change is projected during the mid century. Under a medium emission scenario, rainfall is projected to decrease by 2mm (3.4%) for the near term, 1mm (2.7%) for the mid century and 3mm (5.2%) for the end of century. In a high emission scenario, rainfall is expected to decrease by 3mm (5.2%) for the near term, 1mm (1.0%) for the mid century and 3mm (4.8%) for the end of century.

2.5 Average Annual Sea Level Rise

Across the globe, sea level rise (SLR) is not evenly distributed, and the differences are largely due to gravitational and elastic effects in relation to melting ice, effects of regional ocean dynamics and regional steric effects (Mitrovica and Milne, 2003). The latest IPCC Assessment Report (AR6) includes medium confidence SLR projections ranging up to 2150 (Fox-Kemper et al, 2021; Kopp et al, 2023). This report also makes use of this medium confidence suite of SLR projections across three SSP scenarios (SSP1-2.6, SSP2-4.5 and SSP5-8.5) to assess Ghana's future changes in SLR along the coast.

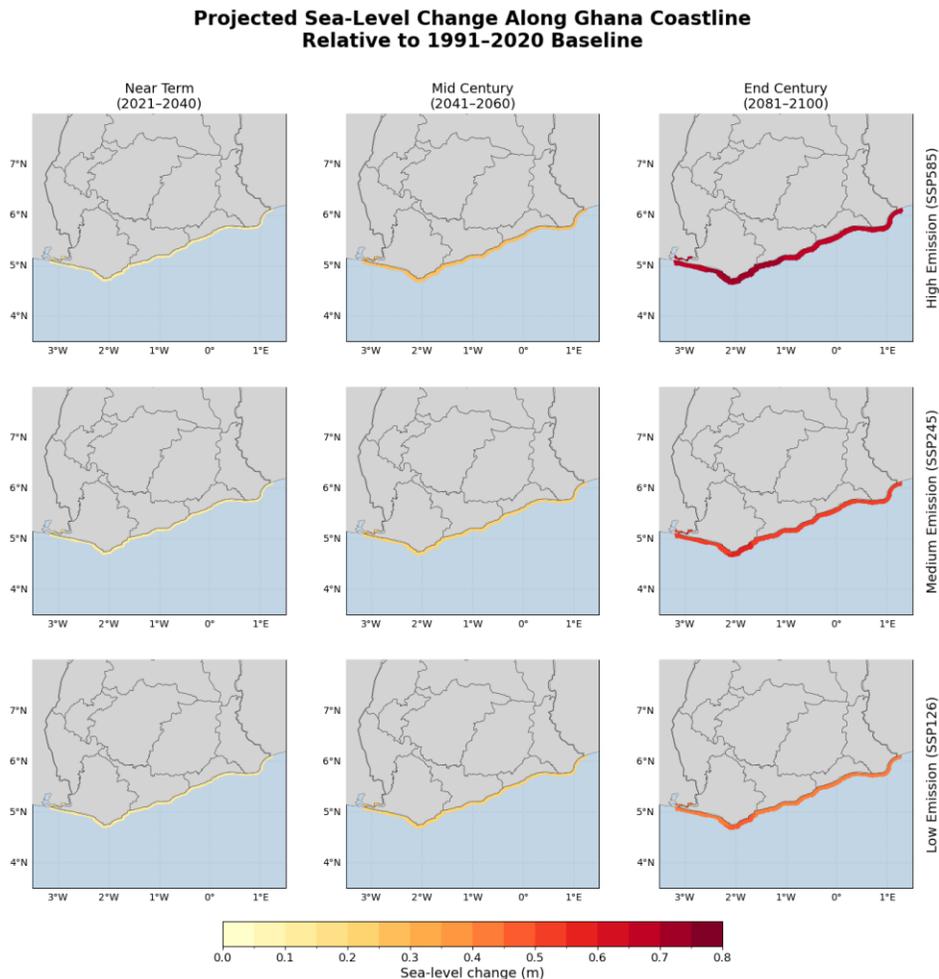


Figure 11. Projections of mean sea level rise over the period 2021 to 2100 relative to the 1991–2020 baseline (a period used for the Intergovernmental Panel on Climate Change Sixth Assessment Report (IPCC, 2021) from a combination of the CMIP6 model ensemble for a high emission, medium emission and low emissions scenarios

The projections of sea level rise show a continuous rise through the near term to end of century along the coastline under the three emission scenarios in **Figure 11**. By end of century, the coastline is projected to have a mean sea level rise of approximately 0.5m under a low emission scenario, 0.6m under a medium emission scenario and 0.7m under a high emission scenario.

3.0 Agro-Climatic Zones Projection

3.1 Agro-climatic Zones of Ghana

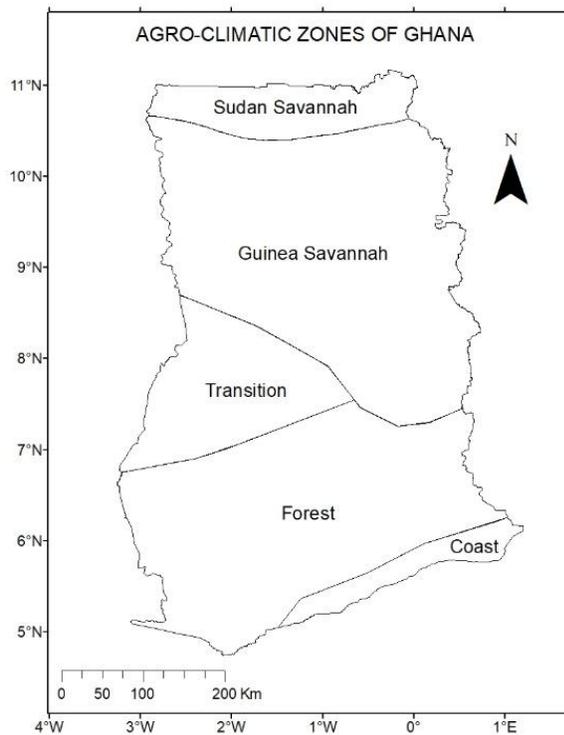


Figure 12 The Agro-Climatic Zones of Ghana

Ghana's climate and natural environment vary widely across the country, creating distinct agro-climatic zones shaped by the differences in rainfall, temperature, vegetation, and land use. For climate analysis in the Ghana Climate Atlas, the country is broadly divided into five major agro-climatic zones: the Coastal Zone, Forest Zone, Transition Zone, Guinea Savannah Zone, and Sudan Savannah Zone.

The Coastal Zone lies along the Gulf of Guinea and is influenced by maritime conditions, with relatively moderate temperatures and a bimodal rainfall pattern. Inland from the coast is the Forest Zone, characterized by the highest rainfall in the country, dense vegetation, and key agricultural activities such as cocoa production. Further north is the Transition Zone, which represents a gradual shift between the forest ecosystems of southern Ghana and the savannah landscapes of the north. The Guinea Savannah Zone, located in the northern part of the country, experiences a single rainy season and supports extensive farming and livestock activities. The Sudan Savannah Zone, found in the far north, is the driest and hottest part of the country, with shorter rainy seasons and higher vulnerability to drought and heat stress.

These climatic zones play an important role in shaping local climate conditions, agricultural systems, water resources, and livelihoods. Analyzing climate change within these zones allows the Ghana Climate Atlas to highlight regional differences in climate impacts and provide more targeted information for adaptation planning and decision-making.

These climatic zones play an important role in shaping local climate conditions, agricultural systems, water resources, and livelihoods. Analyzing climate change within these zones allows the Ghana Climate Atlas to highlight regional differences in climate impacts and provide more targeted information for adaptation planning and decision-making.

3.2 Average Annual Temperature

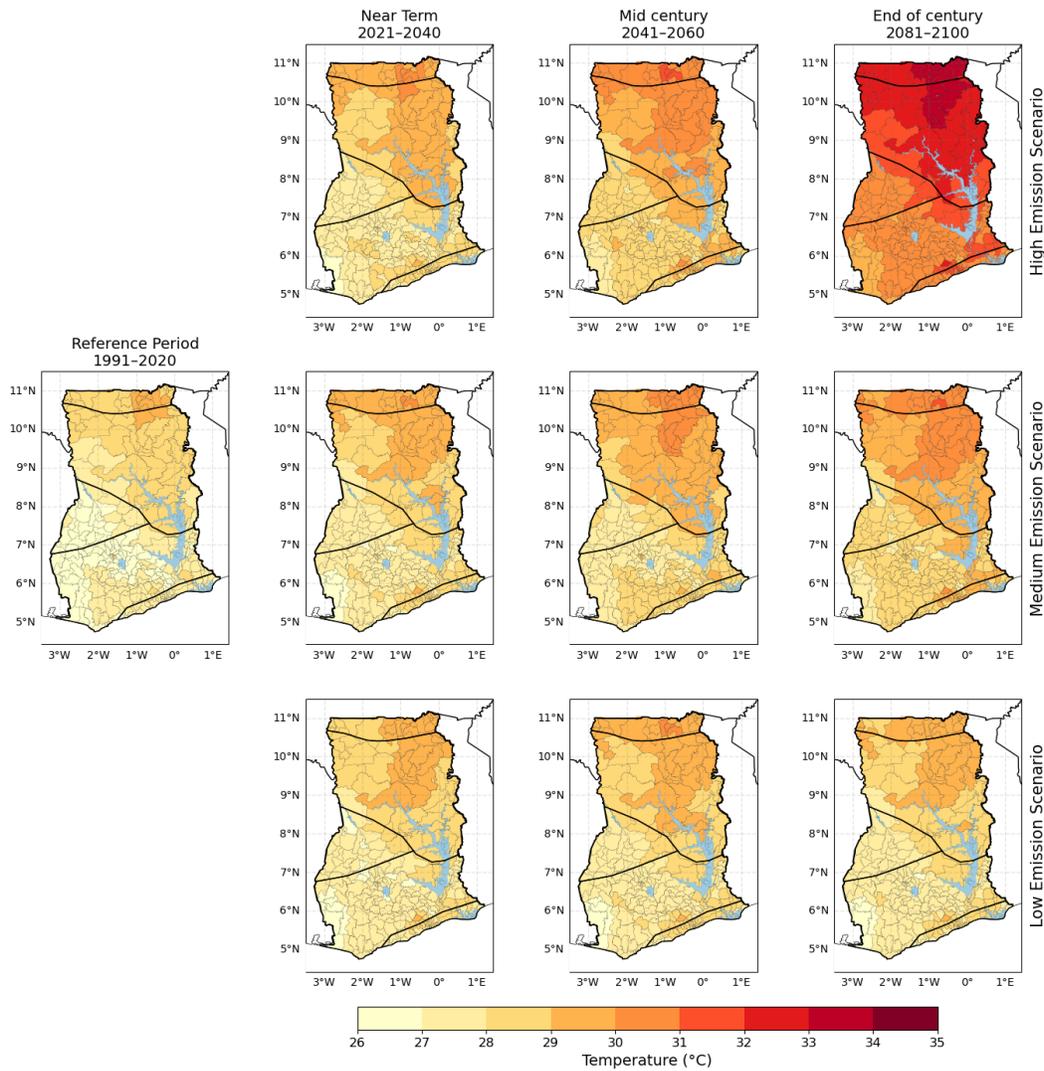


Figure 13. Variations in average annual temperature (50th percentile) across the different Agro-climatic zones of Ghana under low, medium and high emission scenarios for the near term (2021-2040), mid century (2041-2060) and end of century (2081-2100). The stand-alone plot on the far left shows the reference period (1991-2020).

The projections for average annual temperature across the different agro-climatic zones of the country as illustrated in **Figure 14** show a general increase across all zones under all three emission scenarios: low, medium, and high for the near term, mid century and end of century. The high emission scenario shows the highest increase towards the end of century especially in the Guinea and Sudan savannah zone. As expected, annual average temperatures across the different agro-

climatic zones are highest under the high-emission scenario toward the end of the century, reflecting the stronger global warming projected under this pathway

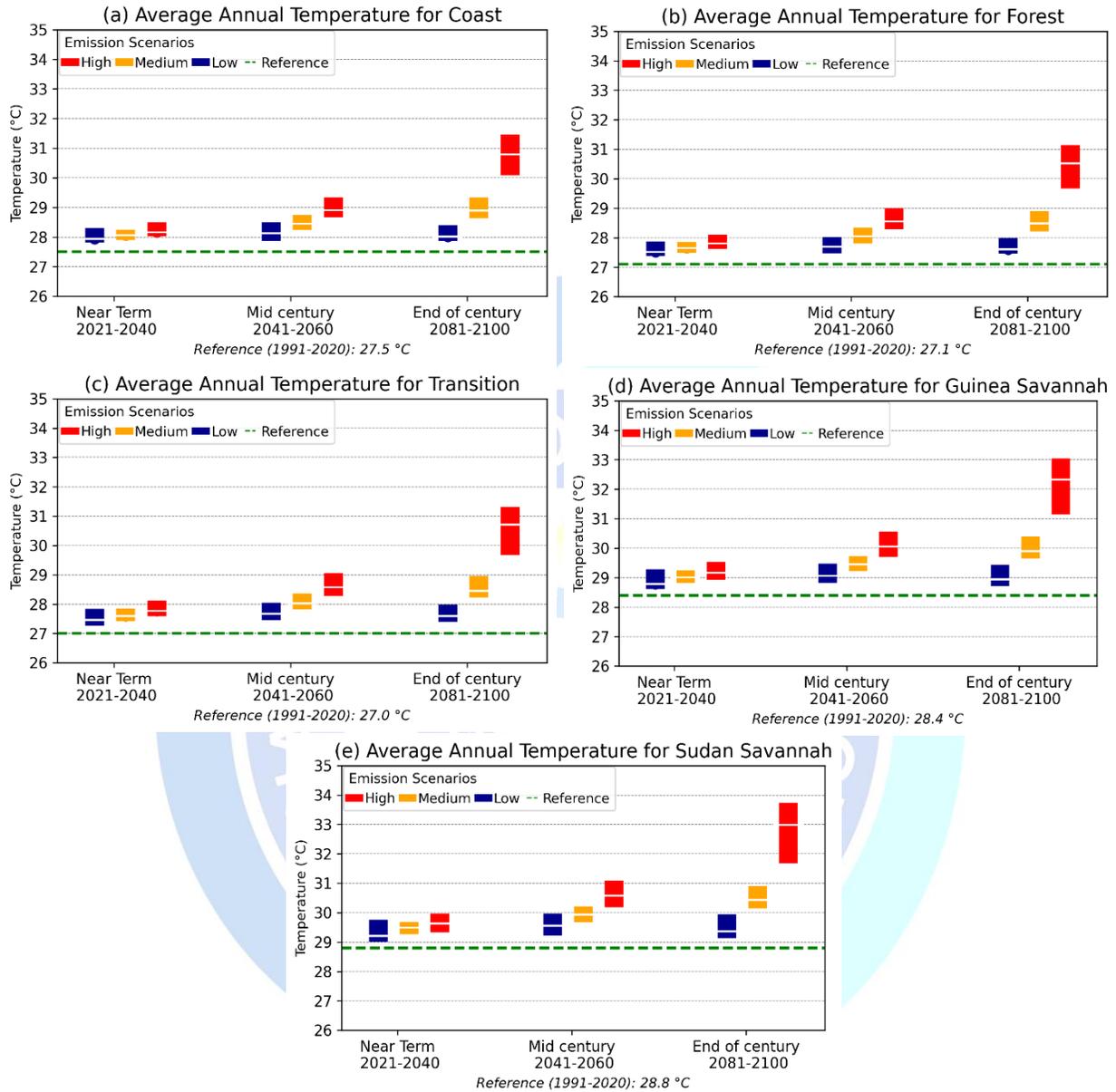


Figure 14. Average annual temperature boxplots for (a) coast, (b) forest, (c) transition, (d) guinea savannah and (e) sudan savannah zones under three emission scenarios in Ghana. The figures show the temperature average in the time periods 2021-2040, 2041-2060 and 2081-2100. The low, medium and high emission scenarios are represented by blue, orange and red colors respectively. The uncertainty bounds shown on the plot are the 10th to 90th percentiles of the models.

Average annual temperature projection for the coast shows a general increase in temperature above the 27.5°C reference period average under all three emission scenarios from the near term to the end of century as shown in **Figure 14(a)**. Projections for a low emission scenario show an increase

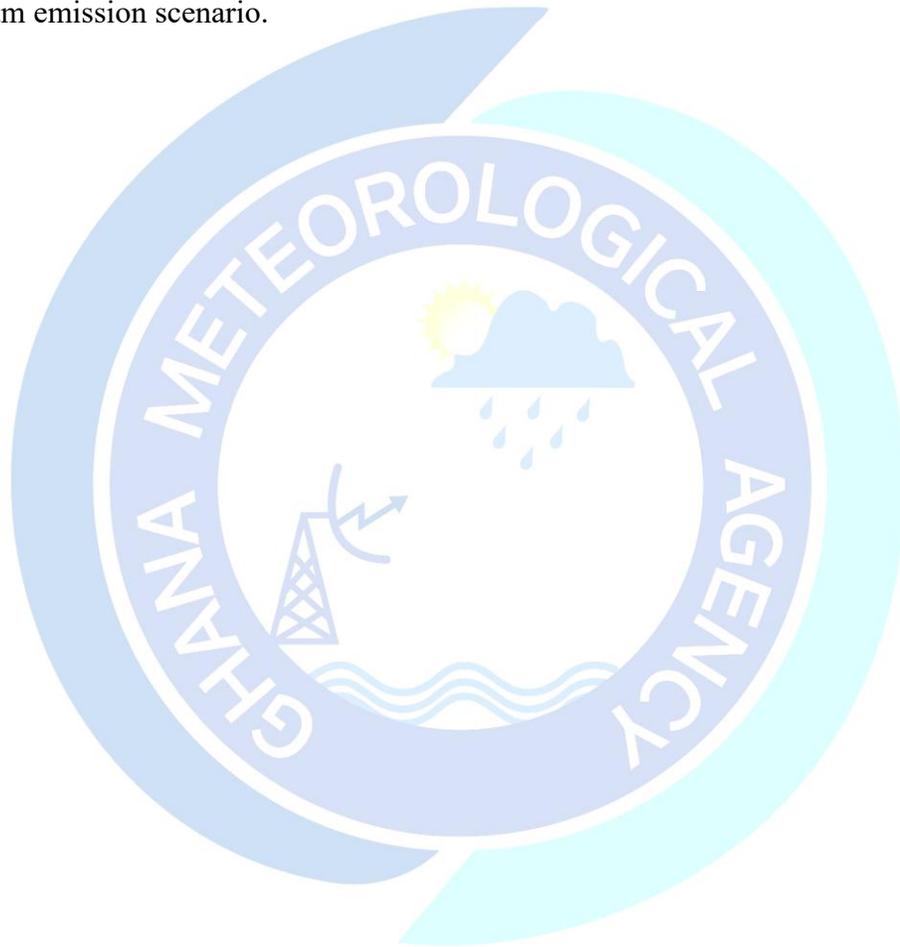
of about 0.4°C, 0.6°C and 0.5°C for the near term, mid century and end of century respectively. A medium emission scenario indicates an increase of 0.6°C, 0.9°C and 1.4°C for the near term, mid century and end of century, respectively. For a high emission scenario, the average temperature increase towards the end of century is 3.3°C whereas the near term and mid century are projected to increase by 0.7°C and 1.4°C respectively. Average annual temperature is expected to be 28.9°C with uncertainty range between 28.6°C and 29.3°C at the end of century under medium emission scenario.

Average annual temperature projection for the Forest shows a general increase in temperature above the 27.1°C reference period average under all three emission scenarios from the near term to the end of century as shown in **Figure 14(b)**. Projections for a low emission scenario show an increase of about 0.4°C, 0.6° and 0.5°C for the near term, mid century and end of century respectively. A medium emission scenario indicates an increase of 0.5°C, 0.9°C and 1.4°C for the near term, mid century and end of century, respectively. For a high emission scenario, the average temperature increase towards the end of century is 3.4°C whereas the near term and mid century are projected to increase by 0.7°C and 1.4°C respectively. Average annual temperature is expected to be 27.1°C with uncertainty range between 28.2°C and 28.9°C at the end of century under medium emission scenario.

Average annual temperature projection for the Transition shows a general increase in temperature above the 27.0°C reference period average under all three emission scenarios from the near term to the end of century as shown in **Figure 14(c)**. Projections for a low emission scenario show an increase of about 0.4°C for the near term and 0.6°C for both mid century and end of century. A medium emission scenario indicates an increase of 0.6°C, 1.0°C and 1.4°C for the near term, mid century and end of century, respectively. For a high emission scenario, the average temperature increase towards the end of century is 3.7°C whereas the near term and mid century are projected to increase by 0.7°C and 1.5°C respectively. Average annual temperature is expected to be 28.5°C with uncertainty range between 28.2°C and 29.0°C at the end of century under medium emission scenario.

The average annual temperature projection for the Guinea Savannah zone shows a consistent increase above the reference period average of 28.4°C across all three emission scenarios, from the near term through to the end of the century, as illustrated in **Figure 14(d)**. Under the low emission scenario, temperatures are projected to rise by 0.4°C, 0.7°C, and 0.6°C for the near term, midcentury, and end of century periods, respectively. The medium emission scenario indicates increases of 0.6°C, 1.1°C, and 1.5°C for the near term, midcentury, and end of century periods, respectively. Under the high emission scenario, temperatures are projected to increase by 0.8°C in the near term and 1.7°C by midcentury, reaching a much larger rise of 3.9°C by the end of century. Average annual temperature is expected to be 28.4°C with uncertainty range between 29.7°C and 30.4°C at the end of century under medium emission scenario.

Average annual temperature projection for Sudan Savannah shows a general increase in temperature above the 28.8°C reference period average under all three emission scenarios from the near term to the end of century as shown in **Figure 14(e)**. Projections for a low emission scenario show an increase of about 0.4°C, 0.8°C and 0.6°C for the near term, mid century and end of century respectively. A medium emission scenario indicates an increase of 0.7°C, 1.2°C and 1.7°C for the near term, mid century and end of century, respectively. For a high emission scenario, the average temperature increase towards the end of century is 4.2°C whereas the near term and mid century are projected to increase by 0.9°C and 1.8°C respectively. Average annual temperature is expected to be 30.4°C with uncertainty range between 30.1°C and 30.9°C at the end of century under medium emission scenario.



3.3 Average Seasonal Temperature

April-May-June

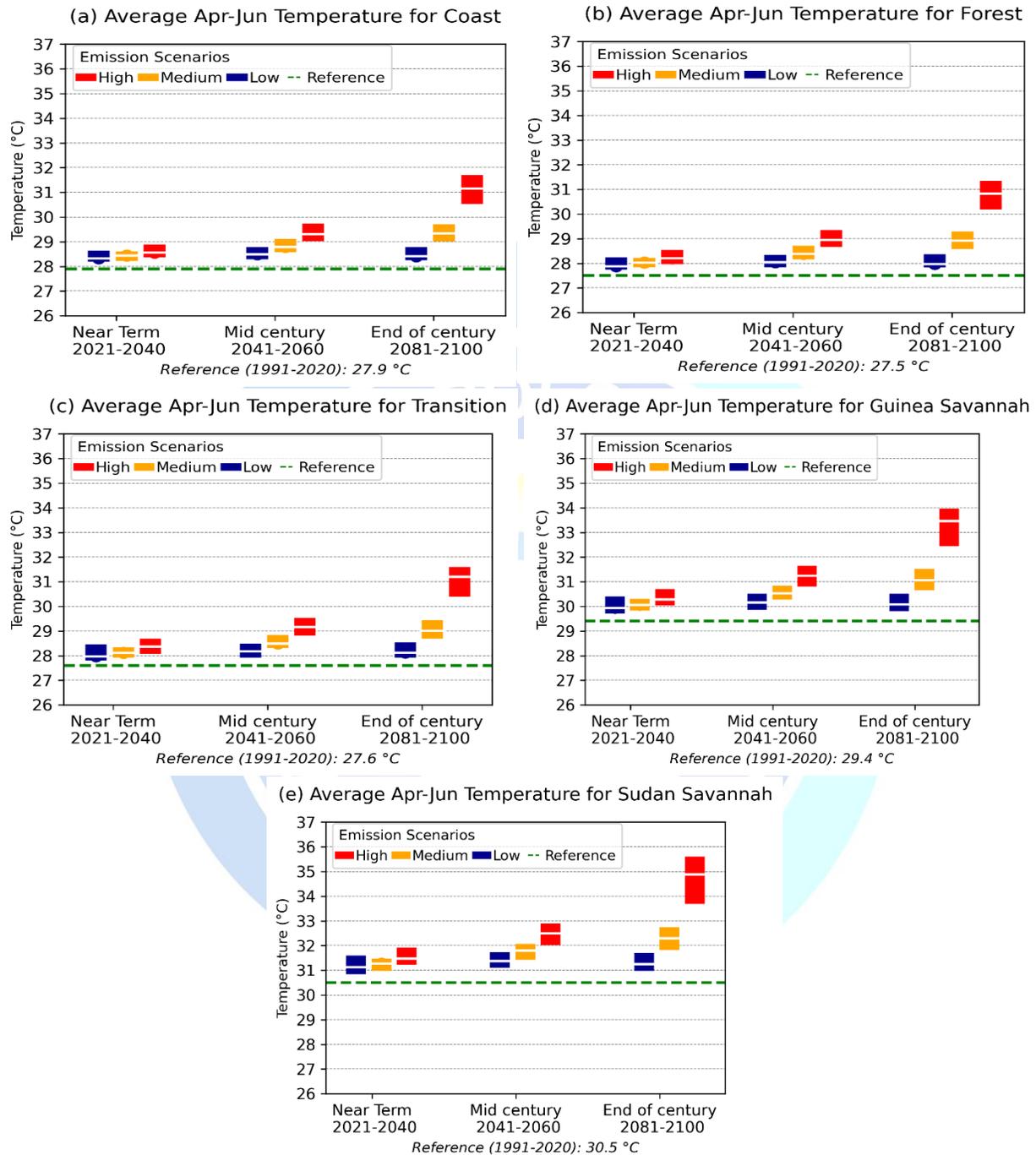


Figure 15. Average AMJ seasonal temperature boxplots for (a) Coast, (b) Forest, (c) Transition, Guinea Savannah and Sudan Savannah agro-climatic zones under three emission scenarios in Ghana. The figures show the temperature average in the time periods 2021-2040, 2041-2060 and 2081-2100. The low, medium and high emission scenarios are represented by blue, orange and red colors respectively. The uncertainty bounds shown on the plot are the 10th to 90th percentiles of the models.

In **Figure 15(a)**, the average seasonal temperature for April-May-June (AMJ), with reference period value of 27.9°C, is projected to rise by 0.4°C, 0.6°C and 0.5°C under a low emission scenario across the time periods. Temperature under the medium emission scenario is expected to increase by 0.6°C, 0.9°C and 1.5°C, for the near term, mid century and end of century. The high emission scenario projection shows an increase of 0.7°C for the near term, 1.4°C for a mid century and 3.3°C for end of century.

In **Figure 15(b)**, the average seasonal temperature for April-May-June (AMJ), with reference period value of 27.5°C, is projected to rise by 0.4°C, 0.6°C and 0.5°C under a low, medium and high emission scenarios respectively for the near term period. Temperature during the mid century is expected to increase by 0.5°C, 0.9°C and 1.4°C, for a low, medium and high emission scenario respectively. The end of century projection shows an increase of 0.7°C for a low emission scenario, 1.5°C for a medium emission scenario and 3.3°C for a high emission scenario.

In **Figure 15(c)**, the average seasonal temperature for April-May-June (AMJ), with reference period value of 27.6°C, is projected to rise by 0.4°C, 0.6°C and 0.8°C under a low, medium and high emission scenarios respectively for the near term period. Temperature during the mid century is expected to increase by 0.6°C, 0.9°C and 1.6°C, for a low, medium and high emission scenario respectively. The end of century projection shows an increase of 0.6°C for a low emission scenario, 1.5°C for a medium emission scenario and 3.7°C for a high emission scenario.

In **Figure 15(d)**, the average seasonal temperature for April-May-June (AMJ), with a reference period value of 29.4°C, is projected to increase across all emission scenarios. Under the low emission scenario, temperatures are expected to rise by 0.5°C in the near term, 0.7°C by mid century, and 0.6°C by the end of the century. The medium emission scenario indicates increases of 0.6°C, 1.1°C, and 1.6°C for the near term, midcentury, and end of century periods, respectively. Under the high emission scenario, temperatures are projected to rise by 0.8°C in the near term and 1.8°C by midcentury, reaching a much larger increase of 4.0°C by the end of the century.

In **Figure 15(e)**, the average seasonal temperature for April-May-June (AMJ), with reference period value of 30.5°C, is projected to rise by 0.6°C, 0.7°C and 0.9°C under a low, medium and high emission scenarios respectively for the near term period. Temperature during the mid century is expected to increase by 0.8°C, 1.3°C and 2.0°C, for a low, medium and high emission scenario respectively. The end of century projection shows an increase of 0.7°C for a low emission scenario, 1.8°C for a medium emission scenario and 4.4°C for a high emission scenario.

July- August- September

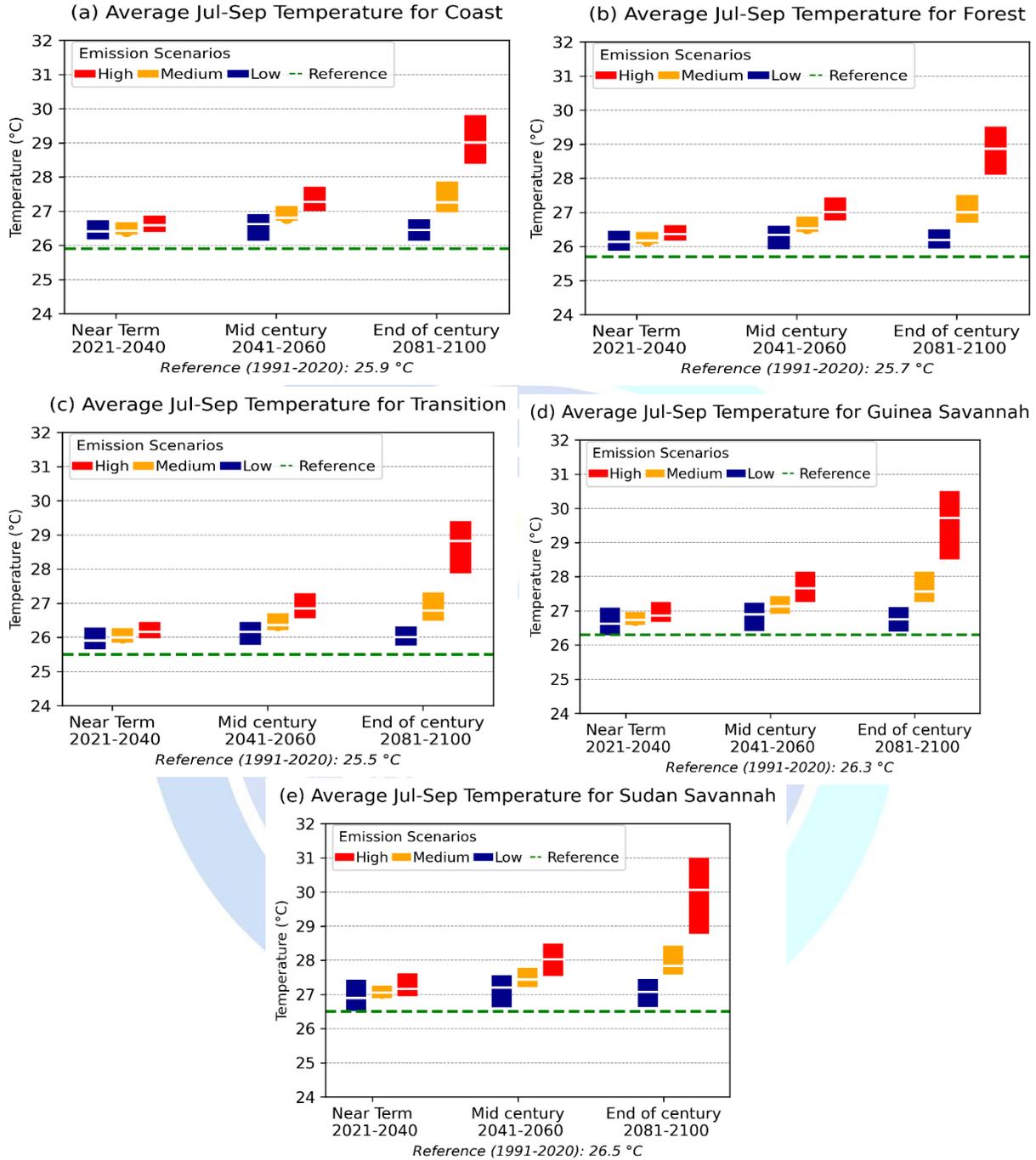


Figure 16. Average JAS seasonal temperature boxplots for (a) Coast, (b) Forest, (c) Transition, Guinea Savannah and Sudan Savannah agro-climatic zones under three emission scenarios in Ghana. The figures show the temperature average in the time periods 2021-2040, 2041-2060 and 2081-2100. The low, medium and high emission scenarios are represented by blue, orange and red colors respectively. The uncertainty bounds shown on the plot are the 10th to 90th percentiles of the models.

With an average seasonal temperature of 25.9°C in the reference period, the projection for July-August-September (JAS) as shown in **Figure 16(a)**, depicts an increase of 0.5°C for the near term and 0.7°C and 0.6°C for mid century and end of century respectively under a low emission scenario. A medium emission scenario shows an increase of 0.5°C, 0.9°C and 1.4°C for the near term, mid century and end of century respectively. A high emission scenario projects an increase of 0.7°C, 1.4°C and 3.1°C for the near term, mid- century and end of century respectively

With an average seasonal temperature of 25.7°C in the reference period, the projection for July-August-September (JAS) as shown in **Figure 16(b)**, depicts an increase of 0.4°C for the near term and 0.7°C for mid century and 0.5°C for end of century under a low emission scenario. A medium emission scenario shows an increase of 0.5°C, 0.8°C and 1.3°C for the near term, mid century and end of century respectively. A high emission scenario projects an increase of 0.7°C, 1.3°C and 3.2°C for the near term, mid term and end of century respectively.

With an average seasonal temperature of 25.5°C for the reference period, the projection for July-August-September (JAS) as shown in **Figure 16(c)**, depicts an increase of 0.4°C for the near term, 0.7°C for the mid century and 0.5°C for the end of century under a low emission scenario. A medium emission scenario shows an increase of 0.5°C, 0.9°C and 1.3°C for the near term, mid century and end of century respectively. A high emission scenario projects an increase of 0.7°C, 1.3°C and 3.3°C for the near term, mid century and end of century respectively.

With a reference period average of 26.3°C, the projected seasonal temperature for July–August–September (JAS) shows an overall warming trend across all emission scenarios (**Figure 16(d)**). Under the low emission scenario, temperatures are expected to rise by 0.4°C in the near term, 0.6°C by midcentury, and 0.5°C by the end of the century. The medium emission scenario projects an increase of 0.5°C, 0.9°C, and 1.3°C for the near term, midcentury, and end of century periods, respectively. Under the high emission scenario, temperatures are projected to increase by 0.6°C in the near term and 1.4°C by midcentury, reaching a higher rise of 3.5°C by the end of the century.

With an average seasonal temperature of 26.5°C in the reference period, the projection for July-August-September (JAS) as shown in **Figure 16(e)**, depicts an increase of 0.4°C, 0.7°C and 0.5°C for the near term, mid century and end of century respectively, under a low emission scenario. The medium emission scenario shows an increase of 0.5°C, 0.9°C and 1.3°C for the near term, mid century and end of century respectively. A high emission scenario projects an increase of 0.6°C, 1.5°C and 3.5°C for the near term, mid term and end of century respectively.

September-October-November

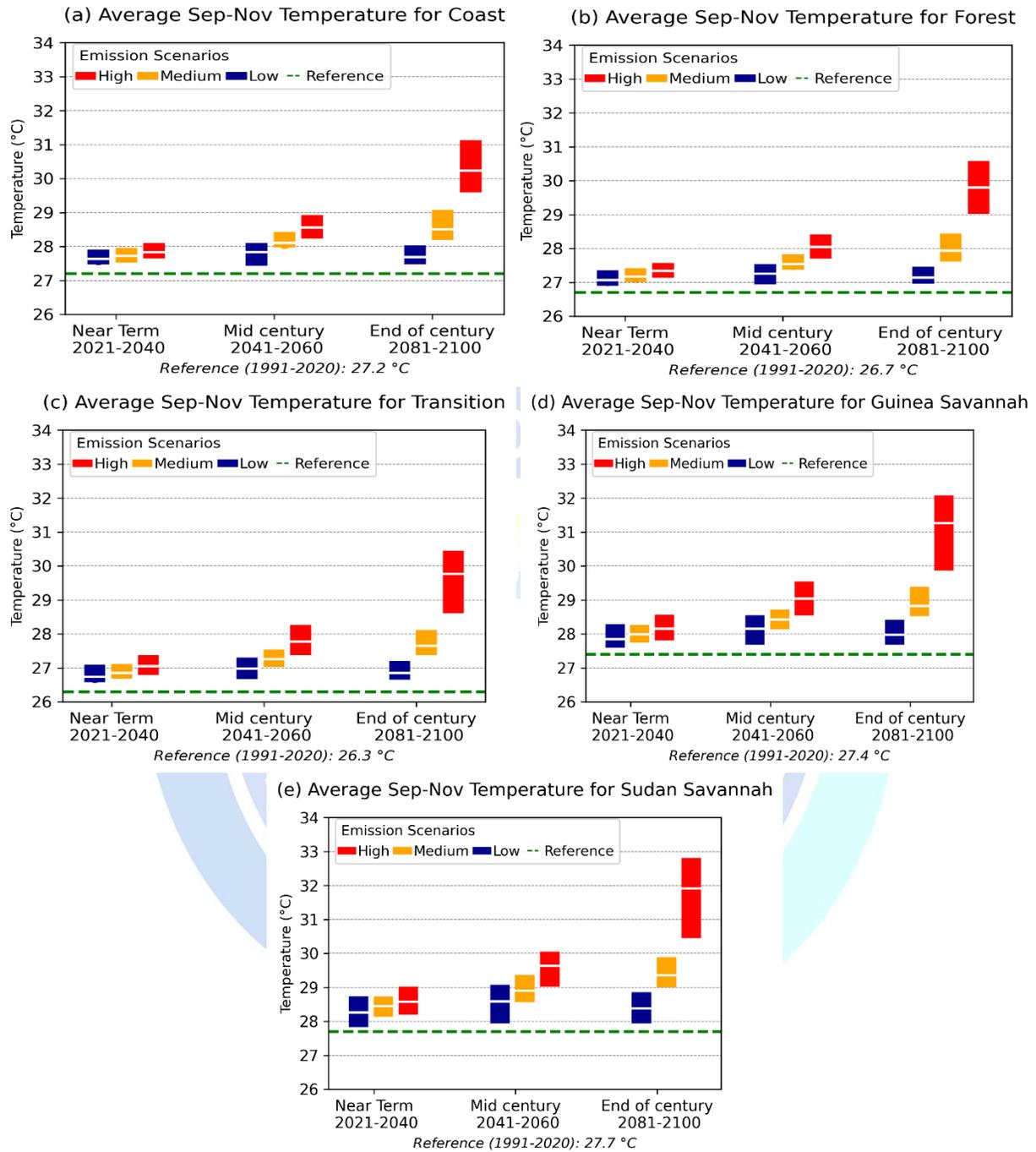


Figure 17. Average SON seasonal temperature boxplots for (a) Coast, (b) Forest, (c) Transition, Guinea Savannah and Sudan Savannah agro-climatic zones under three emission scenarios in Ghana. The figures show the temperature average in the time periods 2021-2040, 2041-2060 and 2081-2100. The low, medium and high emission scenarios are represented by blue, orange and red colors respectively. The uncertainty bounds shown on the plot are the 10th to 90th percentiles of the models.

Projections for the average seasonal temperature for September-October-November (SON) relative to a reference period value of 27.2°C indicate an increase of 0.5°C for near term, 0.7°C for mid century and 0.5°C for end of century for a low emission scenario. A medium emission scenario projects an average temperature rise of 0.6°C, 0.9°C and 1.3°C for near term, mid century and end of century periods respectively. A high emission scenario shows an increase of 0.7°C and 1.4°C for the near term and mid century respectively while the end of century shows an increase of 3.1°C as displayed in **Figure 17(a)**.

Projections for the average seasonal temperature for September-October-November (SON) relative to a reference period value of 26.7°C indicate an increase of 0.4°C for near term, 0.6°C for mid century and 0.5°C for end of century for a low emission scenario. A medium emission scenario projects an average temperature rise of 0.5°C, 0.9°C and 1.3°C for near term, mid century and end of century periods respectively. A high emission scenario shows an increase of 0.7°C and 1.4°C for the near term and mid century respectively while the end of century shows an increase of 3.2°C as displayed in **Figure 17(b)**.

Projections for the average seasonal temperature for September-October-November (SON) relative to a reference period value of 26.3°C indicate an increase of 0.4°C for the near term, 0.6°C for the mid century and 0.5°C for the end of century under a low emission scenario. A medium emission scenario projects an average temperature rise of 0.5°C, 0.9°C and 1.3°C for the near term, mid century and end of century periods respectively. A high emission scenario shows an increase of 0.7°C and 1.4°C for the near term and mid century respectively while the end of century shows an increase of 3.4°C as displayed in **Figure 17(c)**.

Projections for the average seasonal temperature for September-October-November (SON) relative to a reference period value of 27.4°C indicate an increase of 0.5°C for near term, 0.8°C for mid century, and 0.6°C for end of century for a low emission scenario. A medium emission scenario projects an average temperature rise of 0.6°C, 1.0°C, and 1.4°C for near term, mid century, and end of century periods, respectively. A high emission scenario shows an increase of 0.8°C and 1.7°C for the near term and mid century, respectively, while end of century shows a much larger increase of 3.9°C as displayed in **Figure 17(d)**.

Projections for the average seasonal temperature for September-October-November (SON) relative to a reference period value of 27.7°C indicate an increase of 0.6°C for near term, 0.9°C for mid century and 0.7°C for end of century for a low emission scenario. A medium emission scenario projects an average temperature rise of 0.7°C, 1.2°C and 1.7°C for near term, mid century and end of century periods respectively. A high emission scenario shows an increase of 0.9°C and 1.9°C for the near term and mid century respectively while the end of century shows an increase of 4.2°C as displayed in **Figure 17(e)**.

December-January-February

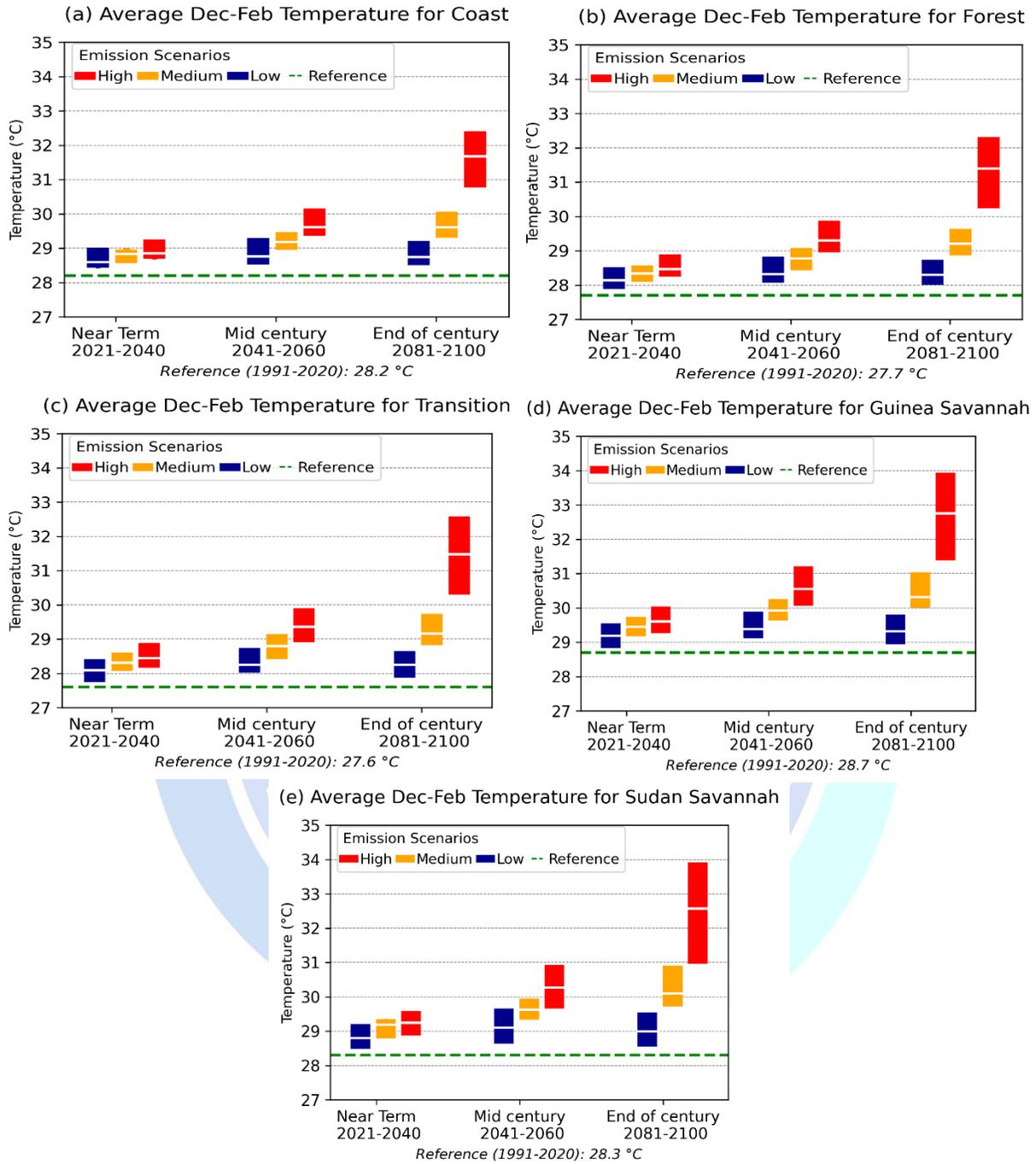


Figure 18. Average DJF seasonal temperature boxplots for (a) Coast, (b) Forest, (c) Transition, Guinea Savannah and Sudan Savannah agro-climatic zones under three emission scenarios in Ghana. The figures show the temperature average in the time periods 2021-2040, 2041-2060 and 2081-2100. The low, medium and high emission scenarios are represented by blue, orange and red colors respectively. The uncertainty bounds shown on the plot are the 10th to 90th percentiles of the models.

The average seasonal temperature projection for December-January-February (DJF), with reference period value of 28.2°C, as shown in **Figure 18(a)**, depicts an increase of 0.4°C for near term and 0.6°C for both mid century and end of century under a low emission scenario. A medium emission scenario shows an increase of 0.7°C, 1.0°C and 1.4°C for the near term, mid century and end of century respectively. A high emission scenario projects an increase of 0.7°C and 1.4°C for the near term and mid century while the end of century shows an increase of 3.5°C.

The average seasonal temperature projection for December-January-February (DJF), with reference period value of 27.7°C, as shown in **Figure 18(b)**, depicts an increase of 0.4°C for near term and 0.6°C for both mid century and end of century under a low emission scenario. A medium emission scenario shows an increase of 0.6°C, 1.1°C and 1.5°C for the near term, mid century and end of century respectively. A high emission scenario projects an increase of 0.8°C and 1.6°C for the near term and mid century while the end of century shows an increase of 3.7°C.

The average seasonal temperature projection for December-January-February (DJF), with reference period value of 27.6°C, as shown in **Figure 18(c)**, depicts an increase of 0.5°C for the near term and 0.6°C for both mid century and end of century under a low emission scenario. A medium emission scenario shows an increase of 0.7°C, 1.2°C and 1.5°C for the near term, mid century and end of century periods respectively. A high emission scenario projects an increase of 0.8°C and 1.7°C for the near term and mid century while the end of century shows an increase of 3.8°C.

The projected average seasonal temperature for December–January–February (DJF), based on a reference value of 28.7°C as shown in **Figure 18(d)**, is expected to rise under all emission scenarios. Under the low emission scenario, temperatures increase by 0.5°C in the near term and by 0.7°C in midcentury and 0.6°C by end of century. The medium emission scenario shows an increase of 0.7°C, 1.2°C, and 1.6°C for the near term, midcentury, and end of century, respectively. Under the high emission scenario, temperatures are projected to rise by 0.9°C in the near term and 1.8°C by midcentury, reaching a much larger increase of 4.0°C by the end of century.

The average seasonal temperature projection for December-January-February (DJF), with reference period value of 28.3°C, as shown in **Figure 18(e)**, depicts an increase of 0.5°C for near term and 0.8°C for mid century and 0.7°C for end of century under a low emission scenario. A medium emission scenario shows an increase of 0.9°C, 1.3°C and 1.8°C for the near term, mid century and end of century respectively. A high emission scenario projects an increase of 1.0°C and 2.0°C for the near term and mid century while the end of century shows an increase of 4.3°C.

3.4 Average Annual Rainfall

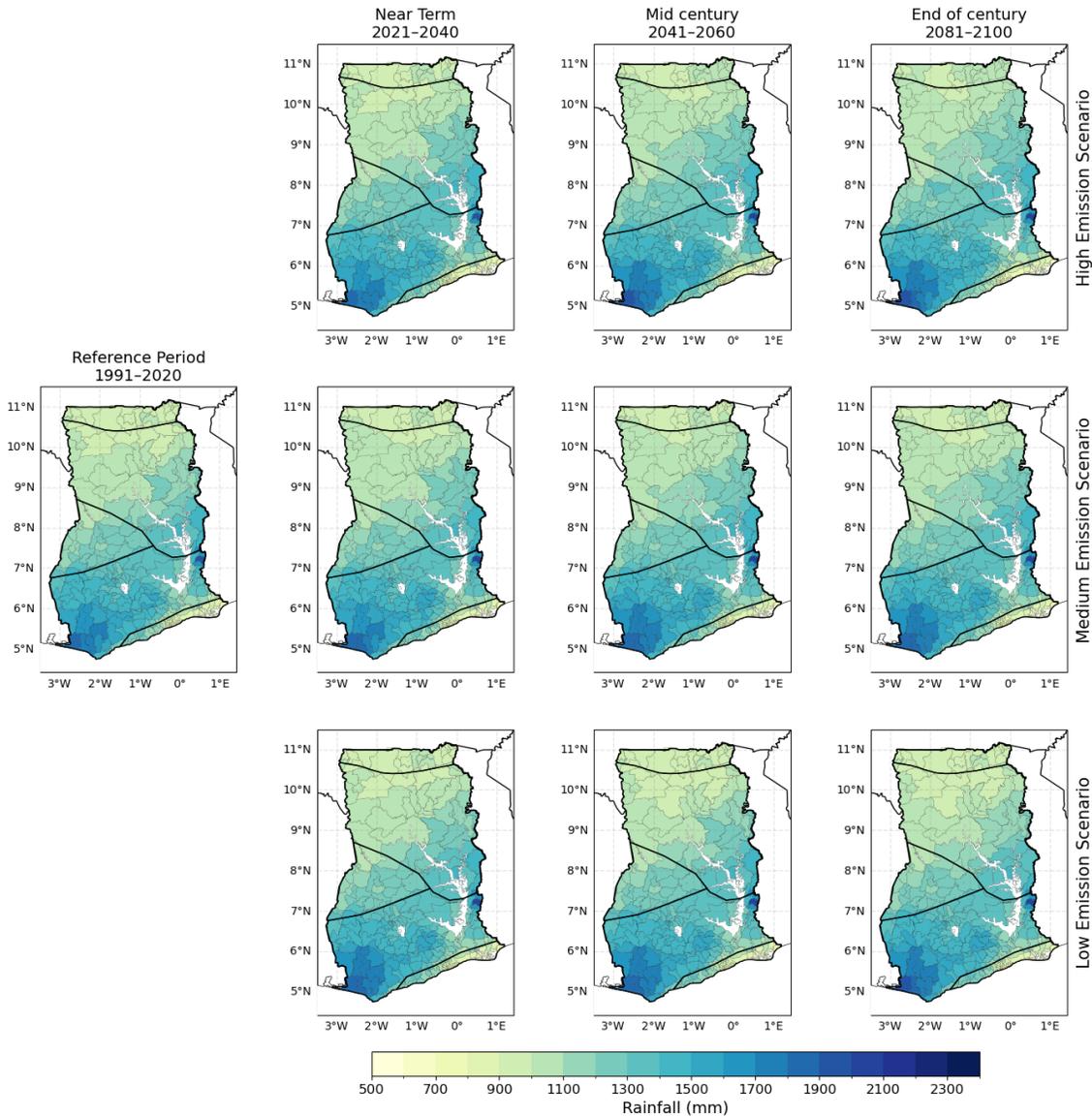


Figure 19. Variations in total annual rainfall (50th percentile) across the different Agro-climatic zones of Ghana under low, medium and high emission scenarios for the near term (2021-2040), mid century (2041-2060) and end of century (2081-2100). The stand-alone plot on the far-left shows for the reference period (1991-2020).

The projections for total annual rainfall across the different agro-climatic zones of the country show a minimal increase for the near term, mid century and end of century as compared to the reference period show minimal increase under all the three emission scenarios (low, medium, and high). However, rainfall is highest in the southern and far eastern parts of the forest zone. The variability in rainfall over these zones is more pronounced when analyzed on a seasonal level.

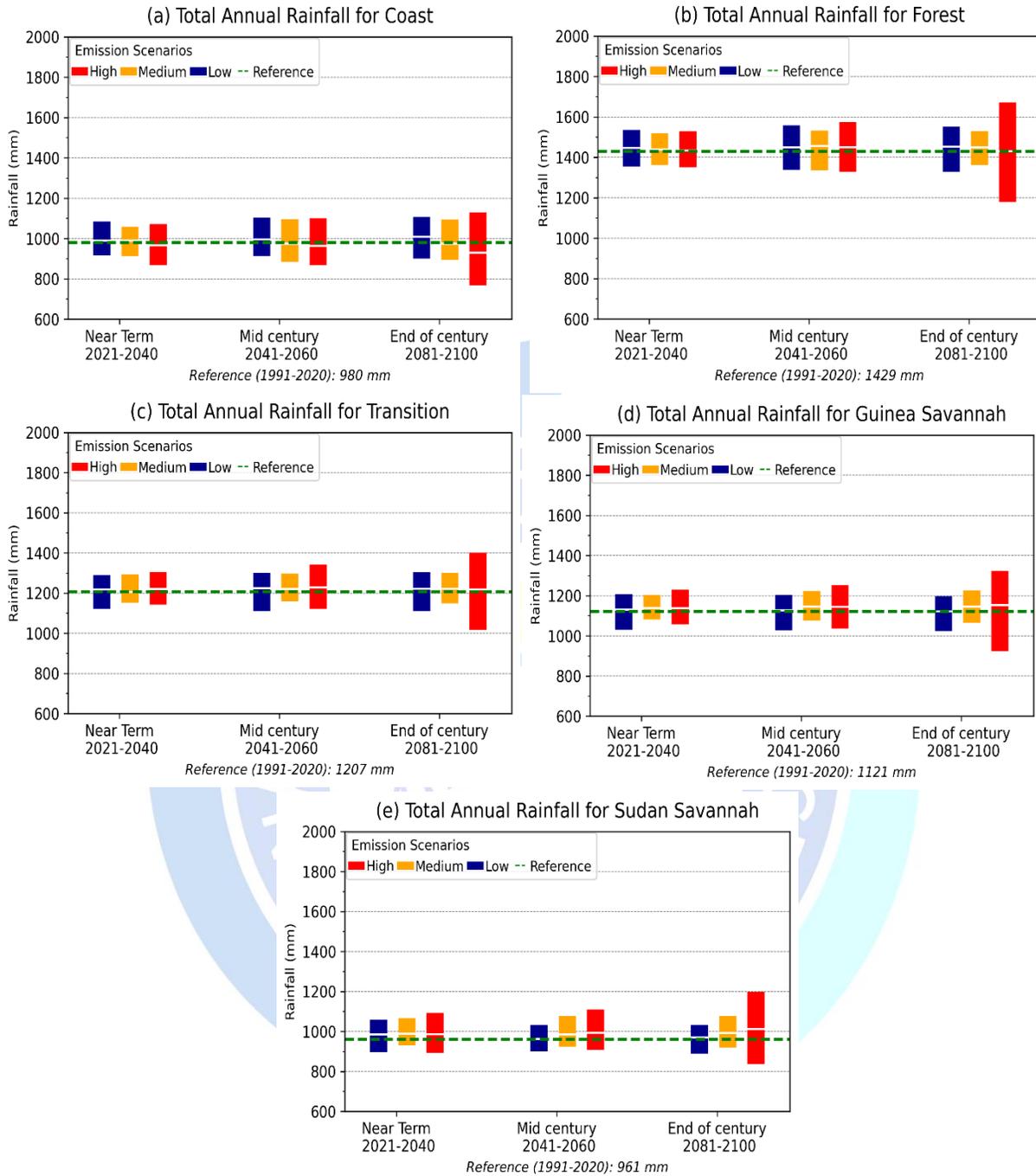


Figure 20. Average annual rainfall boxplots for (a) coast, (b) forest, (c) transition, (d) guinea savannah and (e) sudan savannah zones under three emission scenarios in Ghana. The figures show the temperature average in the time periods 2021-2040, 2041-2060 and 2081-2100. The low, medium and high emission scenarios are represented by blue, orange and red colors respectively. The uncertainty bounds shown on the plot are the 10th to 90th percentiles of the models.

Total annual rainfall projection for the coast of Ghana shows a slight increase above the reference period value of 980mm for the low emission scenarios from near term to end of century, and a decrease in rainfall for the medium and high emission scenario from the near term to end of

century with the medium emission scenario showing a slight increase during the near term as shown in **Figure 20(a)**, albeit with wide uncertainties. Rainfall is projected to increase by 10mm (1.1%) for near term, 14mm (1.5%) for mid century and 28mm (2.9%) for end of century under a low emission scenario. An increase of 10mm (1.1%) for the near term and a decrease of 5mm (0.5%) is expected for the mid century and 6mm (0.6%) for end of century under a medium emission scenario. Under a high emission scenario, rainfall is projected to decrease by 14mm (1.5%) for near term and 17mm (1.7%) by Mid century and 51mm (5.2%) by end of century.

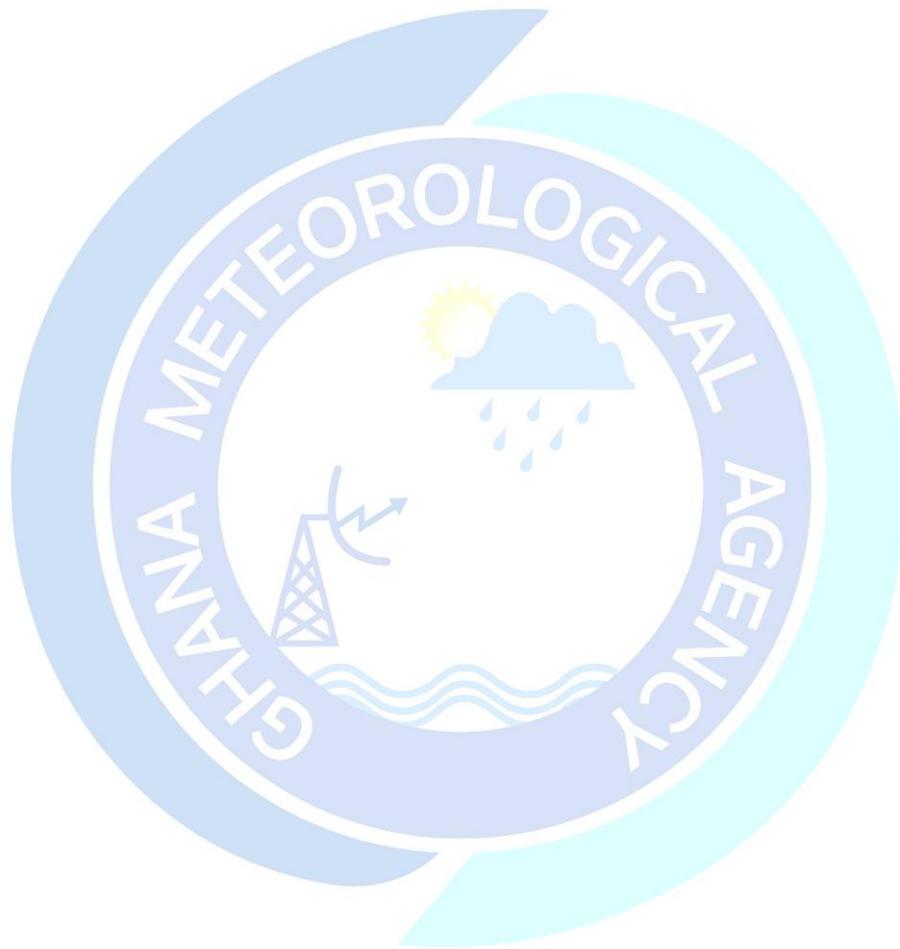
Total annual rainfall projection for Forest shows a slight increase above the reference period value of 1429mm for all three emission scenarios from the near term to the end of century, as shown in Figure 7, albeit with wide uncertainties. Rainfall is projected to increase by 18mm (1.2%) for near term, 20mm (1.5%) for mid century and 23mm (1.6%) for end of century under a low emission scenario. An increase of 10mm (0.7%), 26mm (1.8%) and 20mm (1.4%) is expected for the near term, mid century and end of century respectively under a medium emission scenario. Under a high emission scenario, rainfall is projected to increase by 4mm (0.3%) for near term, 21mm (1.5%) by mid century and 2mm (0.1%) by end of century (**Figure 20(b)**).

Total annual rainfall projection for the Transition zone shows a slight increase above the reference period value of 1207mm for all three emission scenarios from the mid century and end of century, as shown in Figure 7, albeit with wide uncertainties. Rainfall is projected to increase by 13mm (1.0%) for the near term, 17mm (1.4%) for the mid century and 15mm (1.2%) for the end of century under a low emission scenario. Projections under a medium emission scenario for the near term shows a no change whilst an increase of 13mm (1.1%) and 15mm (1.3%) is expected for mid century and end of century periods respectively. Under a high emission scenario, rainfall is projected to increase by 13mm (1.1%) for the near term, 22mm (1.8%) for the mid century and 11mm (0.9%) for the end of century (**Figure 20(c)**).

Total annual rainfall projections for the Guinea Savannah indicate a slight increase above the reference period value of 1121 mm across all three emission scenarios from the near term to the end of century, as illustrated in **Figure 20(d)**. Under a low emission scenario, rainfall is projected to increase by 8 mm (0.8%) in the near term and by 6mm (0.6%) by mid century, followed by 1 mm (0.1%) by the end of century. Under a medium emission scenario, rainfall is expected to rise by 18 mm (1.6%), 26 mm (2.3%), and 25 mm (2.3%) in the near term, mid century, and end of century periods, respectively. In the high emission scenario, rainfall is projected to increase by 17 mm (1.5%) in the near term, 24 mm (2.1%) by mid century, and 31 mm (2.8%) by the end of century.

Total annual rainfall projection for Sudan Savannah shows a slight increase above the reference period value of 961mm for all three emission scenarios from the near term to the end of century, as shown in Figure 7, albeit with wide uncertainties. Rainfall is projected to increase by 23mm (2.4%) in the near term, 1mm (0.1%) for mid century and 8mm (0.8%) for end of century under a low emission scenario. An increase of 27mm (2.8%), 24mm (2.5%) and 31mm (3.2%) is expected

for the near term, mid century and end of century respectively under a medium emission scenario. Under a high emission scenario, rainfall is projected to increase by 25mm (2.6%) for near term, 32mm (3.3%) by mid century and 52mm (5.4%) by end of century (**Figure 20(e)**).



3.5 Average Seasonal Rainfall.

April-May-June

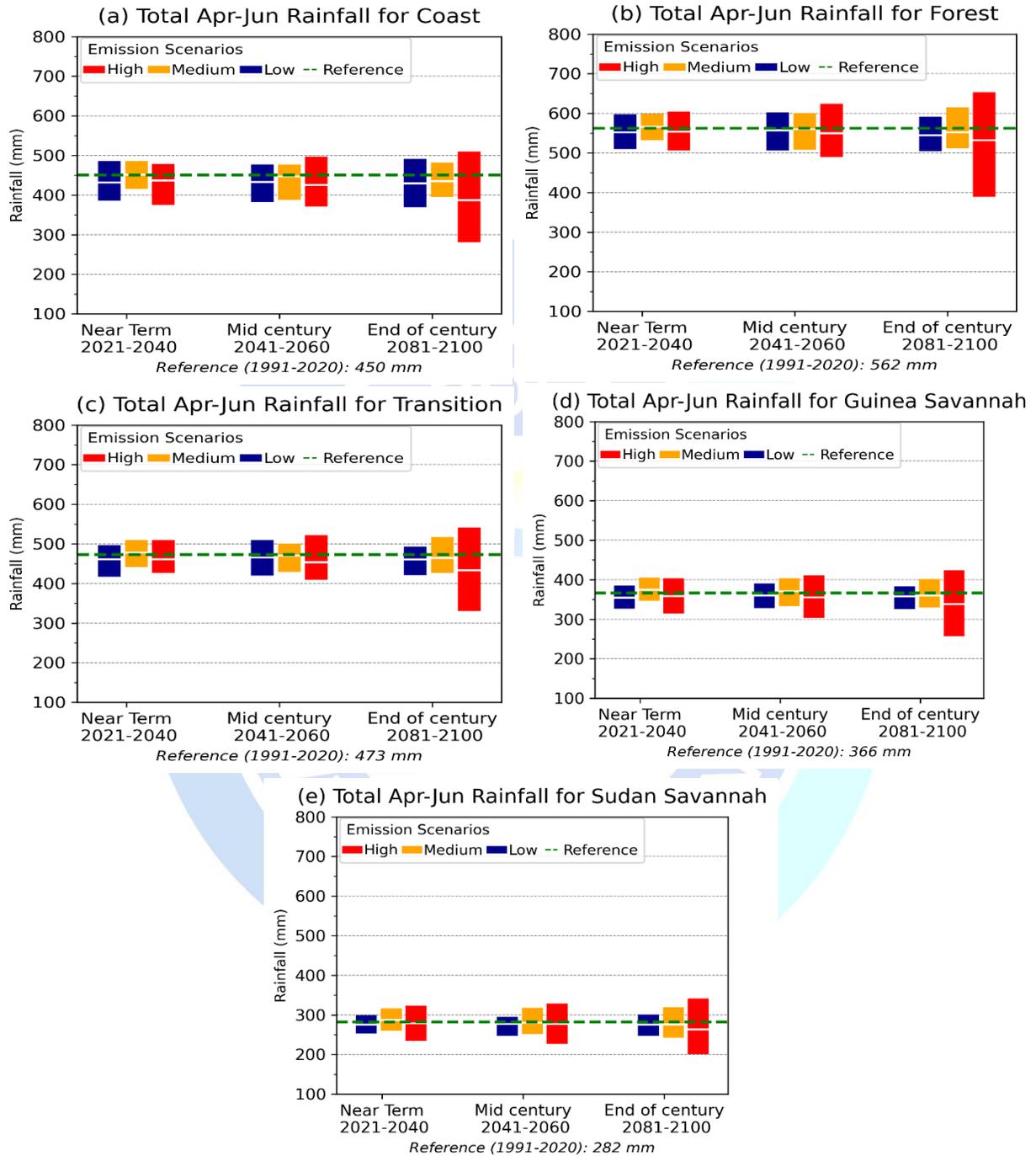


Figure 21. Average AMJ seasonal rainfall boxplots for (a) coast, (b) forest, (c) transition, (d) guinea savannah and (e) sudan savannah zones under three emission scenarios in Ghana. The figures show the temperature average in the time periods 2021-2040, 2041-2060 and 2081-2100. The low, medium and high emission scenarios are represented by blue, orange and red colors respectively. The uncertainty bounds shown on the plot are the 10th to 90th percentiles of the models.

Rainfall projection for April-May-June (AMJ) season as depicted in **Figure 21(a)**, shows a decrease of 19mm (4.2%) in the near term, 18mm (3.9%) by mid century, and 21mm (4.7%) by end of century under a low emission scenario, compared to the reference period amount of 450mm. Under a medium emission scenario, rainfall is projected to increase by 1mm (0.1%) in the near term and decrease by 4mm (0.8%) by mid century and by 16mm (3.5%) by end of century. In a high-emission scenario, rainfall is expected to decrease across all time periods by 14mm (3%) in the near term, 25mm (5.6%) by mid century and 63mm (14.1%) by end of century.

Rainfall projection for April-May-June (AMJ) season as depicted in **Figure 21(b)**, shows a decrease of 10mm (1.7%) in the near term, 5mm (0.9%) by mid century, and 17mm (3.1%) by end of century under a low emission scenario, compared to the reference period amount of 562mm. Under a medium emission scenario, rainfall is projected to increase by 4mm (0.7%) in the near term, decrease by 2mm (0.4%) by mid century and 9mm (1.7%) by end of century. In a high-emission scenario, rainfall is expected to decrease across all time periods by 8mm (1.4%) in the near term, 12mm (2.1%) by mid century and 30mm (5.4%) by end of century.

Rainfall projection for April-May-June (AMJ) season as depicted in **Figure 21(c)**, shows a decrease of 12mm (2.5%) for the near term, 7mm (1.5%) for the mid century, and 12mm (2.6%) for the end of century under a low emission scenario, compared to the reference period amount of 473mm. Under a medium emission scenario, rainfall is projected to increase by 5mm (1.1%) for the near term and a decrease of 2mm (0.5%) and 8mm (1.7%) for the mid century and end of century respectively. In a high emission scenario, rainfall is expected to decrease across all time periods by 12mm (2.6%) for the near term, 20mm (4.2%) for the mid century and 40mm (8.4%) for the end of century.

Rainfall projections for the April–May–June (AMJ) season, shown in **Figure 21(d)**, indicate a decline under almost all three emission scenarios when compared with the reference period total of 366 mm. Under a low emission scenario, rainfall is projected to decrease by 12 mm (3.4%) in the near term, 6 mm (1.6%) by midcentury, and 9 mm (2.4%) by the end of century. In a medium emission scenario, rainfall is expected to rise by 8 mm (2.2%) in the near term and 4 mm (1.0%) by mid century but decline by 6 mm (1.6%) at the end of century. Under a high emission scenario, a reduction is projected across all time periods: 7 mm (2.0%) in the near term, 11 mm (3.1%) by midcentury, and 28 mm (7.7%) by the end of the century.

Rainfall projection for April-May-June (AMJ) season as depicted in **Figure 21(e)**, shows a decrease of 6mm (2.3%) in the near term, 5mm (1.9%) by mid century, and 7mm (2.4%) by end of century under a low emission scenario, compared to the reference period amount of 282mm. Under a medium emission scenario, rainfall is projected to increase by 5mm (1.7%) in the near term, decline by 1mm (0.4%) and 6mm (2.2%) by mid century and end of century. In a high-emission scenario, rainfall is expected to decrease across all time periods by 3mm (1.2%) in the near term, 5mm (1.7%) by mid century and 19mm (6.6%) by end of century.

July-August-September

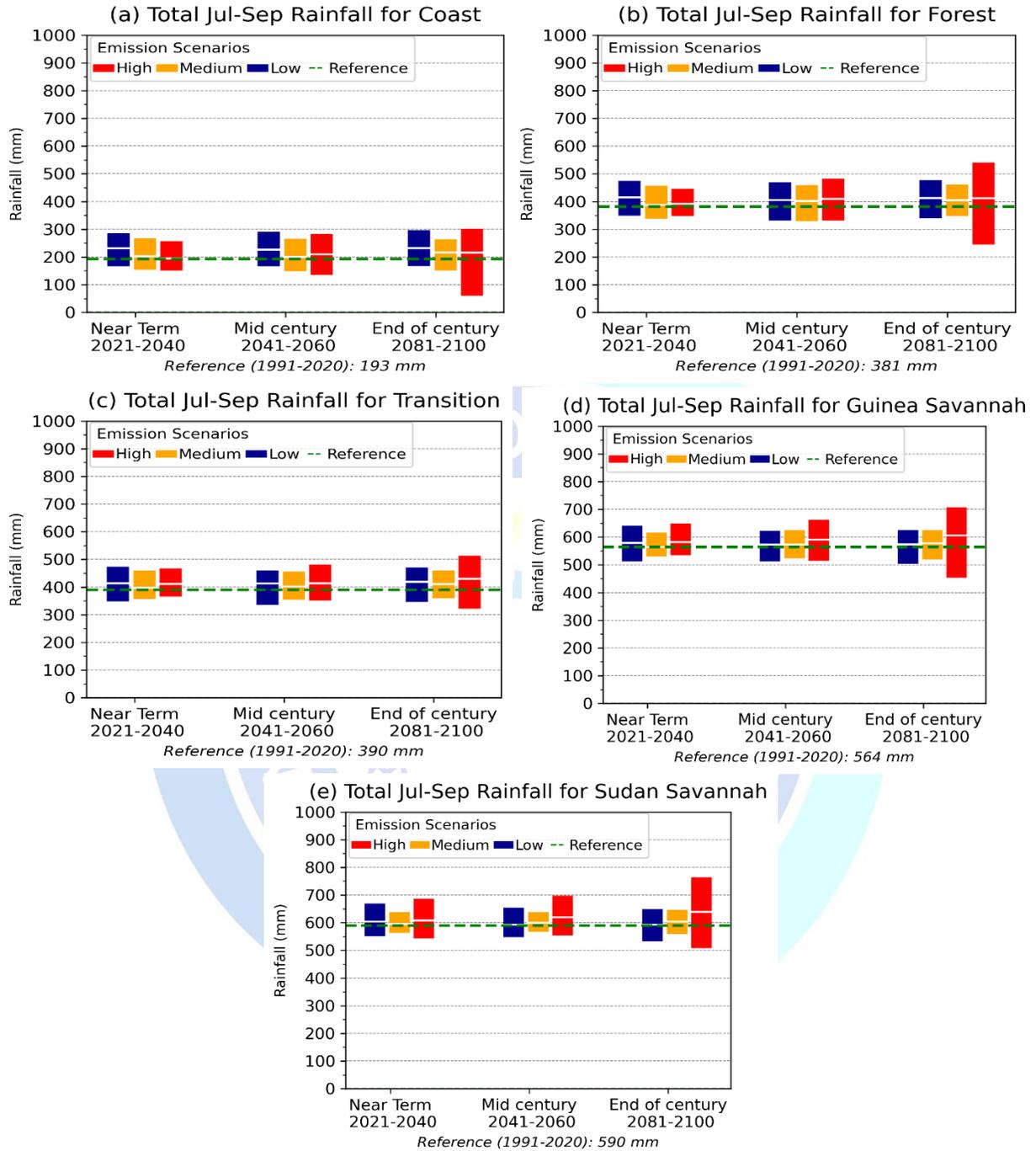


Figure 22. Average JAS seasonal rainfall boxplots for (a) coast, (b) forest, (c) transition, (d) guinea savannah and (e) sudan savannah zones under three emission scenarios in Ghana. The figures show the temperature average in the time periods 2021-2040, 2041-2060 and 2081-2100. The low, medium and high emission scenarios are represented by blue, orange and red colors respectively. The uncertainty bounds shown on the plot are the 10th to 90th percentiles of the models.

The projection for July-August-September (JAS) in comparison with the reference period value of 193mm as presented in **Figure 22(a)** shows an increase for all time periods. A low emission scenario depicts an increase of 38mm (19.4%) for the near term, 33mm (17.1%) for the mid century and 38mm (19.9%) for the end of century. Under a medium emission scenario, rainfall is expected to increase by 9mm (4.7%), 6mm (3.1%) and 23mm (11.8%) for the near term, mid century and end of century respectively while a high emission scenario projects an increase of 2mm (1%), 16mm (8.5%) and 22mm (11.4%) for the near term, mid-term and end of century respectively.

The projection for July-August-September (JAS) in comparison with the reference period value of 381mm as presented in **Figure 22(b)** shows an increase for all time periods. A low emission scenario depicts an increase of 35mm (9.2%) for the near term, 25mm (6.6%) for the mid century and 32mm (8.5%) for the end of century. Under a medium emission scenario, rainfall is expected to increase by 6mm (1.7%), 22mm (5.7%) and 24mm (6.2%) for the near term, mid century and end of century respectively while a high emission scenario projects an increase of 12mm (3.1%), 29mm (7.5%) and 31mm (8.0%) for the near term, mid term and end of century respectively.

The projection for July-August-September (JAS) in comparison with the reference period value of 390mm as presented in **Figure 22(c)** shows an increase for all time periods. A low emission scenario depicts an increase of 24mm (6.1%) for the near term, 23mm (5.8%) for the mid century and 30mm (7.6%) for the end of century. Under a medium emission scenario, rainfall is expected to increase by 7mm (1.8%), 12mm (3.2%) and 20mm (5.2%) for the near term, mid century and end of century periods respectively. A high emission scenario projects an increase of 22mm (5.6%), 25mm (6.3%) and 40mm (10.3%) for the near term, mid century and end of century periods respectively.

Figure 22(d) presents projected changes in July–August–September (JAS) with seasonal rainfall relative to the reference value of 564 mm, showing an overall increase across all time periods. Under a low emission scenario, rainfall is expected to rise by 14 mm (2.6%) in the near term, 8 mm (1.5%) by midcentury, and 10 mm (1.7%) by the end of century. In a medium emission scenario, rainfall is projected to increase by 1 mm (0.1%) in the near term, 9 mm (1.6%) in midcentury, and 13 mm (2.3%) toward the end of century. Under a high emission scenario, rainfall is projected to increase by 18 mm (3.1%) in the near term, 27 mm (4.8%) by midcentury, and 42 mm (7.5%) by the end of century.

The projection for July-August-September (JAS) in comparison with the reference period value of 590mm as presented in **Figure 22(e)** shows an increase for all time periods under low emission scenario 14mm (2.4%), 3mm (0.5%) and 3mm (0.5%) for the near term, mid century and end of century respectively. Under a medium emission scenario, rainfall is expected to increase by 5mm (0.9%), 8mm (1.4%) and 13mm (2.3%) for the near term, mid century and end of century respectively while a high emission scenario projects an increase of 17mm (2.9%), 29mm (4.9%) and 49mm (8.3%) for the near term, mid term and end of century respectively.

September-October-November

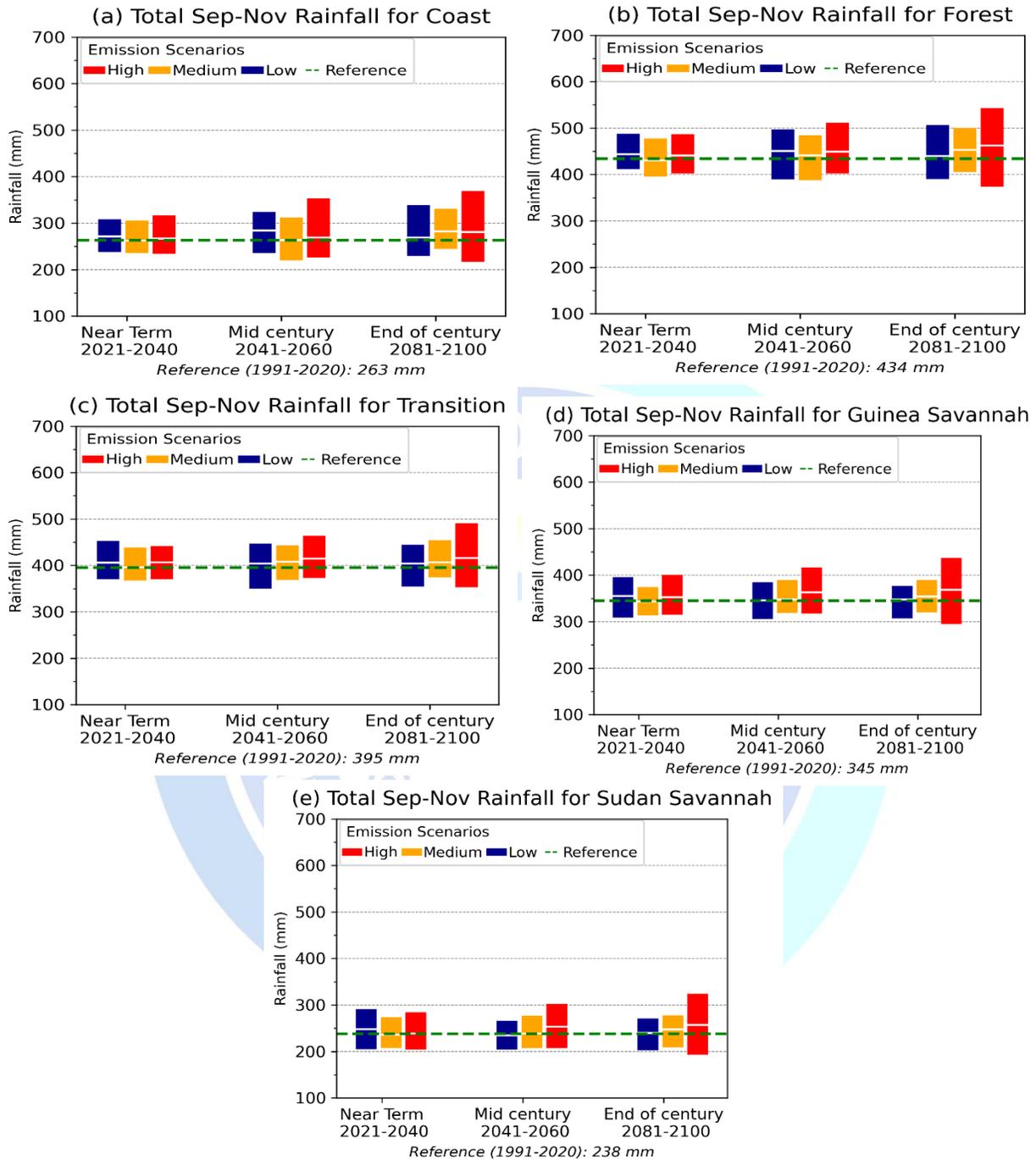


Figure 23. Average SON seasonal rainfall boxplots for (a) coast, (b) forest, (c) transition, (d) guinea savannah and (e) sudan savannah zones under three emission scenarios in Ghana. The figures show the temperature average in the time periods 2021-2040, 2041-2060 and 2081-2100. The low, medium and high emission scenarios are represented by blue, orange and red colors respectively. The uncertainty bounds shown on the plot are the 10th to 90th percentiles of the models.

Figure 23(a) shows projected changes in September-October-November (SON) seasonal rainfall relative to the reference period amount of 263mm. Under a low emission scenario, rainfall is projected to increase by 8mm (2.9%) in the near term, 21mm (8%) by mid century and 6mm (2.2%) by end of century. Under a medium emission scenario, rainfall is projected to decrease marginally by 1mm (0.3%) during the near term. An increment of 18mm (7%) is projected by end of century whereas approximately no change is expected during the mid century. A high emission scenario projects an increase of 4mm (1.5%) for near term, 6mm (2.2%) for midcentury and 17mm (6.6%) towards the end of century.

Figure 23(b) shows projected changes in September-October-November (SON) seasonal rainfall relative to the reference period amount of 434mm. Under a low emission scenario, rainfall is projected to increase by 9mm (2.1%) in the near term, 16mm (3.8%) by mid century and 6mm (1.3%) by end of century. Under a medium emission scenario, rainfall is projected to decrease by 4mm (0.9%) in the near term, increase by 7mm (1.6%) mid century and 19mm (4.4%) by end of century. A high emission scenario projects an increase of 6mm (1.5%) for near term, 15mm (3.4%) for mid century and 28mm (6.4%) towards the end of century.

Figure 23(c) shows projected changes in September-October-November (SON) seasonal rainfall relative to the reference period amount of 395mm. Under a low emission scenario, rainfall is projected to increase by 11mm (2.8%) for the near term and 9mm (2.2%) for both the mid century and end of century respectively. Under a medium emission scenario, rainfall is projected to increase by 1mm (0.2%) for the near term, 13mm (3.3%) for the mid century and 12mm (3.0%) for the end of century. A high emission scenario projects an increase of 11mm (2.9%) for the near term, 19mm (4.9%) for the mid century and 21mm (5.2%) for the end of century.

Figure 23(d) illustrates the projected changes in September–October–November (SON) seasonal rainfall compared to the reference period total of 345 mm. Under a low emission scenario, rainfall is expected to rise by 10 mm (2.8%) in the near term, 1 mm (0.2%) by midcentury, and 3 mm (0.8%) by the end of century. For a medium emission scenario, projections show a slight decrease of 2 mm (0.4%) in the near term, followed by increases of 3 mm (0.9%) at midcentury and 9mm (2.7%) by the end of century. Under a high emission scenario, rainfall is projected to increase by 8 mm (2.3%) in the near term, 18 mm (5.2%) at midcentury, and 24 mm (6.9%) by the end of century.

Figure 23(e) shows projected changes in September-October-November (SON) seasonal rainfall relative to the reference period amount of 238mm. Under a low emission scenario, rainfall is projected to increase by 10mm (4.3%) in the near term, decrease by 3mm (1.4%) by mid century and increase by 2mm (0.8%) by end of century. Under a medium emission scenario, rainfall is projected to decrease by 2mm (0.8%) in the near term, increase by 1mm (0.3%) by mid century and 10mm (4.1%) at the end of century. A high emission scenario projects an increase of 1mm (0.3%) for near term, 16mm (6.6%) for mid century and 19mm (7.9%) towards the end of century.

December-January-February

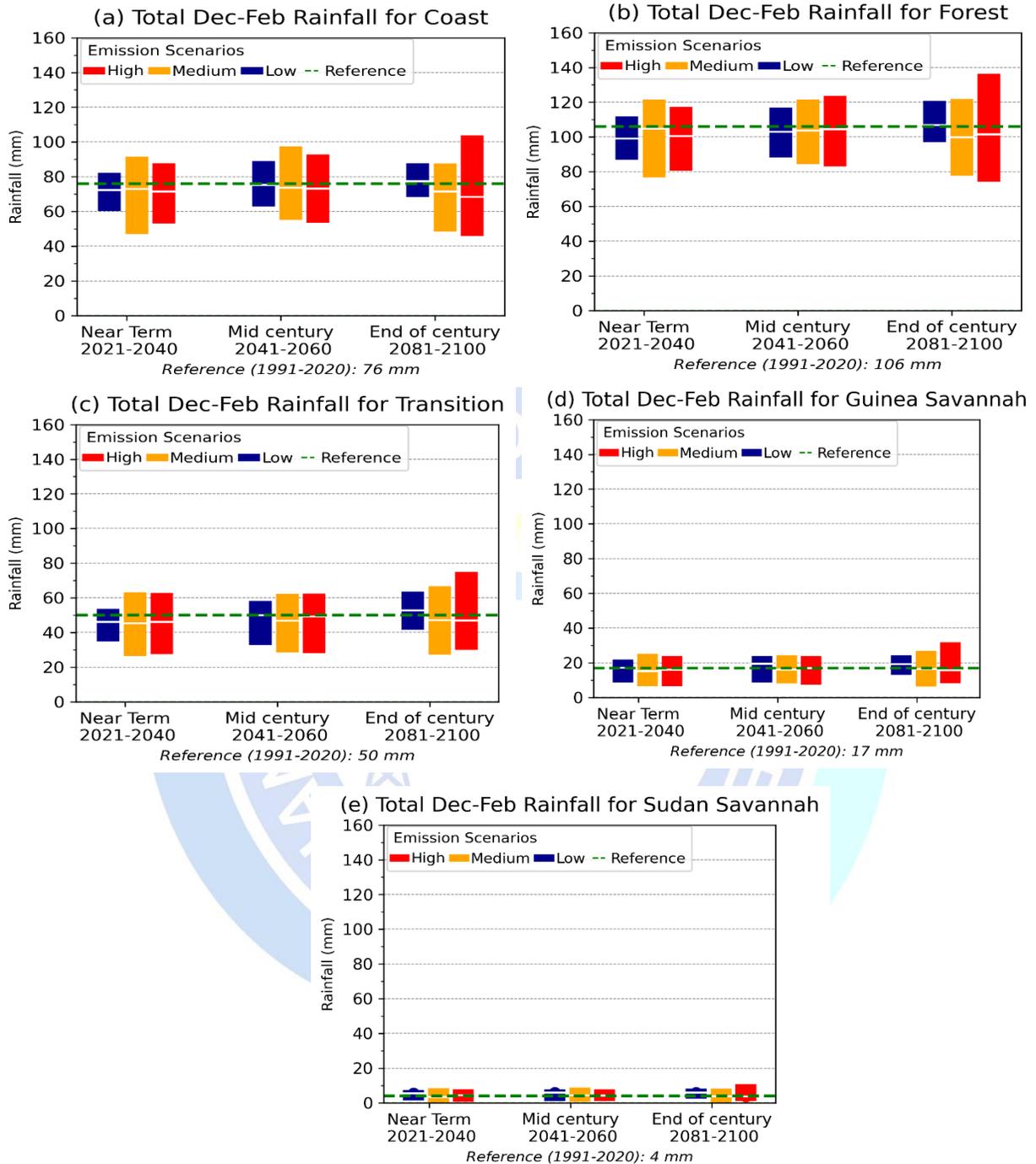


Figure 24. Average DJF seasonal rainfall boxplots for (a) coast, (b) forest, (c) transition, (d) guinea savannah and (e) sudan savannah zones under three emission scenarios in Ghana. The figures show the temperature average in the time periods 2021-2040, 2041-2060 and 2081-2100. The low, medium and high emission scenarios are represented by blue, orange and red colors respectively. The uncertainty bounds shown on the plot are the 10th to 90th percentiles of the models.

The projections for December-January-February (DJF), compared to the reference period value of 76mm as displayed in **Figure 24(a)**, show both increasing and decreasing trends within the low emission scenario and a decreasing trend under the other possible futures. Under a low emission scenario, rainfall is expected to decrease by approximately 4mm (5.2%) and 1mm (1.4%) in the near term and mid century respectively. A marginal increase of 1mm (0.4%) is expected by end of century. Under a medium emission scenario, rainfall is projected to decrease by 3mm (4.4%) in the near term, 3mm (3.4%) by mid century and by 5mm (6.4%) by end of century. In a high emission scenario, rainfall is expected to decrease by 5mm (6.4%), 3mm (4.3%) and 8mm (10.6%) for the near term, mid century and end of century respectively.

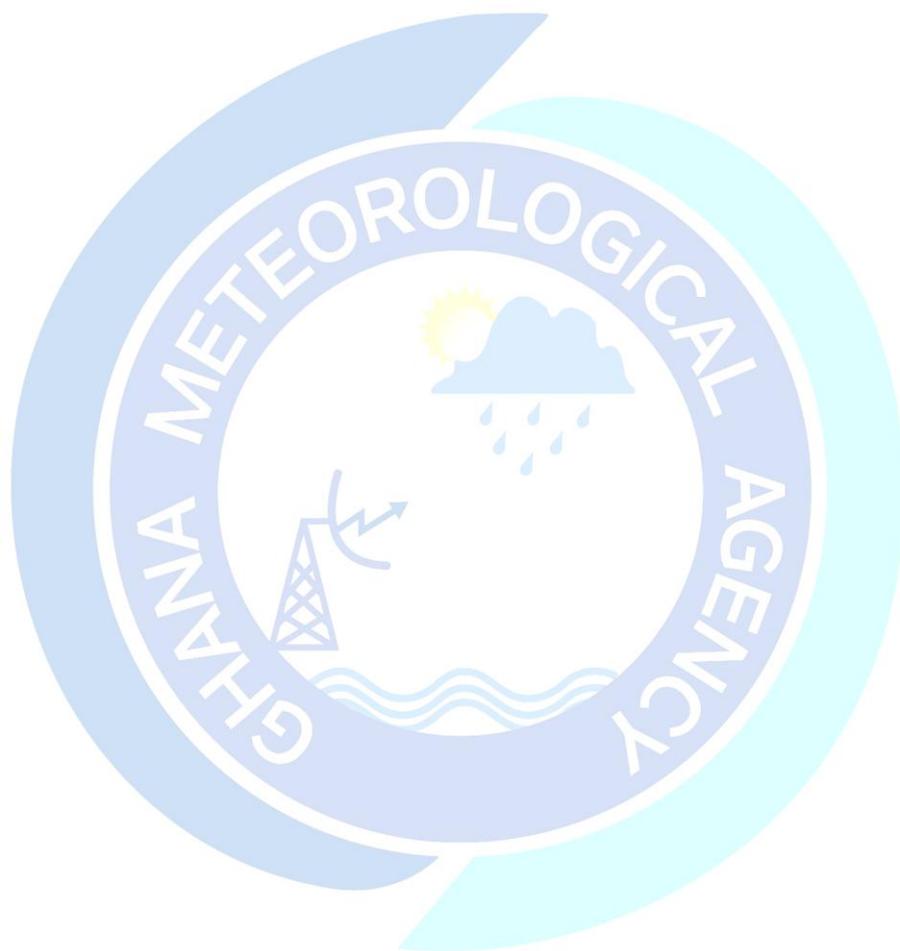
The projections for December-January-February (DJF), compared to the reference period value of 106mm as displayed in **Figure 24(b)**, show both increasing and decreasing trends across all time periods. Under a low emission scenario, rainfall is expected to decrease by approximately 6mm (6.2%) in the near term, 3mm (2.6%) by mid century and an increase of 1mm (1.2%) by end of century. Under a medium emission scenario, rainfall is projected to decrease by 1mm (0.8%) in the near term, 2mm (1.8%) by mid century and 6mm (5.3%) by end of century. In a high emission scenario, rainfall is expected to decrease by 5mm (4.9%), 1mm (1.0%) for mid century and 4mm (3.9%) at the end of century.

The projections for December-January-February (DJF), compared to the reference period value of 50mm as displayed in **Figure 24(c)**, show both increasing and decreasing trends across the time periods. Under a low emission scenario, rainfall is expected to decrease by 4mm (7.4%) for the near term and 3mm (5.9%) for the end of century with no significant change expected during the mid century. Under a medium emission scenario, rainfall is projected to decrease for all time periods by 4mm (9.0%) for the near term and 3mm (6.3%) for both mid century and end of century periods respectively. A decrease in rainfall for all projection periods is also expected under a high emission scenario by 4mm (7.5%) for the near term, 1mm (1.3%) for the mid century and 3mm (5.7%) end of century

The projections for the December–January–February (DJF) season, relative to the reference value of 17 mm shown in **Figure 24(d)**, reveal both increases and decreases in rainfall across the different time periods. Under a low emission scenario, rainfall is expected to show no change in the near term, increase by 3 mm (14.9%) by midcentury, and 2 mm (14.3%) by the end of century. Under a medium emission scenario, rainfall is projected to decrease by 2 mm (10.4%) in the near term, 1mm (4.2%) by midcentury, 1 mm (3.4%), and at the end of century. For a high emission scenario, rainfall is expected to decline by 1 mm (5.0%) in the near term and no change in midcentury, followed by a similar decrease of 1 mm (6%) by the end of the century.

The projections for December-January-February (DJF), relative to the reference period value of 4mm shown in **Figure 24(e)**, indicate an increase of 1mm(36.4%) in the near term, 2mm (46.1%) for both mid century and end of century, under the low emission scenario. Under the medium-emission scenario, a decrease of 1 mm (13.2.1%) is projected in the near term, with no change

projected by mid century and the end of the century. Under the high emission scenario, no change is projected for all time periods.



4.0 Case Studies of Climates Impacts in Ghana

4.1 Mangrove Degradation and Livelihood Vulnerability in Anyanui

Location: Anyanui, Anloga District, Volta Region

Anyanui is a coastal community situated along Ghana's eastern shoreline within the Volta estuary, where a tributary of the Volta River meets the sea. The village is widely known for its extensive mangrove forests, which have long supported both the local environment and the livelihoods of the people who depend on them. Historically, the waterways around Anyanui served as an important transport route, linking the community to nearby trading centers such as Ada Market and facilitating the movement of people, fish, and agricultural produce among coastal settlements.

Mangroves in this area provide critical ecosystem services that support both climate regulation and coastal resilience. As dense "blue carbon" ecosystems, mangrove forests store significant amounts of carbon in their biomass and sediments, helping to reduce greenhouse gases in the atmosphere. Their complex root systems also stabilize shorelines, dissipate wave energy, and protect coastal communities from erosion, tidal flooding, and storm surges. For communities such as Anyanui, these forests function as natural infrastructure that strengthens resilience to climate-related coastal hazards.

Beyond their environmental value, mangroves are central to the local economy. The intricate root systems create breeding grounds for fish and other aquatic species, supporting small-scale fishing activities that sustain many households. Mangroves also provide fuelwood used in fish smoking and domestic energy, as well as materials for small-scale trading. In this way, the mangrove ecosystem forms the backbone of daily life in the community.

However, increasing pressure on mangrove resources is becoming evident. Field observations and community accounts indicate that mangrove harvesting for firewood and commercial purposes has intensified over time. This growing demand, combined with broader coastal pressures, has led to noticeable reductions in mangrove cover in some areas. As forests decline, the consequences extend beyond the environment. Reduced mangrove density can weaken natural coastal protection, increase vulnerability to erosion, and disrupt fish breeding habitats that support local fisheries.

The decline of mangroves therefore presents a significant challenge for Anyanui. As fish stocks and ecosystem services diminish, household income opportunities become more limited, placing greater strain on already climate-sensitive livelihoods. The community thus faces a difficult balance between meeting immediate economic needs and preserving the ecological systems that sustain long-term resilience.

The situation in Anyanui highlights the broader importance of mangrove ecosystems for sustainable development. Healthy mangroves contribute to climate change mitigation through carbon sequestration, support marine biodiversity, and protect coastal infrastructure and settlements. Their conservation therefore plays an important role in advancing multiple sustainable

development objectives, including climate action, sustainable coastal communities, and the protection of marine and terrestrial ecosystems.

This case underscores the need for integrated coastal management approaches that combine mangrove conservation with sustainable livelihood options for local communities. Strengthening community-based mangrove restoration, improving awareness, and promoting alternative energy and income sources can help reduce pressure on these ecosystems while safeguarding the livelihoods that depend on them.



Image 1. Mangrove harvesting along the banks of the Keta-Avu Lagoon at Anyanui in the Anloga District, Volta Region, for firewood and as a source of livelihood

4.2 Coastal Erosion and Community Resilience in Keta

Location: Keta, Keta Municipal, Volta Region

Keta, located along the Gulf of Guinea on a narrow strip of land between the Atlantic Ocean and the Keta Lagoon. This low-lying sandy barrier makes the town particularly vulnerable to coastal erosion and flooding. Over the years, strong wave action and rising sea levels have caused significant shoreline retreat, steadily bringing the sea closer to homes, roads, and public infrastructure. As a result, Keta has become one of the most erosion-prone coastal communities in Ghana.

For residents, coastal erosion is not an abstract environmental issue but a lived reality. Waves have gradually eaten away the shoreline, undermining buildings that once stood safely inland. Many families have been forced to relocate repeatedly as foundations weaken; crack walls, and floodwaters enter homes during high tides and storms. In this way, the advancing sea threatens not only property but also community stability and livelihoods.

One of the most visible symbols of this loss is Fort Prinzenstein, a historic Danish fort constructed in 1784. Once a prominent landmark linked to the history of the transatlantic slave trade, large portions of the fort have already been claimed by the sea. Today, the remaining sections show visible damage, including collapsing walls and exposed foundations weakened by saltwater and

shifting sands. If erosion continues, the disappearance of Fort Prinzenstein would represent not only environmental loss but also the erosion of an important cultural and historical heritage site.

Local accounts further illustrate the scale of the impacts. According to James Ocloo Akorli, a museum and monuments educator who has closely observed changes along the coast, several community structures, including schools, churches, police stations, and traditional leadership buildings, have already been lost to coastal erosion. The fishing community has also been affected. Fishermen report declining fish harvests compared to previous years, reflecting growing pressures on marine resources and the vulnerability of coastal livelihoods.



Image 2. Severe shoreline erosion in Blekusu (Ketu south district) leading to the loss of homes and the gradual disappearance of fort Prinzenstein at Keta

In response to coastal challenges, several protection initiatives have been implemented along Ghana's Volta shoreline. The Keta Sea Defence Project introduced rock revetments and shoreline stabilization measures to mitigate the impact of tidal waves and protect coastal settlements, while complementary infrastructure such as the Kedzi Bridge, with its sluice gates, regulates water exchange between the sea and the Keta Lagoon to control flooding and maintain ecological balance. More recently, the Blekusu Sea Defence Project, launched in 2025, has further strengthened coastal protection through the construction of groynes and reinforced barriers aimed at reducing erosion and safeguarding homes, roads, and fishing communities. Keta's experience highlights the growing risks facing Ghana's coastal settlements as sea levels continue to rise and coastal dynamics intensify. While engineering interventions provide critical protection, the case underscores the need for long-term, integrated coastal management strategies that combine infrastructure, ecosystem restoration, and community adaptation to safeguard both livelihoods and heritage along Ghana's vulnerable coastline.

4.3 Akosombo Dam Spillage Event (2023)

In 2023, Ghana experienced unusually high inflows into the Volta Lake system, culminating in the controlled spillage of excess water from the Akosombo Dam. This event was largely driven by persistent and above-average rainfall over the Volta Basin during the peak of the rainy season, consistent with enhanced West African monsoon activity and increased moisture convergence over the basin (GMet, 2023).

The spillage resulted in extensive downstream flooding, particularly affecting low-lying communities within the Lower Volta Basin. Several settlements were inundated, leading to population displacement, damage to critical infrastructure, disruption of livelihoods, and losses in agricultural production. Similar flooding impacts associated with dam spillages and extreme rainfall events in the Volta Basin have been documented in previous studies, underscoring the vulnerability of downstream communities to hydrometeorological extremes (Asante et al., 2017; Nyadzi et al., 2018). The 2023 event highlights the importance of basin-scale climate monitoring, early warning systems, and integrated water resources management under a changing climate.



Image 3. Communities inundated after the spillage of water from the Akosombo dam (Photo by GBC)

4.4 Farming Against the Odds: Irrigation in Woe, Volta Region

Woe, a coastal town in Ghana's Volta Region, lies on a narrow strip of land between the Atlantic Ocean and the Keta Lagoon. While fishing has long sustained its people, vegetable farming, especially shallots, remains a key livelihood. Today, climate change is reshaping the way Woe's farmers work.

Rising temperatures and unpredictable rainfall have made traditional rain-fed farming unreliable. Dry spells are longer, and rain no longer comes on time. To cope, many farmers have turned to irrigation powered by boreholes, cultivating crops like carrots, cabbage, lettuce, cucumbers, onions, and chili peppers year-round.

Yet irrigation comes at a steep price. Installation, maintenance, and electricity costs are high, and many systems break down, leaving farmers unable to farm during the dry season. Those without irrigation must abandon their fields until the rain returns.

Heat stress and crop diseases compound the problem. Shallots wilt, curl, and bolt prematurely when temperatures rise, while carrot roots are increasingly attacked by nematodes, which thrive in warmer, drier soils. For farmers here, irrigation is no longer a choice, it is survival.

Farmers are calling on government support: solar-powered irrigation to reduce costs, stronger extension services for climate-smart guidance, and access to quality seedlings and fertilizers. Their struggles reflect a national trend: as highlighted by Enoch Young Dogbe, unpredictable weather and weak irrigation infrastructure are driving up vegetable prices across Ghana.

Climate change threatens food security and progress toward Zero Hunger. Supporting farmers in Woe with affordable, resilient irrigation and practical guidance is not just an agricultural need, it is essential for building a sustainable, climate-ready food system for the country.



Image 4. Vegetable farming in Woe, a town located in the Keta municipal assembly

4.5 Dry Spell in Northern Ghana (2024)

Northern Ghana experienced pronounced dry spell during the 2024 rainy season. These dry spells were characterized by delayed onset of seasonal rainfall, extended periods of below-normal precipitation, and prolonged intervals with little or no rainfall. Such conditions are consistent with observed trends of increasing rainfall variability and dry spell frequency across the northern savannah zones of Ghana (Owusu & Waylen, 2013; Klutse et al., 2021).

The dry conditions had adverse impacts on rain-fed agriculture, particularly affecting staple crops such as maize, sorghum, and millet. Reduced soil moisture availability during critical crop growth stages contributed to widespread yield reductions and heightened food security concerns. Previous studies have identified dry spells as a major climate risk for agricultural productivity and rural livelihoods in Northern Ghana, especially in contexts of limited irrigation infrastructure and low adaptive capacity (Antwi-Agyei et al., 2012; Sultan & Gaetani, 2016).

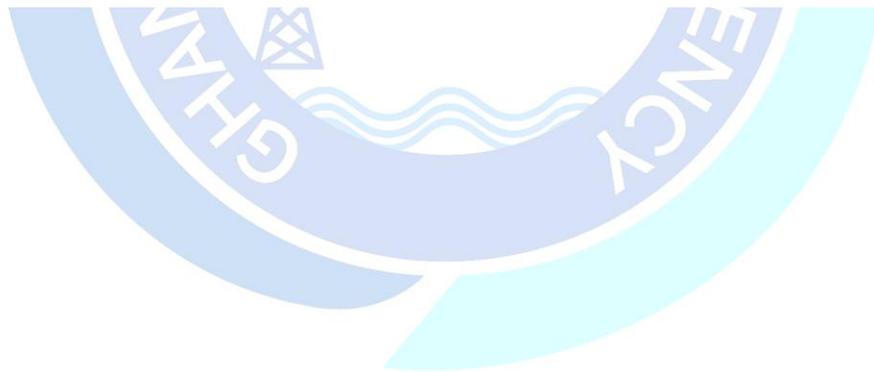
In 2024, these biophysical impacts translated into significant financial losses for farmers and the broader agricultural economy. Crop failure and yield suppression resulted in the loss of farmers' investments in agricultural inputs, including seeds, fertilizers, agrochemicals, labour, and land preparation. National assessments indicate that farmers affected by the 2024 dry spell lost an estimated GHC3.5 billion in farm investments, alongside potential revenue losses exceeding

GHC10 billion, reflecting the scale of production losses across the northern savannah and transitional zones. These financial shocks disproportionately affected smallholder farmers who depend almost entirely on rain-fed agriculture, constraining their ability to recover and reinvest in subsequent cropping seasons. (graphic online, 2nd sept. 2024)

At the macroeconomic level, the widespread agricultural losses associated with the 2024 dry spell contributed to a contraction in agricultural output, increased pressure on food prices, and heightened food insecurity, particularly in Northern Ghana where vulnerability levels are already high. The 2024 dry spell therefore illustrates the escalating economic cost of climate variability in the northern savannah zones and underscores the urgency of strengthening climate-resilient agricultural systems through expanded irrigation, improved seasonal climate information services, and scalable agricultural insurance and risk financing mechanisms.



Image 5. Wilting maize plants due to prolonged dry spell (Photo by Ghana Web)



5.0 Implications for Key Sectors

The climate projections in this report provide important insights into how Ghana's climate may evolve in the future. However, it is important to recognize that climate projections are subject to uncertainties arising from differences among climate models, future greenhouse gas emission pathways, and the natural variability of the climate system. As a result, the projections should be interpreted as plausible ranges of future conditions rather than precise predictions.

Despite these uncertainties, the findings consistently point to several emerging climate signals, particularly rising temperatures and continued variability in rainfall. These changes may influence multiple sectors of the economy and society. The following section highlights the possible implications of these climate trends for key sectors in Ghana, providing a broad overview of areas where climate change may affect livelihoods, infrastructure, natural resources, and development planning.

Energy

Rising temperatures and changes in rainfall patterns may affect both energy demand and supply.

- Higher temperatures can increase electricity demand for cooling.
- Variability in rainfall may influence hydropower generation.
- Prolonged dry periods may limit water availability for power production, reducing energy supply.
- Greater demand due to rising temperatures and variability in supply due to water availability may raise the cost of energy production and distribution.

Agriculture

Agriculture, which is largely rain-fed in Ghana, is particularly vulnerable to changes in temperature and rainfall.

- Rising temperatures may lead to heat stress for crops and livestock.
- Increased temperatures and irregular rainfall may reduce soil moisture, affecting crop growth and yield.
- Shifting rainfall patterns may disrupt planting and growing season.
- Rainfall variability may lead to prolonged dry spells or frequent flooding events that may affect crop yield.
- Reduced agricultural productivity due to increased temperature and rainfall may negatively affect incomes and livelihoods of farmers, farm labourers and agri-businesses.
- Reduced farm productivity may impact the country's food security.

Health

Increasing temperatures and changing rainfall conditions may heighten risks to public health.

- Rising temperatures may lead to heat stress
- Rising temperatures may increase the risk of heat related illness and death among vulnerable communities.
- Flooding may increase the risk of spreading water borne diseases
- Poor air quality during dry periods may increase the risk of respiratory diseases.
- Changes in temperature and rainfall may increase the spread of vector borne diseases such as malaria.

Water Resources

Changes in rainfall patterns and rising temperatures may affect the availability and reliability of water resources across Ghana.

- Rainfall variability can lead to periods of both water shortages due to low rainfall and prolonged dry periods and floods.
- Rainfall variability can affect domestic water supply, irrigation, and hydropower generation.
- Rising temperatures and reduced rainfall will increase evaporation which may lead to drying of water bodies and affecting water reserves

Infrastructure and Development

Rising temperatures, sea level rise, and rainfall variability present significant risks to infrastructure and development.

- Mean sea level rise can lead to inundation of roads, buildings, and critical infrastructure in low-lying coastal areas.
- High temperatures may affect structural integrity
- Coastal erosion due to mean sea level rise may lead to shoreline retreat, damaging infrastructures along the coast.
- Increased frequency of extreme rainfall events (heavy rainfall) may exceed the design capacity of urban drainage
- Saltwater intrusion due to rising mean sea levels may contaminate freshwater systems, affecting water supply

6.0 Conclusion and Recommendation

6.1 Conclusion

This report provides an important basis for understanding future climate change in Ghana and supporting informed decision-making. Analysis of key climate indicators: average annual temperature, average seasonal temperature, total annual rainfall, total seasonal rainfall, and sea-level rise at the National and the various agro climatic zones across different emission scenarios.

At the national level, by the end of century (2081–2100), under the medium emission scenario (RCP4.5), the average annual temperature is projected to increase by about 1.5°C, reaching approximately 29.3°C against the reference value of 27.8°C. The total annual rainfall is expected to remain relatively stable, although southern Ghana may experience slight decreases during the major rainy season (AMJ) and slight increases during the minor season (SON), while northern Ghana may see a slight overall increase in rainfall, albeit with a wide uncertainty range and pronounced seasonal and spatial variability. Sea level is also projected to rise along the coast, reaching approximately 0.4-0.5m by 2100.

Consistent with these national projections, climate trends across Ghana's agro-climatic zones also indicate a clear warming pattern throughout the 21st century, accompanied by comparatively smaller but seasonally variable changes in rainfall.

In the Coastal Zone, average annual temperatures rise under all emission scenarios, exceeding the 27.5°C reference period, with stronger warming toward the end of century. Seasonal warming is most pronounced during AMJ and DJF, while JAS and SON show moderate increases. Total annual rainfall shows minimal change under low emission scenarios but declines under medium and high scenarios, with AMJ rainfall decreasing, JAS and SON rainfall increasing, and DJF showing mixed patterns, while sea level along the coast continues to rise.

In the Forest Zone, temperatures are expected to increase under all emission scenarios above the reference period value of 27.1°C, with the largest increase occurring toward the end of century under medium and high emission pathways. Annual rainfall shows slight increases, although seasonal patterns indicate AMJ rainfall decreases, JAS and SON rainfall increases, and DJF rainfall shows mixed changes.

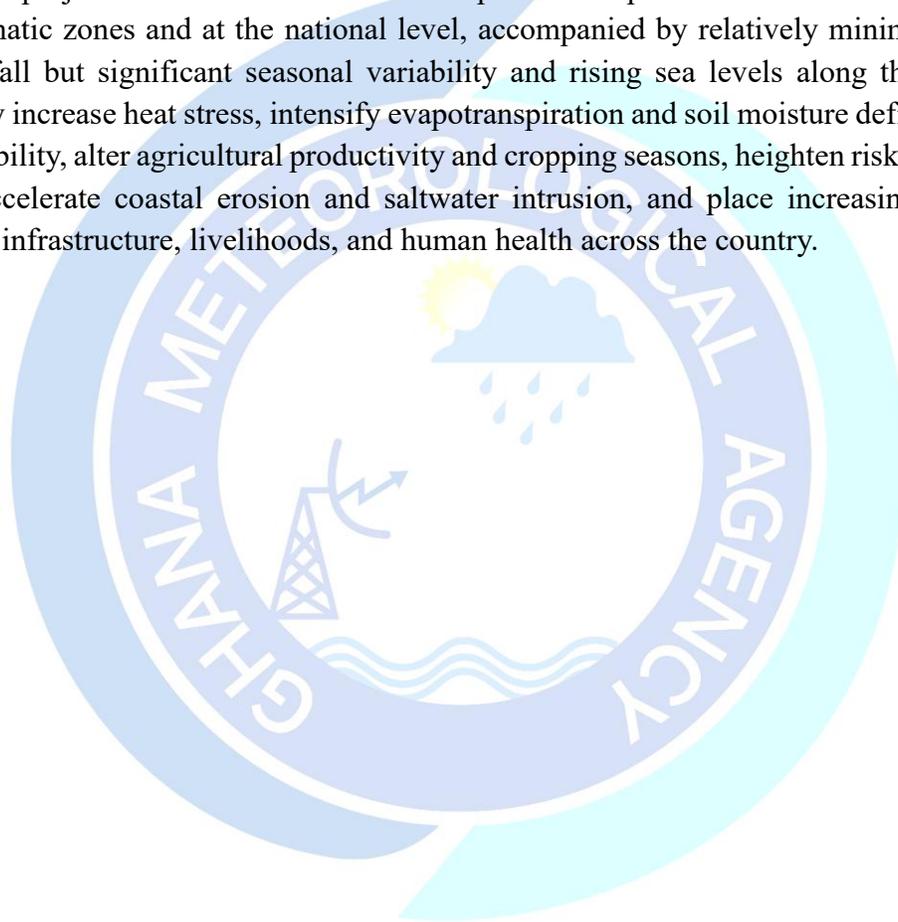
In the Transition Zone, average annual temperatures are projected to increase above the 27.0°C reference period, reaching about 1.4°C warming by the end of century, with temperatures approaching 28.4°C. Seasonal temperatures increase across AMJ, JAS, SON, and DJF. Annual rainfall increases slightly, with seasonal changes showing minimal change. AMJ and DJF show a slight decline and increases in JAS and SON.

In the Guinea Savannah Zone, temperatures are projected to rise by 1.5°C above the 28.4°C reference period by the end of century, reaching about 29.9°C, with warming across AMJ, JAS, SON, and DJF. Annual rainfall increases slightly, with increases in JAS and SON and slight decreases in AMJ and DJF.

In the Sudan Savannah Zone, average annual temperature is expected to rise by 1.7°C by the end of century under the medium emission pathway, reaching approximately 30.4°C relative to the reference period value of 28.8°C. Rainfall changes remain relatively small but uncertain, with projections suggesting reduced rainfall during the AMJ rainy season and increased rainfall during the JAS under medium and high emission scenarios.

Recent events like the 2023 Akosombo Dam spillage, 2024 northern dry spell, and coastal inundation in Ketu South underscore how climate variability and extremes are already driving socio-economic losses, particularly in rain-fed agriculture and vulnerable savannah/coastal areas.

Overall, these projections indicate that Ghana is expected to experience substantial warming across all agro-climatic zones and at the national level, accompanied by relatively minimal changes in annual rainfall but significant seasonal variability and rising sea levels along the coast. Such changes may increase heat stress, intensify evapotranspiration and soil moisture deficits, influence water availability, alter agricultural productivity and cropping seasons, heighten risks of floods and droughts, accelerate coastal erosion and saltwater intrusion, and place increasing pressure on ecosystems, infrastructure, livelihoods, and human health across the country.



6.2 Recommendation

The observed trends and climate projections presented in this report highlight important changes occurring in Ghana's climate system. Rising temperatures, increasing climate variability, and potential shifts in rainfall patterns present significant challenges for key sectors such as agriculture, water resources, health, infrastructure, and coastal management. These changes underscore the need for proactive planning and targeted actions to reduce climate risks and strengthen resilience. The following recommendations are intended to guide policymakers, planners, researchers, and other stakeholders in developing effective strategies to respond to the projected climate changes. They emphasize the importance of integrating climate information into national and sectoral planning, strengthening adaptation measures, and enhancing the country's capacity to manage climate-related risks. By taking informed and coordinated action, Ghana can better safeguard livelihoods, protect ecosystems, and support sustainable development in a changing climate.

- **Strengthen Climate Information Services**

Expand the production and dissemination of climate information, and early warning systems to support decision-making across climate-sensitive sectors.

- **Mainstream Climate Projections into Development Planning**

Integrate climate projections from the Ghana Climate Atlas into national and sectoral planning processes, infrastructure design standards, and long-term development strategies.

- **Promote Climate-Resilient Agricultural Practices**

Encourage irrigation development, drought-tolerant crop varieties, and improved farm management practices to address rainfall variability and dry spell risks, particularly in the northern regions.

- **Improve Flood Risk and Water Resource Management**

Enhance basin-scale monitoring, dam operation coordination, and flood preparedness strategies to reduce the impacts of extreme rainfall events and dam spillages.

- **Strengthen Coastal Adaptation Measures**

Support integrated coastal zone management, shoreline protection, and ecosystem-based adaptation approaches such as mangrove restoration to reduce risks associated with sea-level rise and coastal erosion.

- **Sustain Climate Observation and Research**

Continue strengthening national climate observation networks, research capacity, and periodic updates of the Ghana Climate Atlas to support evidence-based policy and planning

- **Enhance stakeholder collaboration**

Enhance collaboration among stakeholders to improve climate impact analysis and support the development of effective adaptation strategies.

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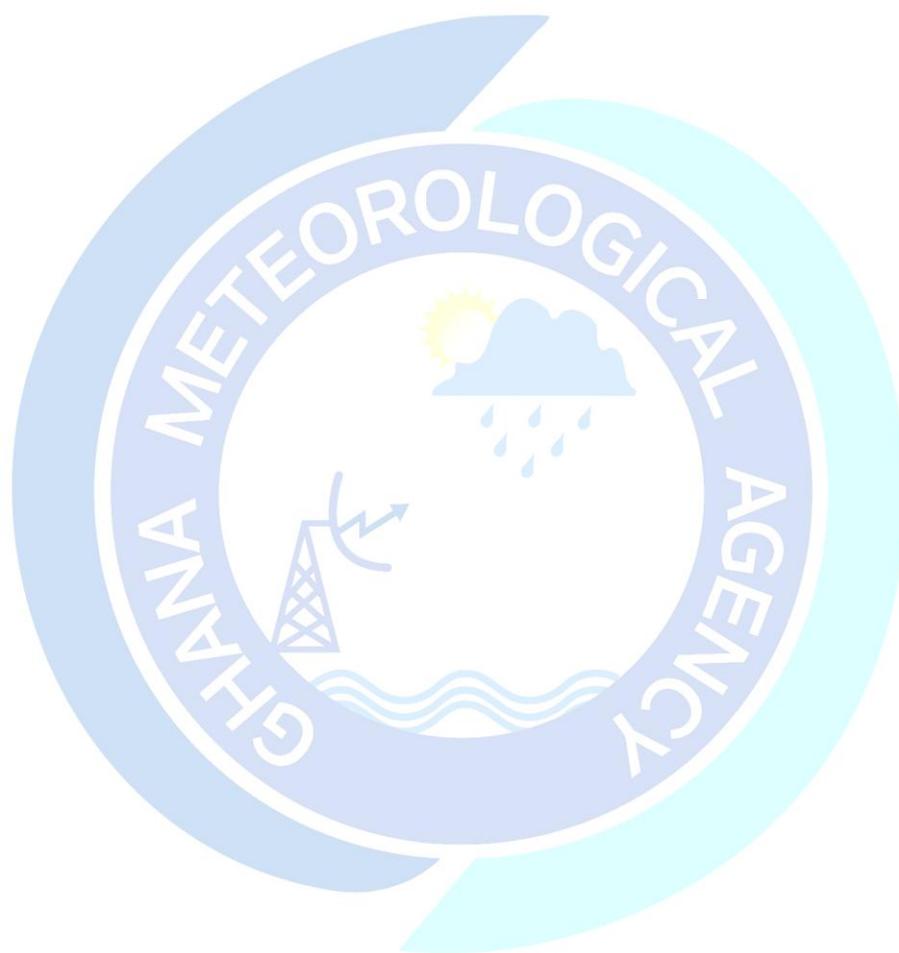
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Appendix

Overview Table

The following table shows an overview of the key indicators presented in this report. These indicators cover the national and the agro-climatic zones

Data are shown are the project changes for low, medium and high emission scenarios at the end of the century (2081-2100) as compared to the reference period (1991-2020). The uncertainty (10th - 90th percentile) is shown in square brackets. The values are shown as averages over the "whole period", "dry" (DJF) or "wet" (AMJ, JAS, SON).

Table 1 Overview of projected changes in key climate indicators for Ghana at the National level under low, medium, and high emission scenarios for the end of the century (2081–2100) relative to the reference period (1991–2020)

Area	Variable	Indicator	Season	Reference (1991-2020)	Low emission (2081-2100)	Medium emission (2081- 2100)	High emission (2081- 2100)	Unit
National	Temperature	Annual temperature	All year	27.8	0.5 [0.3 - 1.0]	1.5 [1.2 - 1.9]	3.7 [2.7 - 4.4]	°C
		Seasonal temperature	DJF	28.2	0.6 [0.3 - 1.1]	1.6 [1.2 - 2.2]	3.9 [2.6 - 5.0]	°C
			AMJ	28.6	0.6 [0.4 - 1.0]	1.5 [1.2 - 2.0]	3.7 [2.9 - 4.2]	°C
			JAS	26.0	0.5 [0.2 - 0.8]	1.3 [1.0 - 1.9]	3.3 [2.3 - 4.1]	°C
			SON	27.0	0.5 [0.3 - 0.9]	1.4 [1.1 - 1.9]	3.6 [2.4 - 4.4]	°C
	Rainfall	Annual rainfall	All year	1221	12 [-96 - 97]	22 [-59 - 103]	17 [-210 - 216]	mm
		Seasonal rainfall	Dry season (DJF)	53	2 [-6 - 11]	-3 [-18 -13]	-3 [-18 - 21]	mm
			Wet season (AMJ)	444	-13 [-49 - 23]	-8 [-43 - 42]	-31 [-135 - 71]	mm
			Wet season (JAS)	469	20	18	38	mm

					[-50 - 77]	[-38 - 69]	[-112 - 147]	
			Wet season (SON)	371	5 [-40 - 50]	13 [-26 - 54]	24 [-52 - 98]	mm
Sea level rise	Mean sea level	All year	NA		0.42 [0.29 - 0.6]	0.52 [0.38 - 0.72]	0.69 [0.53 - 0.92]	m

Table 2 Overview of projected changes in key climate indicators for Ghana over the Coastal zone under low, medium, and high emission scenarios for the end of the century (2081–2100) relative to the reference period (1991–2020)

Area	Variable	Indicator	Season	Reference (1991-2020)	Low emission (2081-2100)	Medium emission (2081-2100)	High emission (2081-2100)	Unit
Coastal Zone	Temperature	Annual temperature	All year	27.5	0.5 [0.4 - 0.9]	1.4 [1.1 - 1.8]	3.3 [2.6 - 4.0]	°C
		Seasonal temperature	(DJF)	28.2	0.6 [0.3 - 1.0]	1.4 [1.1 - 1.9]	3.5 [2.6 - 4.2]	°C
			(AMJ)	27.9	0.5 [0.4 - 0.9]	1.5 [1.1 - 1.8]	3.3 [2.6 - 3.8]	°C
			(JAS)	25.9	0.5 [0.2 - 0.9]	1.4 [1.1 - 2.0]	3.1 [2.5 - 3.9]	°C
			(SON)	27.2	0.5 [0.3 - 0.9]	1.3 [1.0 - 1.9]	3.1 [2.4 - 4.0]	°C
	Rainfall	Annual rainfall	All year	980	28 [-80 - 128]	-6 [-88 - 116]	-51 [-213 - 149]	mm
		Seasonal rainfall	Dry season (DJF)	76	1 [-8 - 11]	-5 [-28 - 11]	-8 [-30 - 28]	mm
			Wet season (AMJ)	450	-21 [-82 - 40]	-16 [-54 - 31]	-63 [-169 - 60]	mm
			Wet season (JAS)	193	38	23	22	mm

					[-27 - 103]	[-41 - 70]	[-133 - 109]	
			Wet season (SON)	263	6 [-34 - 76]	18 [-19 - 67]	17 [-47 - 106]	mm

Table 3 Overview of projected changes in key climate indicators for Ghana across the Forest zone under low, medium, and high emission scenarios for the end of the century (2081–2100) relative to the reference period (1991–2020)

Area	Variable	Indicator	Season	Reference (1991-2020)	Low emission (2081-2100)	Medium emission (2081-2100)	High emission (2081-2100)	Unit
Forest zone	Temperature	Annual temperature	All year	27.1	0.5 [0.3 - 0.9]	1.4 [1.1 - 1.8]	3.4 [2.6 - 4.0]	°C
		Seasonal temperature	(DJF)	27.7	0.6 [0.3 - 1.1]	1.5 [1.2 - 1.9]	4.9 [2.7 - 4.8]	°C
			(AMJ)	27.5	0.5 [0.3 - 0.9]	1.4 [1.1 - 1.8]	3.7 [2.5 - 4.6]	°C
			(JAS)	25.7	0.5 [0.2 - 0.8]	1.3 [1.0 - 1.8]	3.2 [2.4 - 3.8]	°C
			(SON)	26.7	0.5 [0.3 - 0.8]	1.3 [1.0 - 1.8]	3.2 [2.4 - 3.9]	°C
	Rainfall	Annual rainfall	All year	1429	23 [-101 - 123]	20 [-66 - 102]	2 [-250 - 244]	mm
		Seasonal rainfall	Dry season (DJF)	106	1 [-9 - 15]	-6 [-28 - 16]	-4 [-31 - 31]	mm
			Wet season (AMJ)	562	-17 [-58 - 29]	-9 [-50 - 54]	-30 [-173 - 91]	mm
			Wet season (JAS)	381	32 [-41 - 97]	24 [-33 - 81]	31 [-135 - 159]	mm
			Wet season (SON)	434	6 [-44 - 73]	19 [-29 - 65]	28 [-61 - 109]	mm

Table 4 Overview of projected changes in key climate indicators for Ghana across the Transition zone under low, medium, and high emission scenarios for the end of the century (2081–2100) relative to the reference period (1991–2020)

Area	Variable	Indicator	Season	Reference (1991-2020)	Low emission (2081-2100)	Medium emission (2081-2100)	High emission (2081-2100)	Unit
Transition	Temperature	Annual temperature	All year	27.0	0.6 [0.4 - 0.9]	1.4 [1.2 - 1.9]	3.7 [2.6 - 4.3]	°C
		Seasonal temperature	DJF	27.6	0.6 [0.2 - 1.0]	1.5 [1.2 - 2.1]	3.8 [2.7 - 4.9]	°C
			AMJ	27.6	0.6 [0.4 - 1.0]	1.5 [1.1 - 1.9]	3.7 [2.8 - 4.0]	°C
			JAS	25.5	0.5 [0.3 - 0.8]	1.3 [1.0 - 1.8]	3.3 [2.4 - 3.9]	°C
			SON	26.3	0.5 [0.3 - 0.9]	1.3 [1.0 - 1.8]	3.4 [2.3 - 4.1]	°C
	Rainfall	Annual rainfall	All year	1207	15 [-96 - 97]	15 [-57 - 93]	11 [-191 - 193]	mm
		Seasonal rainfall	Dry season (DJF)	50	3 [-8 - 14]	-3 [-23 - 17]	-3 [-20 - 25]	mm
			Wet season (AMJ)	473	-12 [-52 - 21]	-8 [-46 - 44]	-40 [-142 - 68]	mm
			Wet season (JAS)	390	30 [-43 - 81]	20 [-30 - 70]	40 [-69 - 124]	mm
			Wet season (SON)	395	9 [-41 - 49]	12 [-21 - 59]	21 [-42 - 96]	mm

Table 5 Overview of projected changes in key climate indicators for Ghana across the Guinea savannah zone under low, medium, and high emission scenarios for the end of the century (2081–2100) relative to the reference period (1991–2020)

Area	Variable	Indicator	Season	Reference (1991-2020)	Low emission (2081-2100)	Medium emission (2081-2100)	High emission (2081-2100)	Unit
Guinea Savannah	Temperature	Annual temperature	All year	28.4	0.6 [0.3 - 1.1]	1.5 [1.3 - 2.0]	4.0 [2.8 - 4.7]	°C
		Seasonal temperature	Dry season (DJF)	28.7	0.6 [0.2 - 1.1]	1.6 [1.3 - 2.3]	4.0 [2.7 - 5.2]	°C
			Wet season (AMJ)	29.4	0.6 [0.4 - 1.1]	1.6 [1.2 - 2.1]	4.0 [3.0 - 4.5]	°C
			Wet season (JAS)	26.3	0.5 [0.1 - 0.9]	1.3 [1.0 - 1.9]	3.5 [2.3 - 4.3]	°C
			Wet season (SON)	27.4	0.6 [0.3 - 1.0]	1.4 [1.1 - 2.0]	3.9 [2.5 - 4.7]	°C
	Rainfall	Annual rainfall	All year	1121	1 [-97 - 77]	26 [-54 - 104]	31 [-197 - 201]	mm
		Seasonal rainfall	DJF	17	2 [-4 - 8]	-1 [-10 - 10]	-1 [-9 - 15]	mm
			AMJ	366	-9 [-40 - 17]	-6 [-37 - 35]	-28 [-110 - 57]	mm
			JAS	564	10 [-60 - 62]	13 [-46 - 62]	42 [-110 - 143]	mm
			SON	345	3 [-38 - 33]	9 [-25 - 44]	24 [-50 - 92]	mm

Table 6 Overview of projected changes in key climate indicators for Ghana across the Sudan savannah under low, medium, and high emission scenarios for the end of the century (2081–2100) relative to the reference period (1991–2020)

Area	Variable	Indicator	Season	Reference (1991-2020)	Low emission (2081-2100)	Medium emission (2081-2100)	High emission (2081-2100)	Unit
Sudan Savannah	Temperature	Annual temperature	All year	28.8	0.6 [0.4 - 1.2]	1.7 [1.4 - 2.1]	4.2 [2.9 - 5.0]	°C
		Seasonal temperature	DJF	28.3	0.7 [0.2 - 1.2]	1.8 [1.4 - 2.6]	4.3 [2.7 - 5.6]	°C
			AMJ	30.5	0.7 [0.4 - 1.2]	1.8 [1.3 - 2.2]	4.4 [3.1 - 5.1]	°C
			JAS	26.5	0.5 [0.1 - 0.9]	1.3 [1.0 - 1.9]	3.5 [2.2 - 4.5]	°C
			SON	27.7	0.7 [0.2 - 1.2]	1.7 [1.3 - 2.2]	4.2 [2.7 - 5.1]	°C
	Rainfall	Annual rainfall	All year	961	8 [-74 - 72]	31 [-42 - 114]	52 [-123 - 236]	mm
		Seasonal rainfall	Dry season (DJF)	4	2 [-1 - 4]	0 [-4 - 4]	0 [-3 - 7]	mm
			Wet season (AMJ)	282	-7 [-36 - 19]	-6 [-40 - 38]	-19 [-82 - 59]	mm
			Wet season (JAS)	590	3 [-57 - 59]	13 [-33 - 56]	49 [-83 - 174]	mm
			Wet season (SON)	238	2 [-35 - 33]	10 [-30 - 40]	19 [-45 - 86]	mm

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