State of the Climate in

Ghana

2023

Ghana Meteorological Agency (GMet)

State of the Climate

Ghana

2023

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ABBREVIATIONS

GMet	Ghana Meteorological Agency
LTM	Long-Term Mean
ITCZ	Inter-Tropical Convergence Zone
FMA	February March April
MAM	March April May
AMJ	April May June
MJJ	May June July
JJA	June July August
JAS	July August September
ASO	August September October
SON	September October November

PREFACE

The State of the Climate in Ghana 2023 represents a significant milestone in Ghana's ongoing effort to document, analyze, and understand its climate patterns within global atmospheric variations. As the Ghana Meteorological Agency (GMet), we have undertaken the rigorous process of collecting, quality-controlling, and analyzing meteorological data from our network of stations strategically positioned throughout Ghana's diverse ecological zones.

This report emerges from GMet's commitment to maintaining high-quality climate records that conform to the World Meteorological Organization's standards for climate monitoring. The data presented herein utilizes the 1991-2020 climatological reference period, which provides the baseline against which the anomalies of 2023 are assessed. This 30-year reference period captures the recent climate norms while allowing for meaningful comparative analysis within the context of longer-term climate variability and change.

Our methodological approach integrates both traditional and contemporary analytical techniques. Temperature data analysis includes assessments of diurnal and seasonal variations, extremes (10th percentile minimum and 90th percentile maximum), and the frequency distribution of days exceeding various temperature thresholds. The precipitation analysis involves a detailed examination of annual and seasonal rainfall totals, the spatial and temporal distribution of precipitation events, standardized anomalies relative to the long-term mean, and the quantification of rainfall characteristics, including onset dates, early(1^{st}) and late(2^{nd}) dry spells, and cessation dates.

The report's structure follows the atmospheric variables of primary importance to Ghana's socio-economic activities. Chapter 2 focuses on temperature patterns, which directly influence energy demand, human comfort, and agricultural productivity. Chapter 3 provides a comprehensive analysis of precipitation variability across multiple seasonal windows, including the standard meteorological seasons (JFM, FMA, MAM, AMJ, MJJ, JJA, JAS, ASO, SON) that capture Ghana's bimodal and monomodal rainfall regimes. Chapter 4 examines specific rainfall characteristics critical for agricultural planning, including onset dates and dry spell frequencies that impact planting decisions and crop development cycles.

The findings presented in this document reveal significant spatial heterogeneity in Ghana's climate system during 2023. The northern regions, particularly around Navrongo,

maintained their characteristic high maximum temperatures (~35°C), while the elevated regions like Abetifi experienced temperatures approximately 28.8°C. Rainfall distribution followed the established west-to-east gradient, with western coastal stations like Axim recording nearly three times the precipitation of eastern coastal stations like Tema. These observations reinforce our understanding of the complex interactions between Ghana's topography, proximity to the Gulf of Guinea, and the seasonal migration of the Inter-Tropical Convergence Zone (ITCZ).

In preparing this report, GMet acknowledges the limitations inherent in observational networks. Despite our best efforts, there remain challenges in data acquisition, particularly in remote areas. We have employed rigorous quality control protocols to ensure data integrity, but users should be cognizant of these limitations when interpreting results from areas with sparse station coverage.

We extend our sincere gratitude to the dedicated meteorological observers who diligently maintain our observation network, often under challenging conditions. Their commitment to accurate and timely data collection forms the foundation upon which this climate assessment is built. This forecast owes its depth and precision to the leadership of Dr. Eric Asuman, Director General of GMet, and the diligence of Mrs. Francisca Martey, Deputy Director of Research and Applied Meteorology, as lead author. We also acknowledge contributions from the entire Research and Applied Meteorology Department, whose collective expertise shaped this assessment.

As we present this comprehensive analysis of Ghana's climate in 2023, we invite researchers, policymakers, agricultural planners, water resource managers, and the broader public to utilize this information for evidence-based decision-making. We hope that this document will contribute meaningfully to Ghana's resilience in the face of climate variability and change.

FOREWORD

Mr. Eric Asuman

I have witnessed the evolution of climate science from its early foundations in Research and applied meteorology to today's integration of observational networks, remote sensing, and numerical modeling. Throughout this journey, national climate reports like the State of the Climate in Ghana 2023 have remained the cornerstones of our scientific understanding. These reports provide the ground truth against which all other data sources and models must ultimately be validated.

Ghana's geographical position within the West African monsoon system places it at a fascinating climatological crossroads. The interplay between the Guinea Current, the seasonal migration of the Inter-Tropical Convergence Zone (ITCZ), and the complex topography creates a climate mosaic that demands meticulous documentation and analysis. This report admirably fulfills that requirement, offering a comprehensive assessment of temperature and precipitation patterns during 2023 across Ghana's diverse ecological zones.

The temperature analysis reveals patterns consistent with the climatological expectations but with notable deviations. While Navrongo maintained its characteristic high temperatures in line with its long-term mean, the slight warming observed in Abetifi (from 28.8°C to 29.1°C) and the increasing trend along the western coast and forest areas merit attention. Such micro-regional variations are precisely what comprehensive climate monitoring systems are designed to detect, allowing for targeted adaptation rather than one-size-fits-all approaches.

Particularly noteworthy is the positioning of 2023 as the 16th warmest year in the 42-year record (1981-2023), indicating that while not exceptional, the year continued the general warming trajectory evidenced by the positive slope of 0.042°C per year in the interannual temperature analysis. This places Ghana's temperature trends in harmony with the global warming signal, though with important regional characteristics that only local monitoring can reveal.

The precipitation patterns documented herein reflect the complex dynamics of Ghana's

rainfall regimes. The substantial spatial variability-from Axim's abundant 1896.2mm annual total to Tema's modest 713mm underscores the challenges of water resource management in a country with such diverse hydroclimatic conditions. The seasonal analyses of rainfall across the JFM, FMA, MAM, AMJ, and MJJ periods provide crucial insights into the timing and distribution of precipitation, information vital for agricultural planning in both the bimodal south and monomodal north.

The standardized anomaly analyses for temperature and precipitation allow us to contextualize 2023's climate within the longer-term climatological record. These anomalies reveal that while some areas experienced significant departures from normal conditions (such as surplus rainfall along the west coast), the overall climate pattern maintained its fundamental structure while showing the fingerprints of year-to-year variability and potential longer-term trends.

For policymakers and planners, this report offers invaluable guidance. The temperature and precipitation patterns documented here directly impact energy demand (for cooling), water availability for domestic and industrial use, agricultural productivity, and public health. The seasonal breakdowns provide sector-specific intelligence: agricultural planners can utilize the onset, dry spell, and cessation analyses for optimizing planting schedules; water resource managers can interpret the seasonal rainfall totals to anticipate reservoir inputs; energy planners can correlate temperature patterns with cooling demand.

What distinguishes this report is its attention to the climatological foundation (1991-2020) and the specific characteristics of 2023. This dual perspective allows readers to distinguish between the stable climate features upon which long-term planning should be based and the year-specific anomalies that require short-term adaptation measures.

As Ghana continues to develop its economy while facing the challenges of climate variability and change, documents like this State of the Climate report become increasingly valuable. They provide the evidence base for climate-smart development strategies, enabling Ghana to build resilience while pursuing its economic and social goals. I commend the Ghana Meteorological Agency for maintaining the observational infrastructure and analytical capabilities necessary to produce this comprehensive assessment and encourage all stakeholders to utilize this information in their decision-making processes.

In climate science, we often say that prediction is built upon understanding of the past.

This document contributes significantly to that understanding, establishing the foundation for improved climate services that will benefit all sectors of Ghanaian society.

SUMMARY

Mrs. Francisca Martey

The State of the Climate shows the climatology (1991-2020) average maximum temperature for Ghana where Navrongo and its surroundings in the Northern region experienced the highest temperatures in the country of about 35°C and above, while Abetifi in the eastern region has the lowest temperature (28.8°C) due to its higher elevation. In 2023, Navrongo maintained its temperature compared to its long-term average, while Abetifi experienced an increase in temperature of 29.1°C.

Overall, there was a constant maximum temperature in the northern regions and a slight increasing trend in the western coast and forest areas of Ghana.

March consistently records the highest temperatures ranging from 31°C to 39°C, while August has the lowest maximum temperatures between 27°C and 32°C. This seasonality pattern remains consistent in both the long-term climatology and the year 2023.Temperatures in Ghana have shown an increasing trend over the years, with a positive slope of 0.042 in the interannual analysis spanning from 1981 to 2023. The year 2021 had the highest temperature value of 45°C in Navrongo, ranking as the warmest year from 1981 to 2022. In comparison, 2023 was the 16th warmest year.

Annual minimum temperatures range from 20°C to 26°C, with cooler nights recorded in the mid-central and transitional savanna regions. Coastal regions and the eastern corridor tend to have warmer nighttime temperatures. The year 2023 exhibited a similar pattern to the long-term mean for minimum temperatures, but with slight warming in most areas, particularly along the eastern portions of the country. The coastal sector generally experiences relatively warm temperatures during the coolest months of January and December, while the northern sector records the lowest temperatures during these months. In 2023, the coolest months were warmer than the long-term mean. The analysis of extreme minimum and maximum temperatures in 2023 showed that the northern sector had the highest records, occurring in different months. The year 2023 ranked as the 16th warmest and the 43rd coolest year since 1981. The frequency of days with temperatures above certain thresholds (ranging from 28°C to 35°C during the day and 21°C to 25°C at night)

indicates an increasing trend in daytime temperatures and a decreasing trend in nighttime temperatures over the years. Ghana's average minimum and maximum temperatures are 22°C to 32°C respectively with long term mean annual rainfall between 700 mm and 2030 mm.

The climatological rainfall (1991-2020) shows varying rainfall patterns across the country. The west coast and forest zone received over 1500mm of rainfall annually, while the east coast and north experienced lower rainfall ranging between 700mm and 1000mm. Specific locations like Axim and Half Assini on the west coast received average annual rainfall of approximately 1800mm and 1900mm respectively. In 2023, there was surplus rainfall along the west coast, with Sefwi-Bekwai, Axim, Half Assini, and Salaga receiving high amounts of rainfall, while Accra and Tema on the east coast recorded lower amounts of rainfall. The western regions generally received higher annual rainfall exceeding 1700mm, while the forest zone experienced rainfall between 1000mm and 1800mm. The northern regions had relatively lower annual rainfall between 1000mm and 1400mm, with Salaga recording the highest amount of 2235.8mm. Among the 36 rainfall stations analyzed, Axim had the highest accumulated total rainfall of 1896.2mm, followed by Half-Assini with 1817.7mm, while Tema had the lowest amount of approximately 713mm.

In Ghana, the distribution of seasonal rainfall during JFM 2023 varied across different regions. The western coast and central areas received the highest amounts of rainfall, surpassing 200mm. Some regions north of the coast and parts of the forest zone also experienced rainfall exceeding 100mm, while the lowest seasonal rainfall of 3.1mm was observed in Wa in the northern region. An analysis of rainfall anomalies revealed that most parts of the country received normal rainfall, but there were significant increases in rainfall at stations like Accra, Half-Assini, Bechem, Bolga, Zuarungu, Navrongo, Sefwi Bekwai, and Sunyani compared to their long-term averages, resulting in above-normal precipitation. However, the eastern flanks and western northern areas experienced normal to below-normal (deficit) rainfall, with noticeable decreases in precipitation at stations like Saltpond, Akuse, Goaso, Kpando, Prang, Walewale, and Wa compared to their long-term averages.

The climatology rainfall (1991-2020) for FMA season showed higher rainfall in the forested areas along the southwestern coast, exceeding 500mm on average. Rainfall decreased towards the north, with values below 500mm. In FMA 2023, the forest areas and southwestern coast had rainfall totals above 350.1mm, Coastal, transitional, and north

western regions received rainfall ranging from 180mm to 260mm, while the northeast portions had the lowest seasonal rainfall below 100mm. The rainfall anomaly analysis indicated above-normal rainfall in most parts of the country, but below-average rainfall in certain stations like Yendi and Saltpond. The average number of rainy days during the FMA season was higher in the southern parts compared to the north, with over 25 rainy days on average in southern stations. In FMA 2023, more stations in the southern parts had over 20 rainy days, while areas in the transition zone towards the north had fewer than 20 rainy days. The rainy days anomaly analysis revealed above-normal rainy days in many stations, including Abetifi and Koforidua, but a decrease in rainfall occurrences in Kpando and Salaga.

The climatology (1991-2020) for the MAM season shows that the southwestern portion of the country received higher rainfall, while the northeast had the least amount of rainfall. The south-western areas experienced average rainfall above 500mm, while the east coast, transitional zone, and northern regions received less than 400mm on average. In MAM 2023, stations in the forest zone recorded rainfall ranging from 500mm to slightly over 600mm, while the coast and other forest areas had below 500mm. The highest rainfall was recorded in Sefwi Bekwai with 649.1mm, while the north had below 350mm, with Yendi and Navrongo recording the lowest values. The rainfall anomaly analysis indicated above-normal rainfall in stations like Tema, Akatsi, Kumasi, and Tamale, while deficit rainfall was observed in stations such as Axim, Takoradi, and Yendi. The average number of rainy days during the MAM season was highest in the forest and coastal areas, ranging from 25 to 45 days, while the north and transitional zones had fewer than 25 days. The rainy days analysis for MAM 2023 showed a similar pattern, with the forest and coast having the highest number of rainy days, and the north and transitional zones having fewer days. The rainy days anomaly analysis revealed below-normal rainy days for most stations, with a decrease in rainy days in stations like Akim Oda, Kpando, and Salaga, but an increase in stations like Kumasi and Ho.

The AMJ climatology analysis showed that the extreme northern region received an average rainfall of 280-400 mm, while the forest zone, transition zone, and east coast had rainfall ranging from 500-700

mm. In 2023, the extreme north experienced decreased rainfall of 200-300 mm, with Navrongo having a 21% reduction compared to its long-term average. Stations like Half-

Assini and Axim recorded the highest rainfall amounts. Rainfall anomalies indicated deficits in some stations, including Goaso, Dormaa Ahenkro, Yendi, Navrongo, and Bole, while others like Sefwi-Bekwai, Axim, Akim Oda, Kpando, Akuse, Akatsi, and Tema had surplus rainfall. The average number of rainy days ranged from 20-26 in the north and some parts of the transition zone, while the south and other parts of the transition zone experienced 32-56 rainy days. Axim had the highest number of rainy days with an average of 56. In 2023, the northern and transition zones had 20-26 rainy days, while the southern and some northern areas had 31-51 rainy days. The standardized anomaly for rainy days indicated deficits in the north, transition zone, forest, and southwestern coast, while areas like Sefwi-Bekwai, Wa, Bolga, Tamale, and the east coast had surplus rainy days. Wenchi, Walewale, Kpando, and Kade had normal rainy days compared to their long-term averages.

The climatology analysis of the MJJ season reveals that the southwestern portion and some areas in the transition zone received over 500mm of rainfall, while the rest of the country experienced rainfall between 300mm and 500mm. In 2023, the total seasonal rainfall showed high amounts across most parts of the country, with the southwestern portions and eastern areas receiving rainfall above their long-term means. The rainfall anomaly distribution indicated normal to above-normal rains in stations such as Axim, Akim Oda, Takoradi, Ho, Salaga, Tamale, Wa, Kpando, Sefwi Bekwai, and Prang, while below-normal rains were observed in Bole, Navrongo, Bolga, Zuarungu, Dorma Ahenkro, Bechem, Goaso, Abetifi, Cape Coast, and Asamankese. Some stations experienced a significant increase in rainfall compared to their long-term means, while others had a decrease. The average rainy days for the MJJ season in Ghana showed that stations in the forest zone had above 40 rainy days. The coastal region and the northern part of the country generally received 35 and below rainy days. In 2023, most stations in the forest zone experienced 40 to about 63 rainy days, with Axim and Sefwi Bekwai having the highest number of rainy days. The north, forest, and coastal zones had varying levels of changes in the number of rainy days compared to their long-term means.

The JJA climatology (1991 - 2020) shows that the southwestern and northern regions received the highest rainfall, ranging from 500mm to 700mm. The transition zone had lower average rainfall, with the middle and eastern portions receiving about 300mm and 500mm, respectively. In 2023, the highest seasonal rainfall occurred in the western coast and eastern parts of the country, exceeding 900mm. Some stations in the forest zone also

had rainfall above 300mm, while the northern sector mostly experienced rainfall above 500mm. The rainfall analyses indicated above-normal rainfall for most of the country, with below-normal rainfall in Bole, Wenchi, Bolga, and Zuarungu. Axim, Half Assini, Sefwi Bekwai, and Salaga had particularly high above-normal rainfall. Most stations experienced an increase in rainfall compared to the long-term mean, except for Wenchi, which had a decrease of 10%. Axim, Half Assini, Salaga, and Takoradi had significant increases ranging from 48% to 125%. In terms of rainy days, most stations in the northern and forest zones, as well as Kete Krachi and Wenchi, had more than 40 rainy days, while areas in the transition zone and southeastern portions of the country had fewer than 40 rainy days. Rainy day anomalies were mostly well above-normal, except for Navrongo, Bolga, and Zuarungu, which had normal rainfall occurrences. In 2023, Sefwi Bekwai and Axim had notable increases in rainy days, while Zuarungu, Salaga, Bechem, and Akuse experienced decreases compared to their long-term means.

The climatology (1991 to 2020) analysis for the JAS season shows that the northern parts of the country receive higher rainfall, exceeding 500mm, while the coastal and forest areas have lower average rainfall below 500mm. In 2023, the northern regions and the transition zone experienced rainfall above 500mm, with Salaga recording the highest rainfall of 1078.3mm. The forest and coastal areas had rainfall below 500mm, except for a few stations. Rainfall anomalies indicated above-normal rainfall in most parts of the country, including Salaga, Cape Coast, and Accra. Some stations experienced decreases in rainfall compared to their long-term means, such as Dormaa, Sunyani, and Bolga. The average number of rainy days during the JAS season was higher in the northern regions and some parts of the south, with over 40 rainy days. However, the transition zone and southeastern areas had fewer than 40 rainy days. Rainy day anomalies showed above-normal rainfall in most areas, with stations like Sefwi Bekwai, Akim Oda,and Axim experiencing increases in rainy days. Some stations, including Bolga, Zuarungu, and Sunyani, had below-normal rainy days compared to their long-term means.

ASO climatology (1991 to 2020), Ghana experienced higher rainfall in the northern regions, transition zone, and forests ranging from 200mm to 600mm. Coastal areas received less rainfall below 200mm. In 2023, most stations, including coastal areas, had above-average rainfall during the ASO season. Stations like Cape Coast, Atebubu, Prang,

Kete Krachi, Salaga, Bole, Wa, and Navrongo reported rainfall exceeding 600mm, with Salaga receiving the highest amount of 1250.2mm, a significant increase compared to the long-term average. Stations such as Salaga, Accra, Tema, Cape Coast, Bole, Navrongo, and Atebubu experienced above-normal rainfall in 2023, while below-normal rainfall was observed in stations like Bolga, Tamale, Wenchi, Dormaa, Goaso, Ho, Koforidua, and Asamankese. The number of rainy days averaged over 25 for most parts of the country during the ASO season, with over 30 rainy days in the northern zone, transition zone, forests, and western coast. However, some stations recorded fewer than 30 average rainy days. In 2023, the number of rainy days varied across the country, ranging from 22 to 63 days. The northern parts generally had more rainy days than the southern parts, experiencing over 35 rainy days. An analysis of rainy-day anomalies in 2023 compared to the LTM revealed above-normal rainy days in stations such as Tema, Cape Coast, Saltpond, Axim, Takoradi, Kete Krachi, Wa, and Tamale, with significant percentage increases. Stations like Zuarungu, Yendi, Salaga, Wenchi, Atebubu, Kade, and Kpando experienced below-normal rainy days, with a decrease in the number of rainy days. Navrongo and Koforidua had rainy days within the normal range.

From 1991 to 2020, Ghana's SON season had lower rainfall in the northern and coastal regions, while the middle and transition zones experienced moderate rainfall. Tamale had the highest average rainfall, while Tema had the lowest. In SON 2023, there was an overall increase in rainfall, particularly in the middle and transition zones. Salaga received the highest amount of rainfall, followed by Atebubu, Kintampo, and Prang. However, some areas like Zuarungu, Walewale, Bolga, Dormaa Ahenkro, and Akatsi had lower rainfall. Anomaly analysis revealed significant increases in rainfall for Accra and Cape Coast, Wa, Bole, Damango, Salaga, and Saltpond experienced varying degrees of rainfall deficits. Dormaa Ahenkro, Walewale, Zuarungu, Half-Assini, and Tamale also had below-normal rainfall. The average number of rainy days in the SON season ranged from 20 to 45 days, with Axim, Accra, Kade, and Salaga having more rainy days. Wa had the fewest rainy days. In SON 2023, rainy days ranged from 30 to 61 days, with Bui and Axim recording the highest numbers. Babile, Dormaa Ahenkro, Navrongo, and Zuarungu had the fewest rainy days. Anomaly analysis for rainy days indicated above- normal values for Accra, Axim, Bui, Sefwi-Bekwai, and Wa. Atebubu, Dormaa Ahenkro, Kpando, Mim, Navrongo, Salaga, Tema, and Zuarungu had below-normal rainy days. Several stations recorded normal rainy days compared to their long-term averages. Climatological data from 1991-2020 shows that areas in the forest region and western middle portion of the country have

the shortest Early Dry Spells, averaging seven days, while the northern part of the country experiences longer dry spells, averaging more than ten days. In 2023, Kumasi, Sefwi Bekwai, and Dunkwa had significantly shorter spells compared to their climatological averages, while Kade and Axim had the longest spells of 16 days. Most places in Northern Ghana showed slightly shorter spells than their climatological averages, except for Wa and Salaga, which had slightly longer dry spells of 12 days each in 2023.

Climatological data (1991-2020) shows that most of Ghana experiences average late dry spells of 9 to 14 days, but some areas like Ada, Bimbila, Bui, Prang, and Sefwi Bekwai have longer spells of 15 to 17 days. In 2023, Takoradi and Walewale had the shortest dry spells of 4 days, which were below their long-term averages. Overall, the late dry spells in 2023 were generally shorter compared to the long- term average.

Rainfall cessation in Ghana typically starts in the north and moves south, as observed in the long-term analysis from 1991-2020 and during the 2023 season. In 2023, there was early cessation in the upper east and west regions, while Tamale and surrounding areas experienced late cessation. The cessation dates in 2023 were slightly later than the climatological dates, ranging from the 1st to 4th weeks of October. The central region to the Volta regions had early cessations, but Accra had an extremely late cessation in November. Some coastal areas also had late cessation in 2023.

CHAPTER 1: INTRODUCTION

The Ghana Meteorological Agency (GMet) is responsible for monitoring and providing weather and climate information to support decision-making processes in various sectors. Ghana is prone to both riverine and urban floods, which are often triggered by heavy rainfall, inadequate drainage systems, rapid urbanization, and poor land use practices. Flooding can lead to loss of life, displacement of communities, damage to infrastructure, disruption of socioeconomic activities, and the spread of waterborne diseases. Drought is a recurrent natural hazard in Ghana that can have severe impacts on agriculture, water resources, livelihoods, and overall economic development.

GMet utilizes advanced technologies, including weather satellites, radar systems, and weather models, to monitor weather conditions and issue forecasts. These forecasts provide critical information about the likelihood of heavy rainfall, storm systems, or other weather events that could contribute to flooding. In recent years, efforts have been made to enhance early warning systems in Ghana to mitigate the impacts of floods. Meteorological agencies work in collaboration with disaster management authorities to disseminate timely and accurate weather information to communities at risk. This allows for proactive measures such as evacuation, emergency preparedness, and resource allocation to be implemented.

Meteorology plays a vital role in understanding and predicting weather patterns, including the occurrence of floods in Ghana. Floods can have devastating impacts on communities, infrastructure, and the economy. Meteorology, the study of the Earth's atmosphere, and agriculture, the cultivation of food and other products, may seem disparate at first glance. Meteorology and agriculture share an intimate connection, one that has evolved over centuries into a vital partnership. Meteorological data offers crucial insights into temperature, precipitation, and humidity—factors that significantly influence farming decisions.

Climate is expected to impact Ghana's weather patterns, potentially leading to more frequent and intense rainfall events. Meteorologists and climate scientists' study long-term climate trends to understand how climate change may influence the occurrence and severity of floods in the country. This information is crucial for developing adaptation strategies and implementing climate-resilient infrastructure.

It's important to note that while meteorology provides valuable tools for flood prediction and mitigation, addressing the underlying causes of floods, such as urban planning,

infrastructure development, and environmental management, is also crucial in reducing the vulnerability of communities to flooding in Ghana. The impact of climate especially on life and property still continuous on an increasing trend hence placing additional burden on poverty alleviation efforts thereby significantly hampering growth in prosperity.

The State of the Climate in Ghana report is to inform the Government on a regular basis hence provide critical science-based information for climate policy and decision-making about the status of the climate and its associated annual variability. The climate of Ghana in time and space, like any region in parts of the tropics, is prone to extreme climatic episodes such as frequent floods and recurring rainfall variability. Ghana's weather and climate are changing in response to global warming that is currently being experienced globally (IPCC, 2013). To deal with this, proper adaptation and mitigation measures should be put in place to cushion the population against the current and future negative climate change impacts.

Ghana is located between latitude 4'N to 120'N and longitude 1.5'E to 3.5'W in West Africa with a monsoonal climate dominated by wet and dry seasons. The Northern sector of the country experiences unimodal rainfall (April to October) whilst the Southern sector experiences bimodal; Major rainy season (March to July) and Minor season (September to November). The month of August experience a break in the rainy season for the south known as the little dry season. The dry season referred to as Harmattan occurs from December to February and is mainly dominated by dry north easterly winds which carries dust into the country, hence affecting visibility. The main weather phenomena are rainfall, fog, mist, haze, thunderstorm, lightning, gusty winds, hail and the climate phenomena includes floods, drought, high temperatures and coastal inundation. The forecast of rains and its performance are of great significance to the agricultural sector as well as to the overall performance of the economy. The annual north and south migration of the overhead sun across the equator, which influences the position of the Inter-Tropical Convergence Zone (ITCZ), is the main driver of weather in Ghana. Seasonal forecasts are valuable for energy planning and management. For instance, in Ghana, where hydroelectric power generation is significant, forecasts predicting above-average or below-average rainfall can help energy companies estimate water availability for hydropower generation and plan alternative power sources accordingly. This information allows for efficient energy resource allocation and helps mitigate potential power shortages or surpluses.

CHAPTER 2:
TEMPERATURE

2.1 Maximum Temperature

Analysis of the annual mean (i.e., climatology (1991 – 2020)) maximum temperature (i.e., daytime temperature) reveals that Navrongo and its environs in the upper east region of the country is characterized by warmer conditions with values above 35°C hence the hottest and warmest region of the country (Figure1(a)). The area with the lowest climatological record is Abetifi and its environs in the eastern region with record value of 28.8°C. This is mainly due to its relatively high elevation.

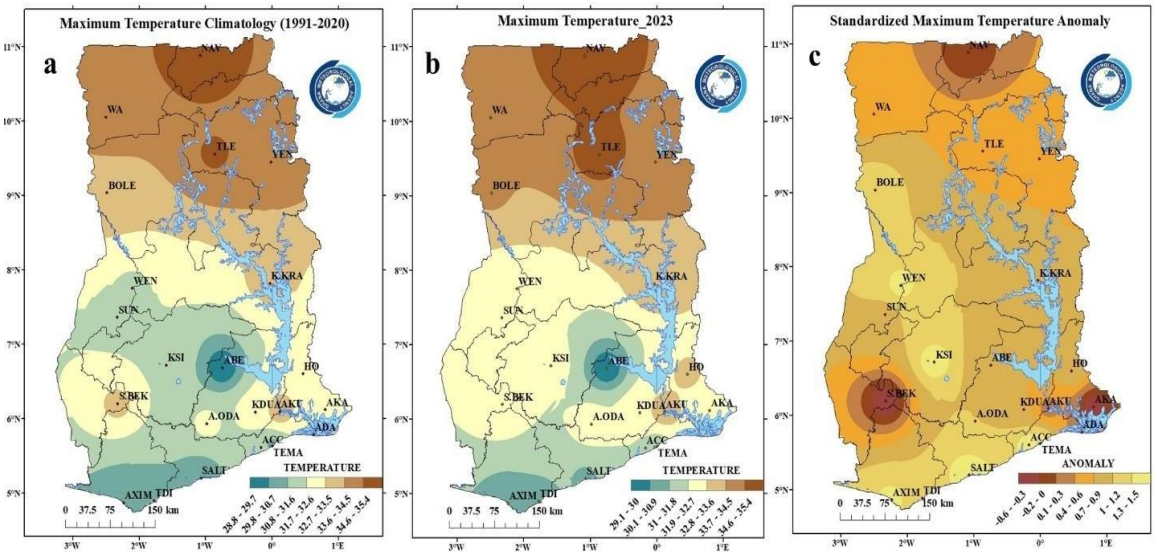


Figure 1(a) Climatology , (b) 2023 Maximum Temperature and (c) Standardized Anomaly

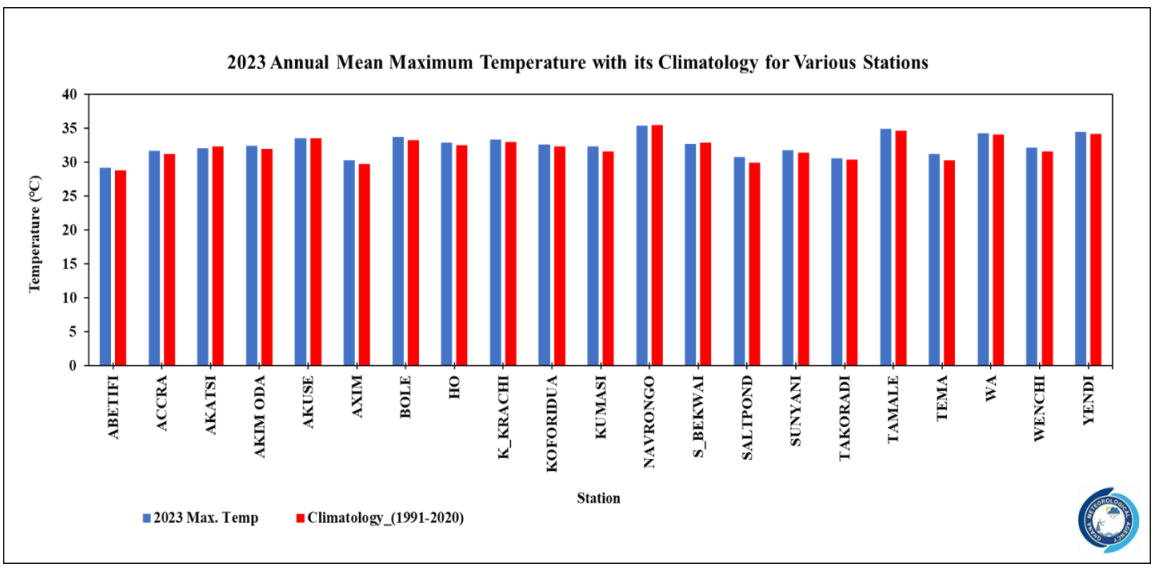


Figure 2: Climatology (1991 - 2020) and 2023 Maximum Temperature

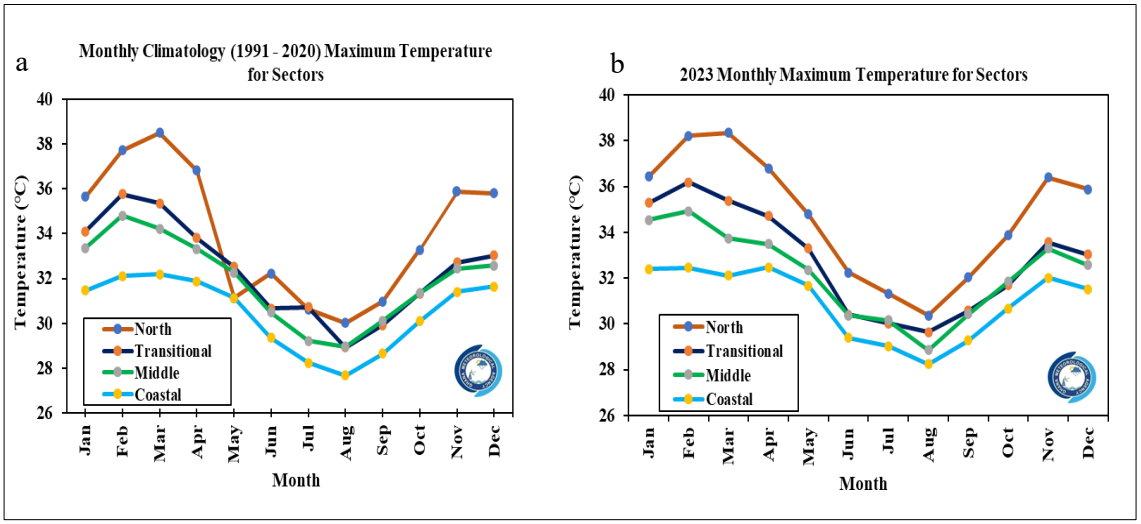


Figure 3: (a)Monthly climatology across sectors and (b) Monthly maximum temperature across sectors for 2023

According to the data for 2023, in Figure 2.1 and figure 2.2, Navrongo exhibited the same temperature value as its LTM. Abetifi which is characterized by relatively cool temperature due to its altitude, experienced a slight increase (29.1°C) as shown in Figure 2.2. The 2023 standardized maximum temperature anomaly in general revealed slight increasing trend over the northern portions of the country and slight decreasing trend from the western coast and few places in the forest areas of Ghana. Analysis of the average maximum temperature over the northern sector of the country indicates that, parts of the country recorded the highest maximum temperature. Generally, across all the sectors, the month of March recorded the highest temperatures ranging between **31°C** and **39°C** whilst August recorded the lowest maximum temperatures between **27°C** and **32°C** based on the recent climatological data (1991 -2020) as shown in figure 3(a). A similar characteristic was experienced in the year 2023. However, the range between both hottest and coolest months reduced. March recorded temperatures between **32°C** and **39°C** whereas August also had temperatures ranging between **28°C** and **31°C** as seen in figure 3(b).

2.2 Highest Recorded Temperature

Temperature record over Ghana generally depicts an increasing trend according to an interannual analysis of the standardized anomaly, which spans from 1981 – 2023 as shown in (Figure 2.4)

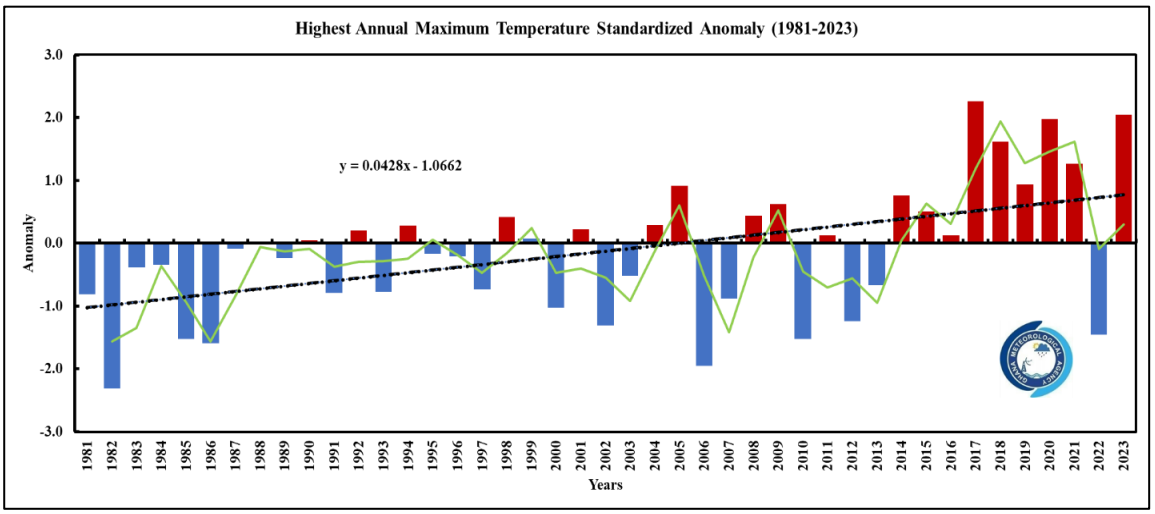


Figure .4 Highest Annual Minimum Temperature Anomaly over Ghana

A positive slope of 0.042 confirms the general warming trend observed across the globe. In a further analysis, a two-year moving average (green line) was overlayed on the interannual variability, and this revealed an increasing trend and the seasonality within a period from 19812023. An annual ranking showed that the year with the highest temperature within the period was 2021 with value of **45°C** specifically over Navrongo. The year 2023 was ranked 16th warmest comparably (Figure 5).

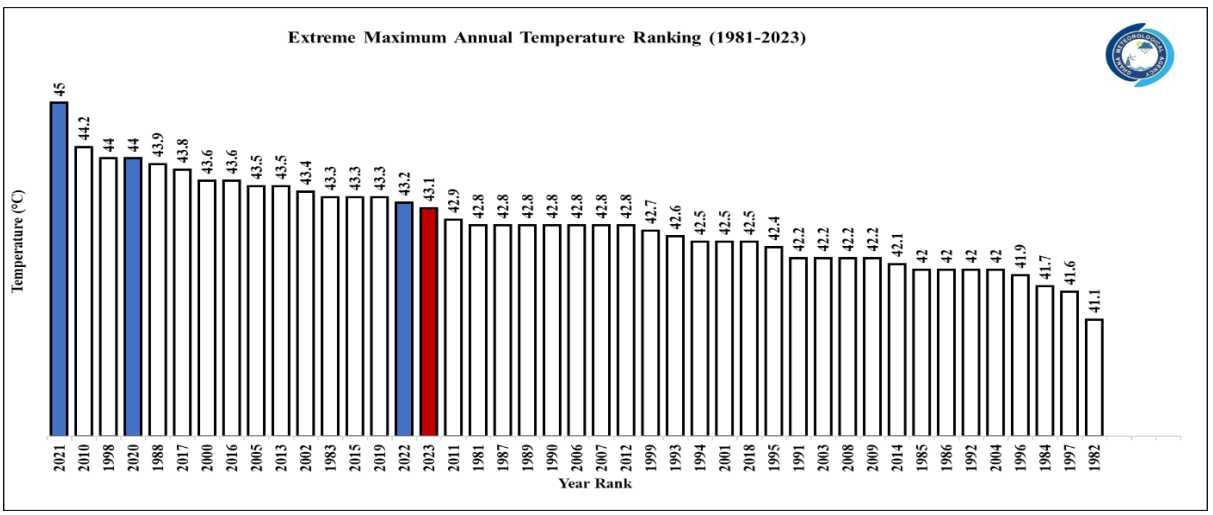


Figure 5 Ranking of Highest Annual Maximum Temperatures

2.3 Minimum Temperature

The long term (1991 – 2020) annual minimum temperature in Ghana ranges from **21°C** to **26°C** as shown in figure 6(a). From the analysis, minimum of the minimum temperatures is mostly recorded over places in the eastern region of the country stretching to the western part of the transitional zone (savanna region) whilst the remaining regions remain warm especially along the coastal regions and the eastern corridors.

The minimum temperatures for the year 2023 in figure 6(b) exhibited a similar pattern as the long-term mean. However, there was slight warming over most places comparably, especially along the eastern portions of the country. The standardized anomaly (Figure 6(c)) revealed specific areas of deficits and above normal in detail.

The monthly minimum temperature as shown in figure 8 (a) indicates that lowest minimum temperatures in January and December. The northern sector records the least temperature during these months per the records. On the contrary, the coastal sector records relatively warm temperatures climatologically. In the year 2023 (Figure 8(b)) the coolest months identified were observed to be above its long-term mean (LTM), a situation indicating that 2023 had warmer night temperature.

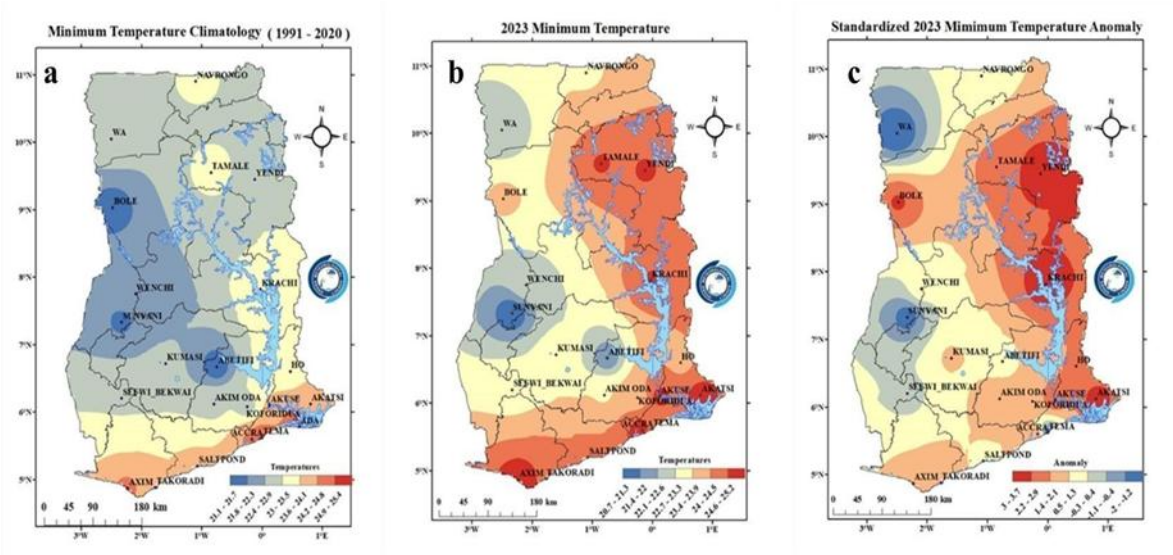


Figure 6(a) Climatology, (b) 2023 Minimum Temperature and (c) Standardized Anomaly

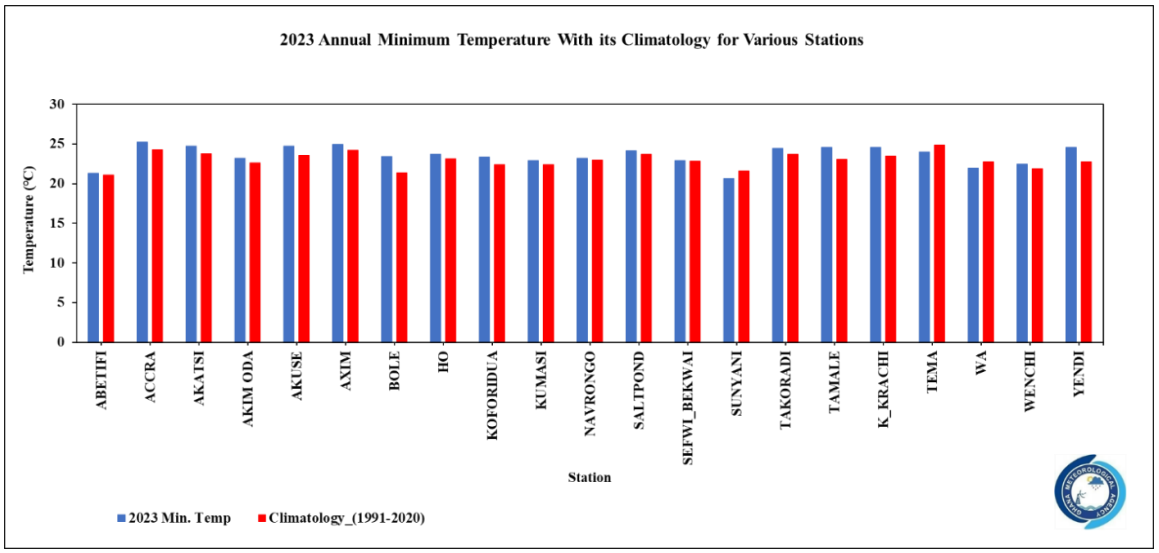


Figure 7 Climatology of Minimum Temperature and 2023 Minimum Temperature

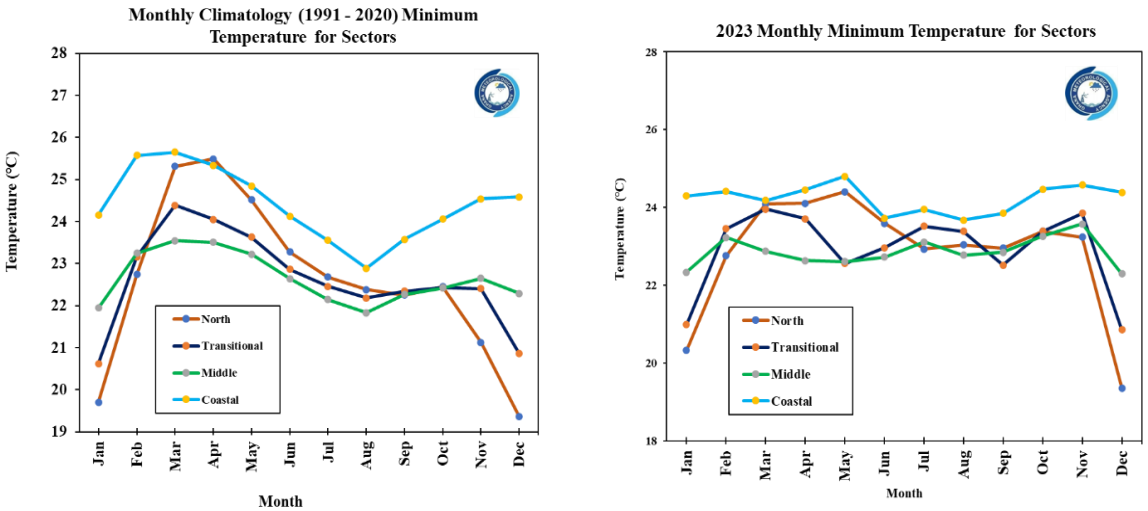


Figure 8: (a) Monthly climatology and (b) Monthly minimum temperature across sectors for 2022

2.4 Lowest Recorded Temperature

A rank of the lowest annual temperature from 1981 to 2023 showed that 1982 and 2023 ranked first and second respectively. In general, a standardized anomaly indicates a warming trend with a positive gradient of 0.0428. A two-year moving average overlay conforms with a uniform increasing pattern.

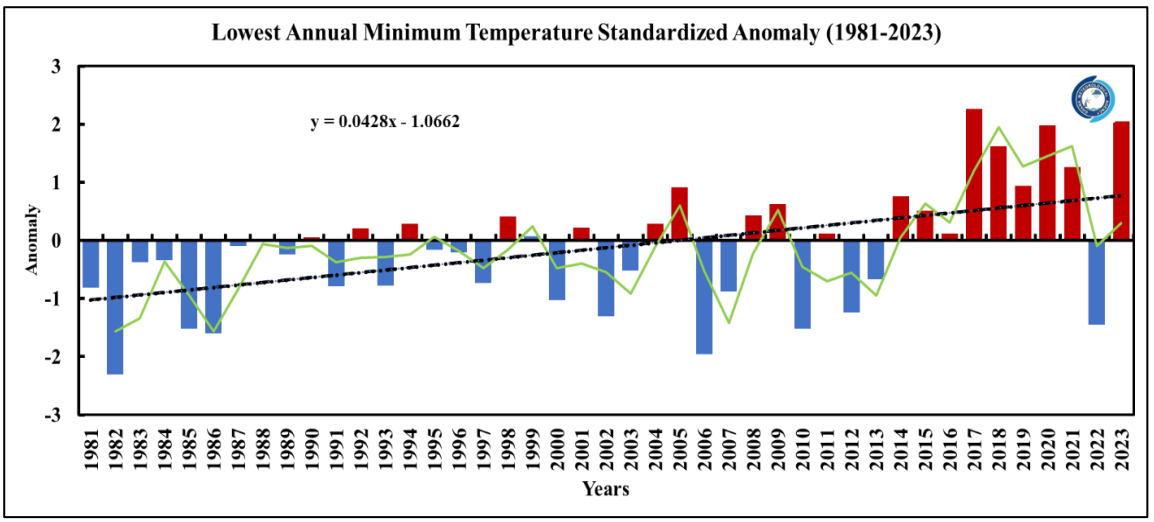


Figure 9 Lowest Annual Minimum Temperature Anomaly from 1981 to 2023

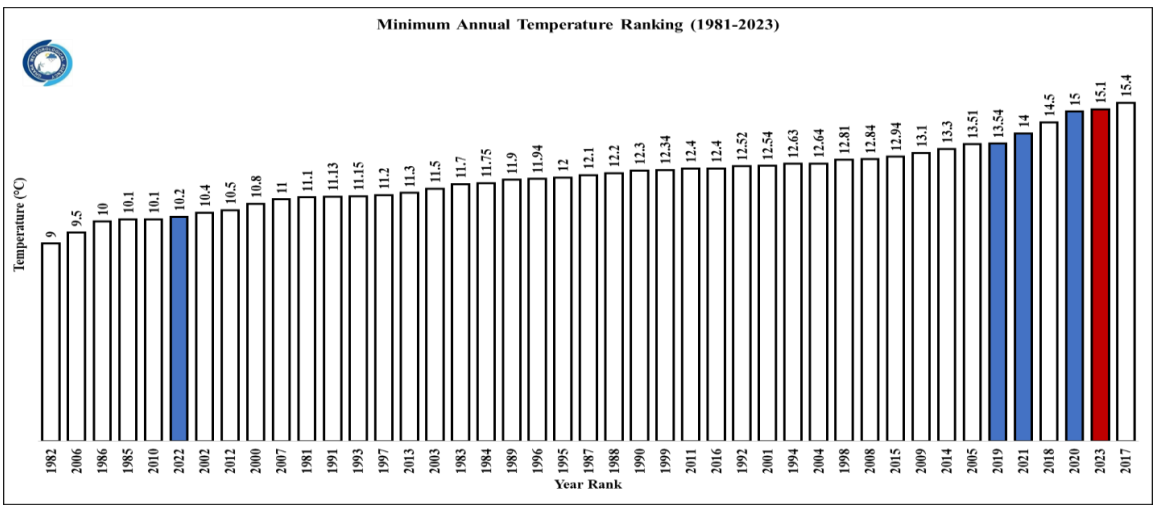


Figure 10 Ranking of Annual Minimum Temperature over Ghana from 1981 to 2023

2.5 Extreme Maximum and Minimum Temperature for 2023

In 2023, the sector with the extreme minimum and maximum temperatures was recorded over the northern sector. Although these records occurred in different months, the extreme maximum specifically occurred over upper east whilst that of the minimum occurred in upper west. In reference to the climatology, the year 2023 was ranked the 16th warmest since 1981 and when it comes to the coolest ranked year, the year 2023 was also ranked 43rd in position.

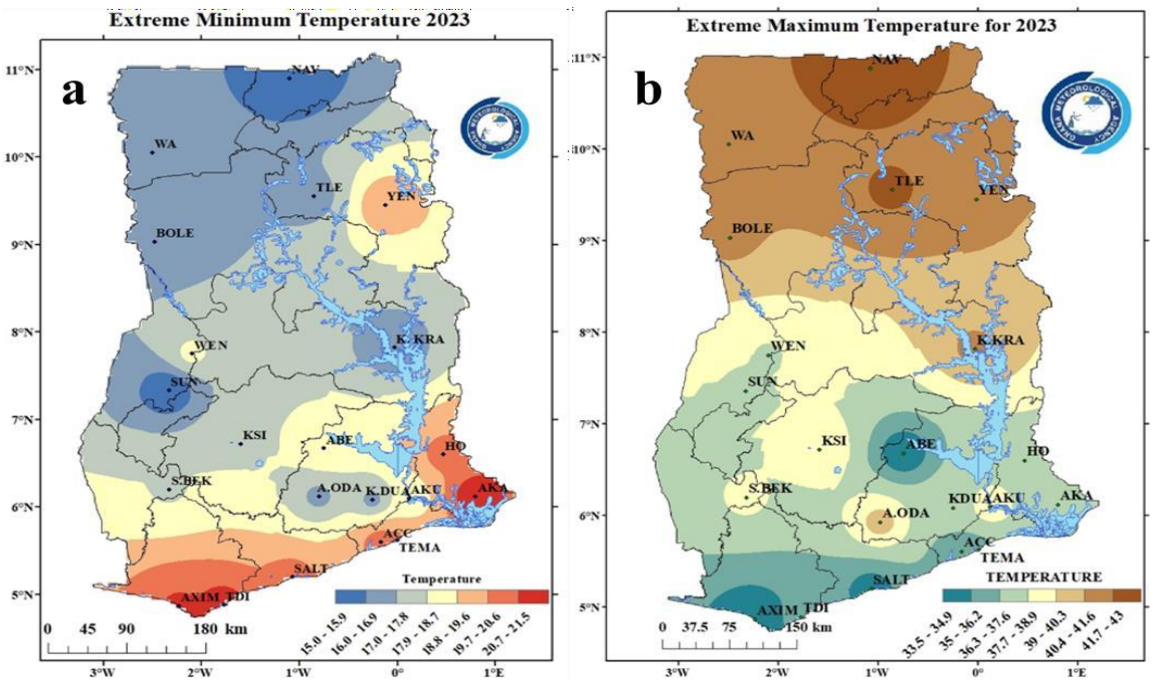


Figure 11Extreme (a) Minimum and (b) Maximum Temperature in 2023

2.5.1 10th Percentile of Minimum and 90th Percentile Maximum Temperatures

In describing the 10th and the 90th percentile of temperature over the country, the frequency of days when temperatures were above certain climatological (1991 -2020) thresholds was analysed. Thresholds during the day ranged between **28°C** and **35°C** whilst for night-time was **21°C** and **25°C**. The daytime temperatures with threshold values of respective locations were recorded and results showed that daytime temperatures are increasing over the years whilst the night-time temperatures are decreasing; thus, becoming warmer during the day and during the night.

CHAPTER 3:
PRECIPITATION

3.1 Annual Total Rainfall

The climatological rainfall map for Ghana from 1991-2020 depicts; the west coast and the forest zone received rainfall amount of over **1500mm** while the east coast and the north received relatively less rainfall, ranging between **700mm-1000mm**. Axim and Half Assini, around the west coast, received an annual average rainfall of about 1800mm and 1900mm respectively (Figure 12(a)). The year 2023 experienced surplus Annual rainfall around the west coast Sefwi-Bekwai (**1904.1mm**), Axim (**2349.4mm**), Half Assini (**2038.3mm**) and Salaga (**2235.8mm**) whilst the extreme portions of the east coast, specifically Accra and Tema recorded **1116.4mm** and **997.5mm** respectively. Higher annual values of over **1700 mm** were recorded around the western portions of the country, whilst most parts of the forest zone received annual rainfall values between **1000mm to 1800mm**. The extreme northern portions received relatively low annual total values between **1000mm to 1400mm** with Salaga recording the highest of **2235.8mm**

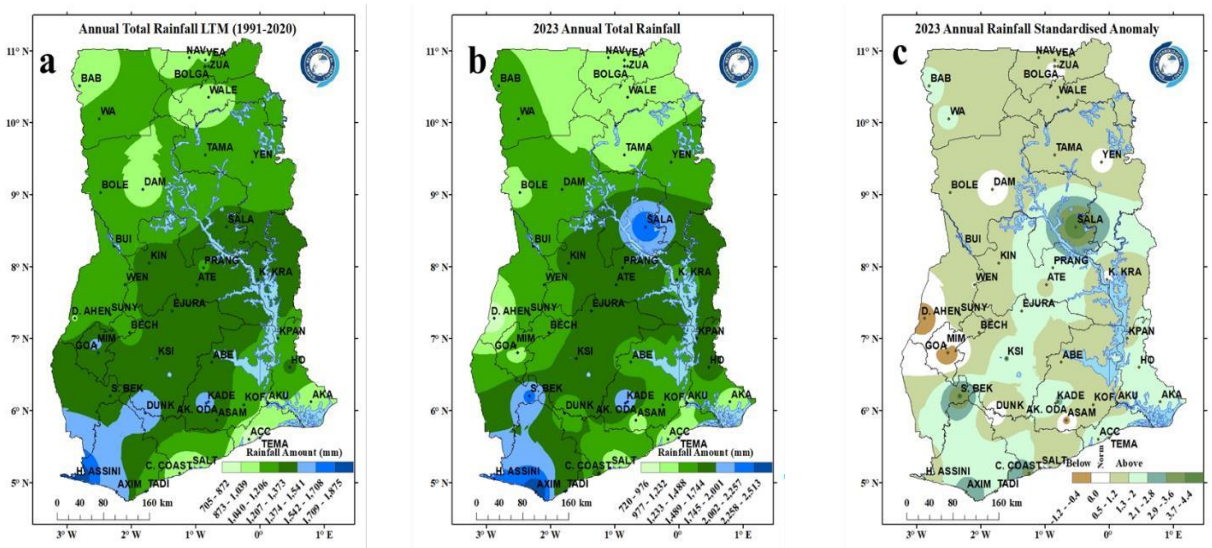


Figure 12(a) LTM Rainfall, (b) Total Rainfall, 2023 and (c) Rainfall Standardized Anomaly

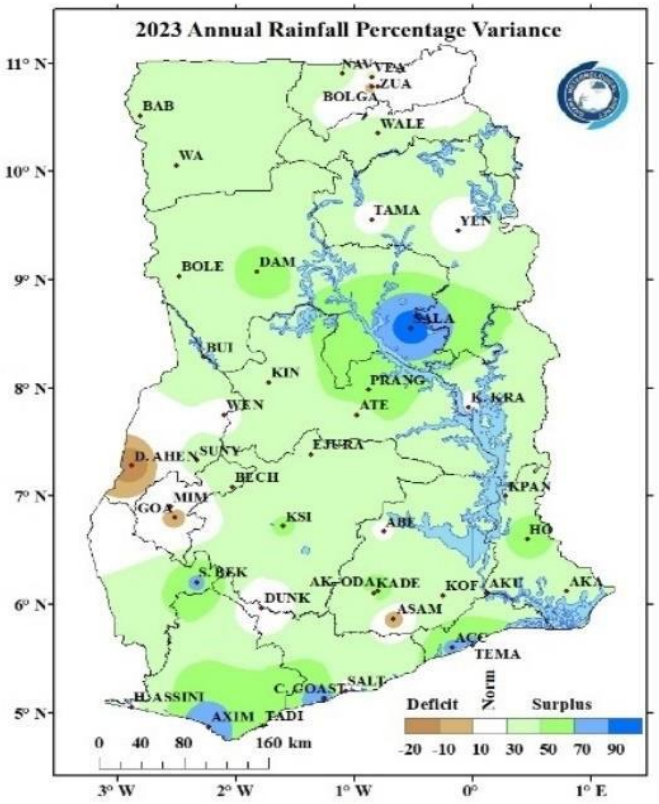


Figure 13 Percentage Variance for 2023 Annual Total Rainfall

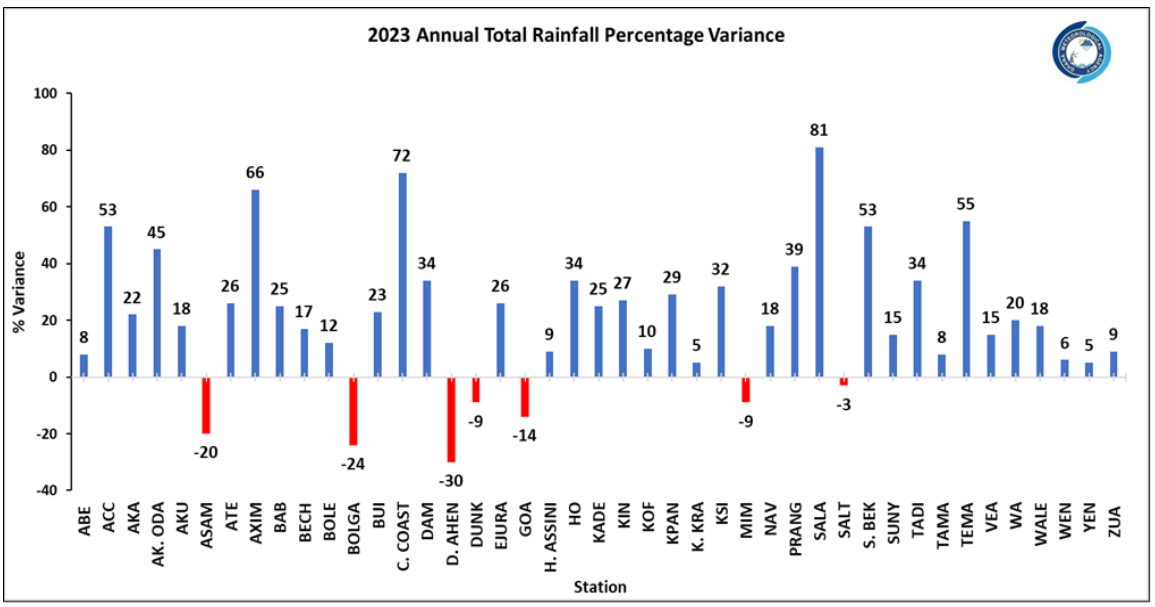


Figure 14 Percentage Variance for 2023 Annual Total Rainfall

3.2 Annual Total Rainfall Ranking

Out of the 36 rainfall stations used to compute this analysis, an annual accumulated total rainfall climatology from 1991 to 2020 was ranked and the result indicated that Axim recorded the highest amount of 1896.2mm followed by Half-Assini with 1817.7mm (Figure 15). Both stations are located near the western coastline. Tema had the lowest amount of about 713mm

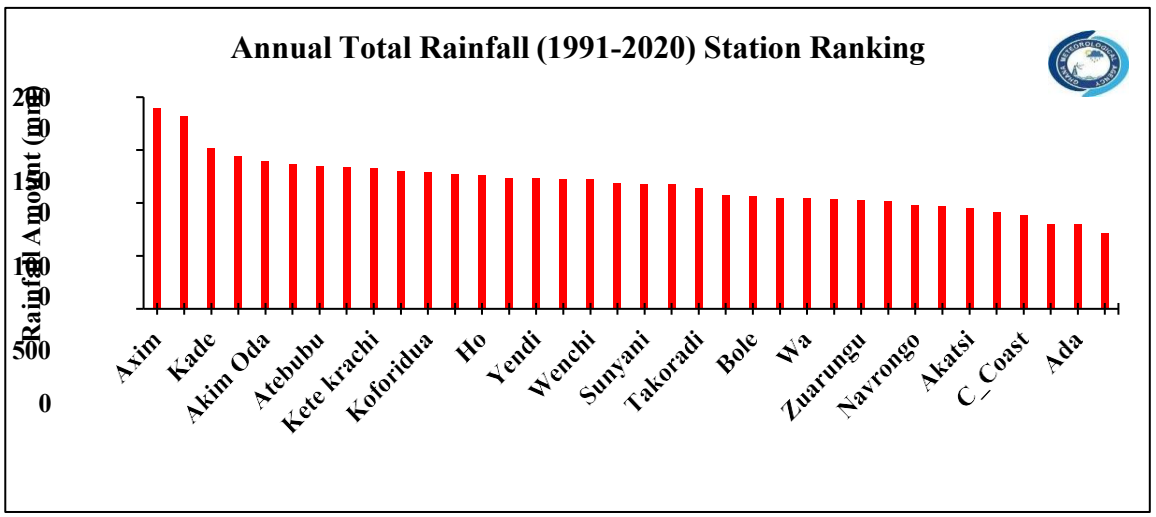


Figure 15 : LTM Annual total rainfall station ranking.

3.3 Total Rainfall Station Ranking 2023

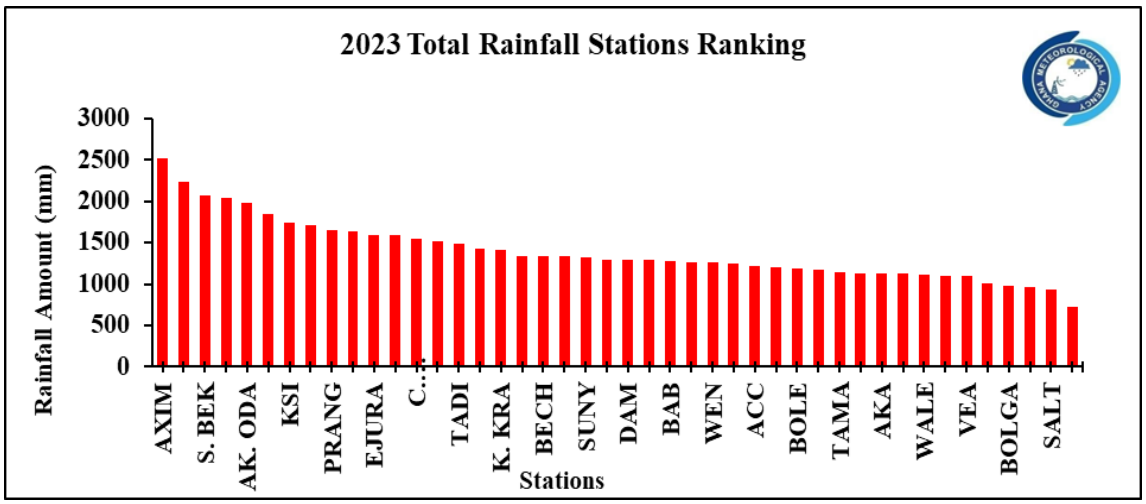


Figure 16 Total Rainfall station ranking 2023

3.4 Seasonal Total Rainfall, Rainy Days and Standardized Anomaly

3.4.1 JFM Total Rainfall

The climatology map for JFM (1991-2020) rainfall (Figure 17 (a)) shows that the south-western portion of the country recorded the highest amount of rainfall. The amount of the rains however reduced towards the north, with the least seasonal averages occurring over the north-eastern portion. The south-western and areas in the middle sector experienced LTM seasonal rainfall ranging from 120 to 250mm. The transition and the northern zones on the other hand received LTM seasonal values of about 70mm and 30mm respectively

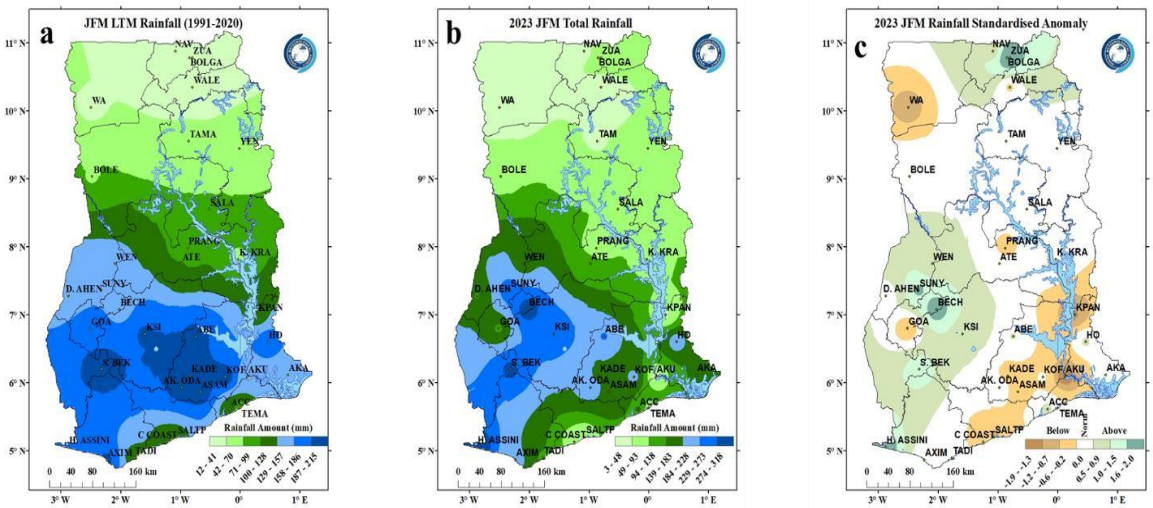


Figure 17 :(a) JFM LTM Rainfall, (b) JFM Total Rainfall, 2023 and (c) JFM Standardized Anomaly

The total seasonal rainfall for JFM 2023 is shown in figure 17(b) above. The western portions of the coast and middle sectors of the country recorded the highest rainfall amounts of over 200mm. Bechem, Half Assini, and Sefwi-Bekwai recorded seasonal totals of 305.3mm, 318.4mm and 283mm respectively. Few stations slightly north of the coast and some parts of the forest zone also experienced values above 100mm, whilst the least seasonal value was 3.1mm at Wa in the north.

The rainfall anomaly (Figure 17 (c)) within the JFM season revealed normal rains over most parts of the country. However, there were significant increase in rainfall amount over stations such as, Accra (37%), Half-Assini (89%), Bechem (110%), Bolga (260%), Zuarungu (277%), Navrongo (65%), Sefwi Bekwai (35%) and Sunyani (65%) as compared to their LTM causing above normal rains over the period. The eastern flanks and the western north portions recorded normal to below normal (deficit) rains, with significant decrease in rainfall amount over, Saltpond (53%), Akuse (73%), Goaso (27%), Kpando (60%), Prang (26%), Walewale (39%) and Wa (92%) as compared to their LTM.

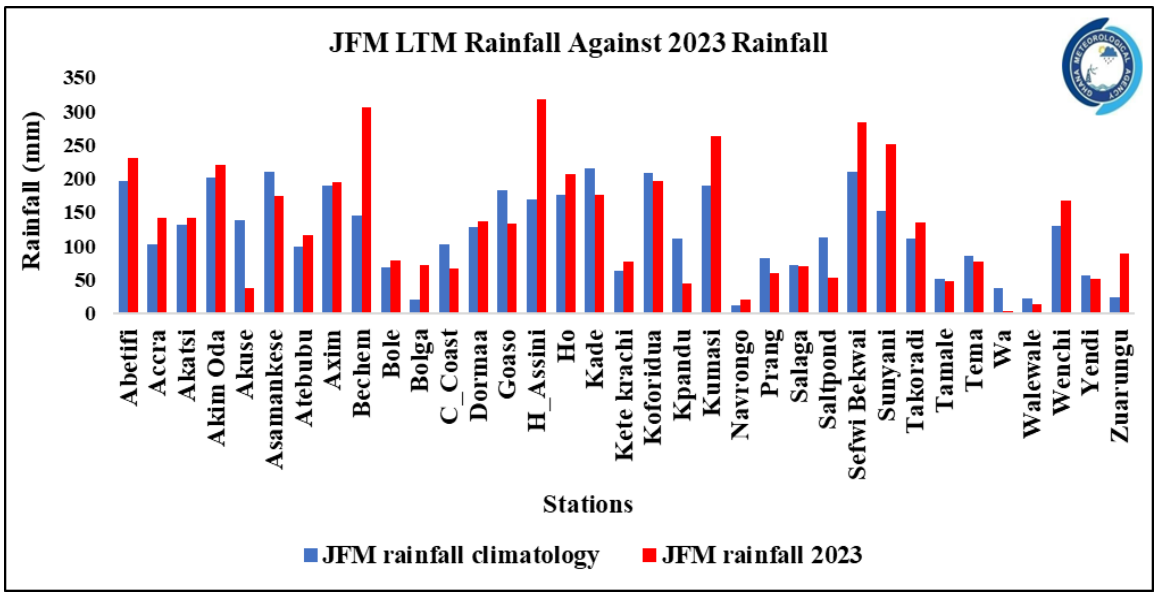


Figure 18 JFM LTM Rainfall Against Total Rainfall, 2023

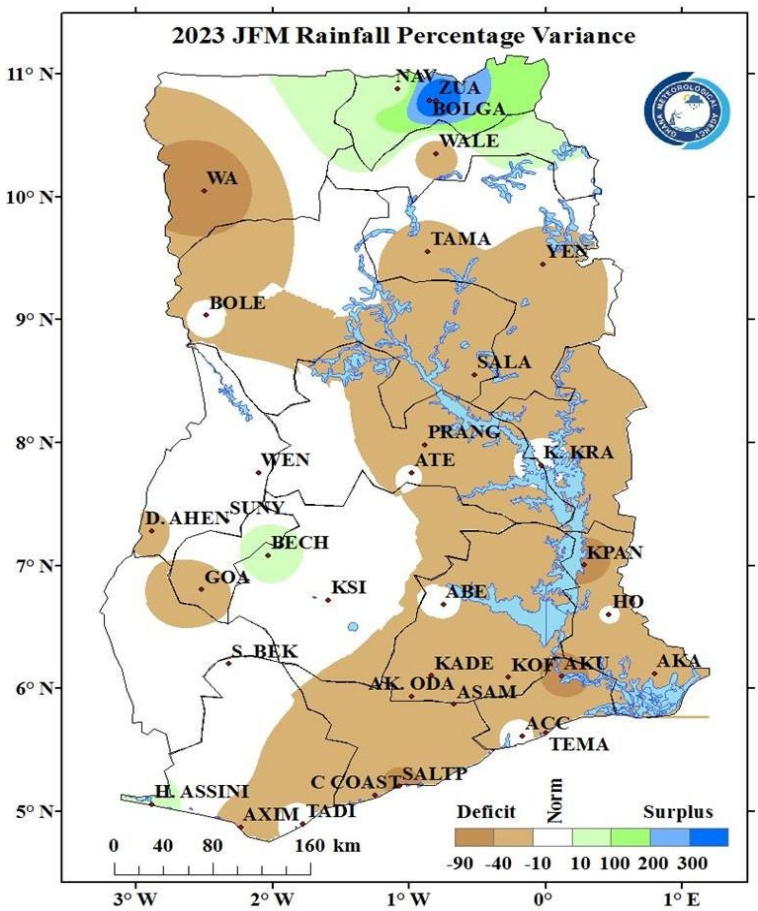


Figure 19 Percentage Variance for 2023 Annual Total Rainfall

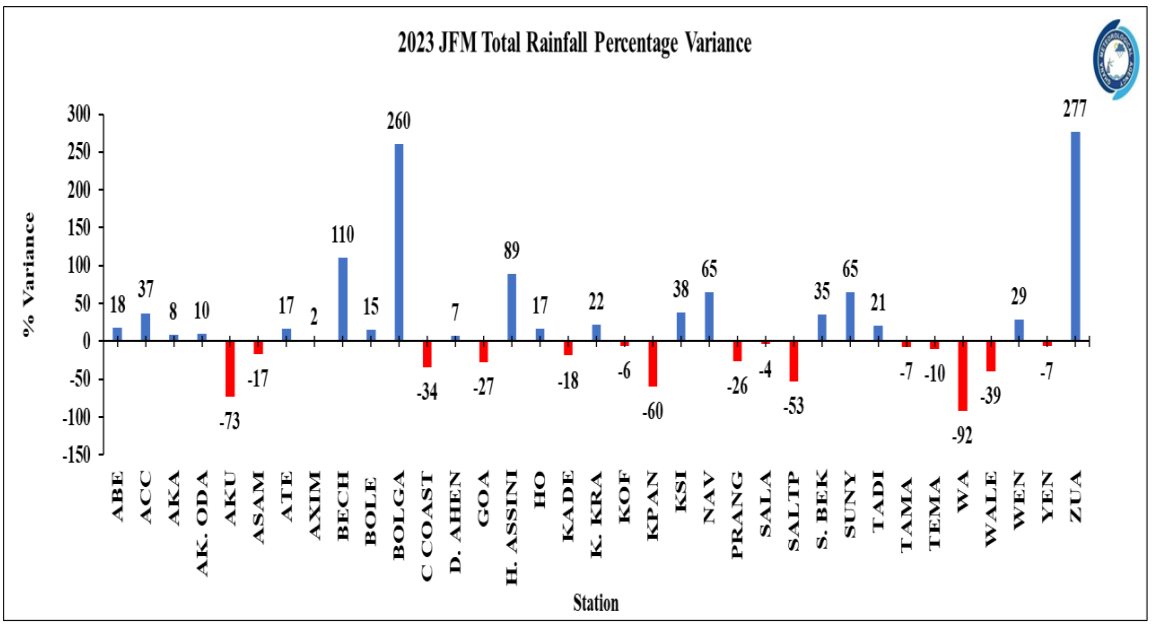


Figure 20 Percentage Variance for 2023 Annual Total Rainfall

The 2023 JFM rainfall percentage variance depicts that, some north-western and eastern portions of the country show a deficit percentage variance ranging from -73 to -4, with patches around some portions of the western. Some areas within the northeastern and transition portions of the country experienced surplus percentage variance ranging from (2 to 277), with Bolga and Zuarungu exhibiting extreme percentage variances of 260 and 277 respectively. Normal percentage variances are experienced in portions of the northern, western, eastern (Atebubu, Kete Krachi, Abetifi, and Ho) and coastal sectors (Accra, Takoradi, and Axim).

3.4.2 JFM Rainy days

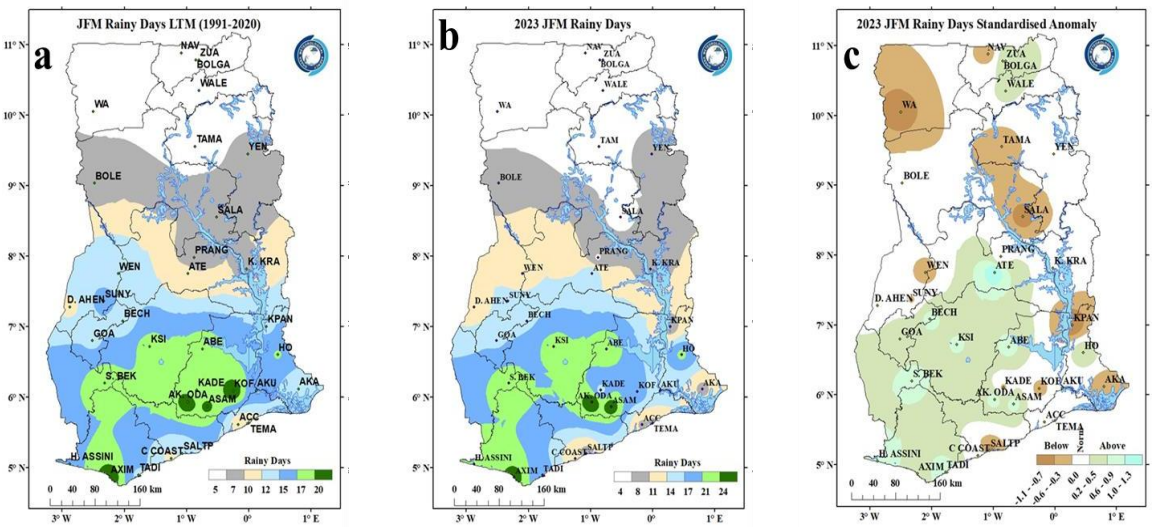


Figure 21 :(a) JFM LTM, (b) JFM Total Rainy Day, 2023 and (c) JFM Standardized Anomaly

The climatological average seasonal rainy days for JFM season shows that, most portions of the forest zone including the west coast experienced the highest number of rainfall occurrences (15 to 20), compared to the other parts of the country. The Northern sector had the lowest number of rainy days of 6 days.

The rainy days during the 2023 JFM season was a little above the climatology. The forest zone and the west coast visibly dominated with the highest number of rainfall occurrences ranging from 15 to 24. The extreme east coast, transition belt and the northern sector had rainfall activities between 2 to 8 days

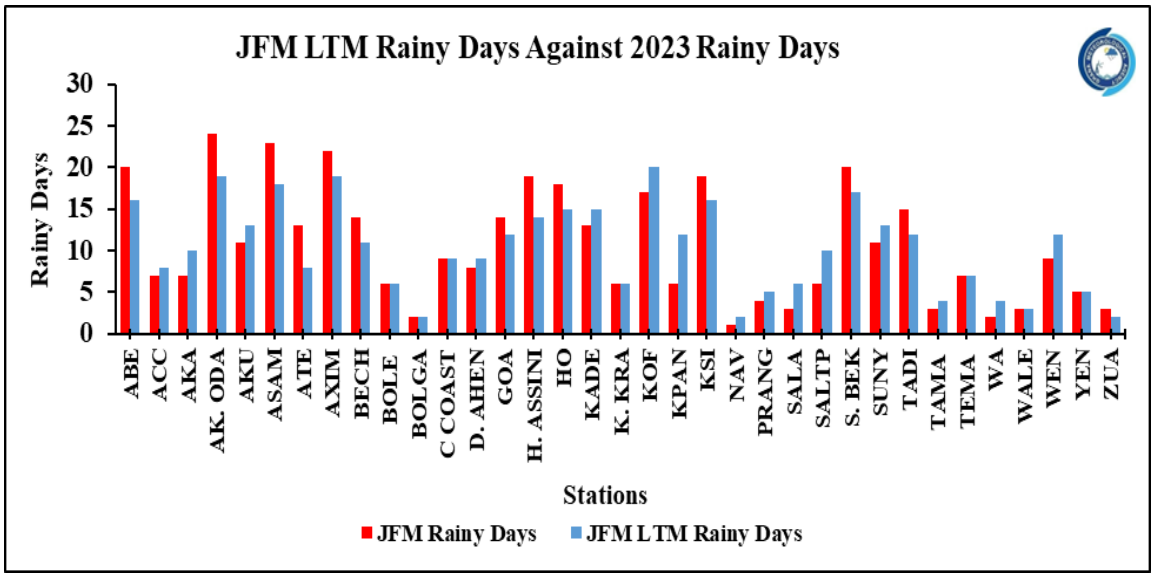


Figure 22 2023 JFM LTM s Against 2023 Rainy Days

The rainy days of the average rainfall anomaly for the 2023 JFM season revealed the south-western portions, the forest, places in the transition and the upper-east, visibly experienced positive anomaly. With the exception of Wa, Tamale, Salaga and stations over the extreme east coast that had below normal rainy days, the rest of the country was dominated by normal to above rainy days. Stations such as Akim Oda (26%), Abetifi (63%) Asamankese (28%) Half Assini (35%), Takoradi (25%) and Zuarungu (50%) experienced appreciable increase I their number of rainy days as compared to their LTM. On the other hand, stations such as Akatsi (30%), Kpando (50%), Navrongo (50%), Prang (20%), Salaga (50%), Saltpond (40%), Tamale (25%) and Wenchi (25%) recorded a significant decrease in their number of rainy days as compared to their LTM

3.4.3 FMA Total Rainfall

The climatology map for the FMA season (1991-2020) depicts that, rainfall was more in the forest areas, towards the south -western coast of the country. In these parts of the country, the average rainfall recorded during the season exceeded 500mm. The amount of rain decreased towards the North, with rainfall values below 500mm

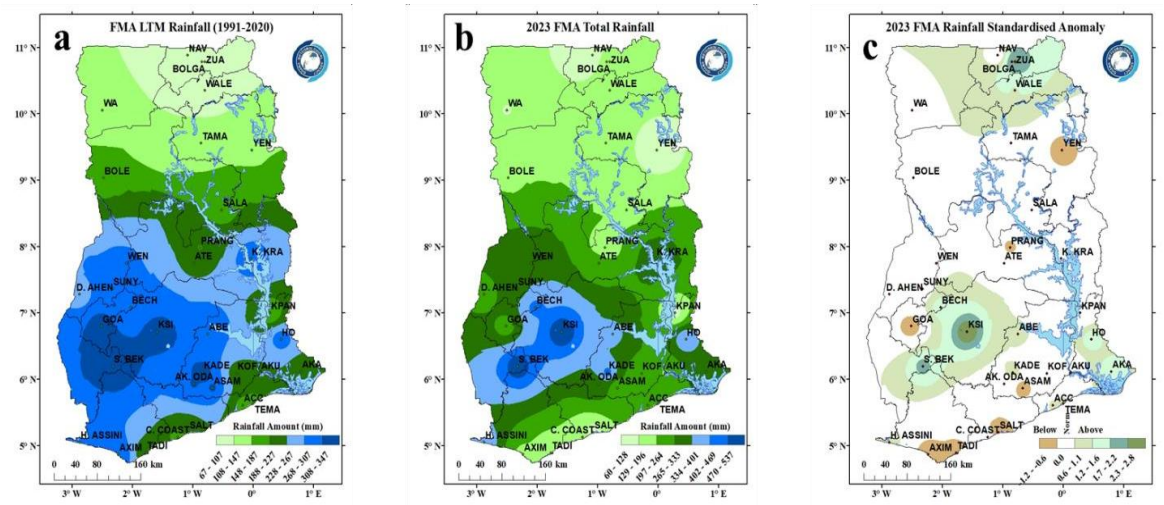


Figure 23 FMA LTM , (b) FMA Total Rainfall, 2023 and (c) FMA Standardized Anomaly

The total seasonal rainfall for FMA 2023 indicates that the forest areas (Kumasi, Goaso, Sefwi Bekwai, Abetifi and Akim Oda) to the south-western coast (Axim) mainly recorded rainfall totals above 350.1mm. Sefwi-Bekwai recorded the highest rainfall, with a value of 380mm in the period. Remaining areas situated at the Coast, Transitional as well as North-west recorded rainfall values of about 180mm to 260mm. The North-East portions (Walewale, Bolga, Zuarungu and Navrongo) recorded the least seasonal rainfall values below 100mm.

The rainfall anomaly analysis for the FMA season, revealed above-normal rainfall in most parts of the country, including Kumasi (166.2 %), Sefwi-Bekwai (147.8%). On the other hand, stations such as Yendi and Saltpond recorded rainfall amounts below their long-term means (LTMs) during this period.

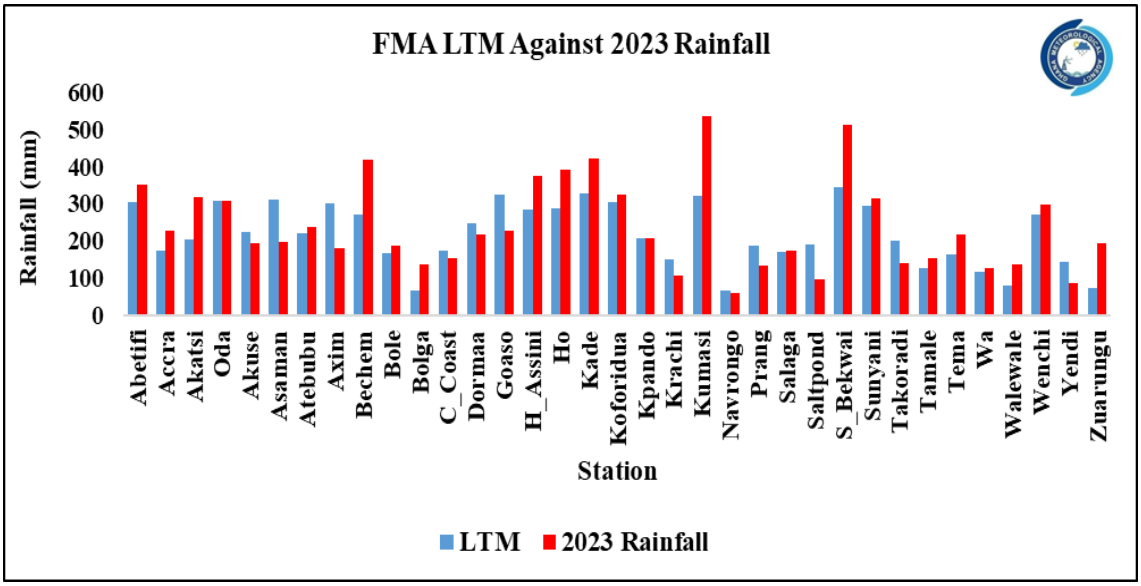


Figure 24 FMA LTM Rainfall Against Total Rainfall, 2023

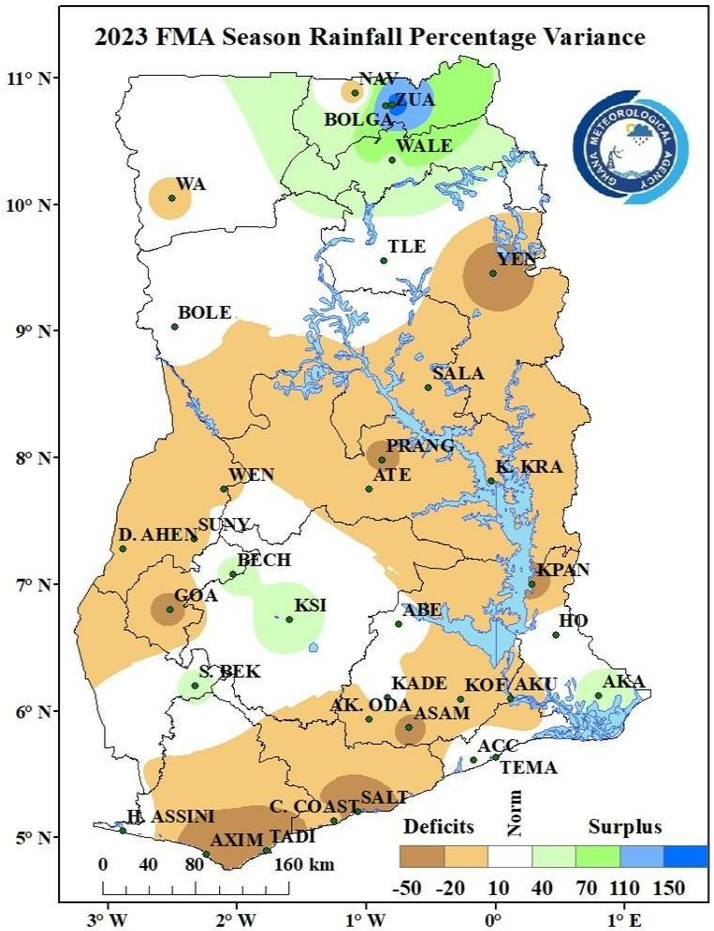


Figure 25 Percentage Variance for 2023 Annual Total Rainfall

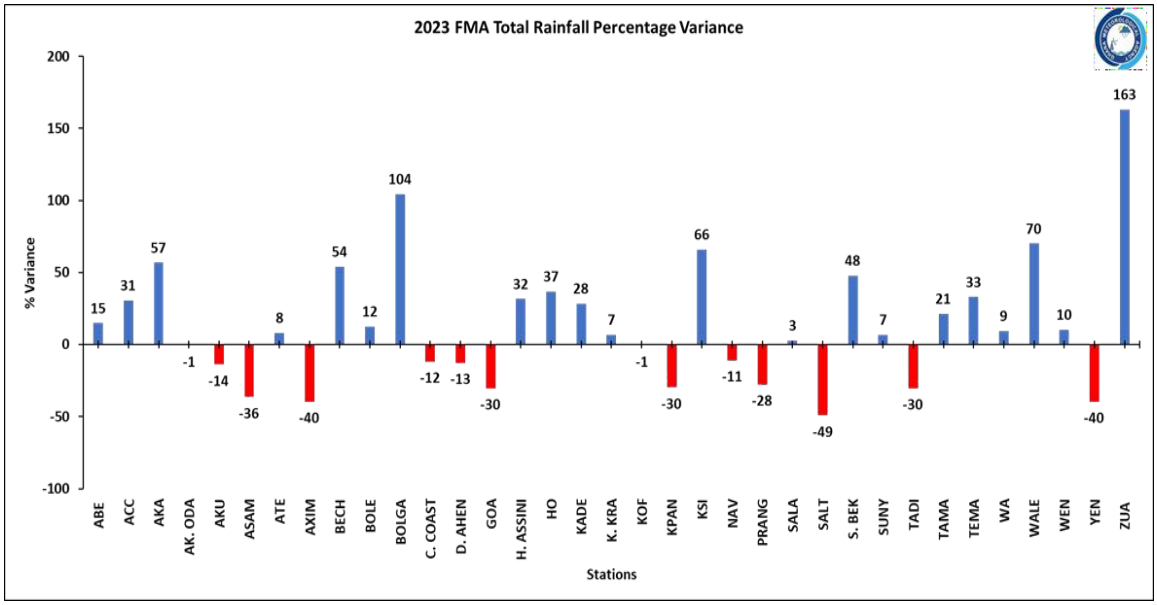


Figure 26 Percentage Variance for 2023 Annual Total Rainfall

3.4.4 FMA Rainy days

The average rainy days (LTM) recorded during the FMA season is higher in the Southern parts of the country compared to the Northern parts. Stations in the south, such as Akim Oda, Asamankese, Koforidua and Sefwi-Bekwai experienced average rainfall occurrences of over 25 days for the FMA season. The average number of rainy days with value less than 10 was witnessed in the Northern area.

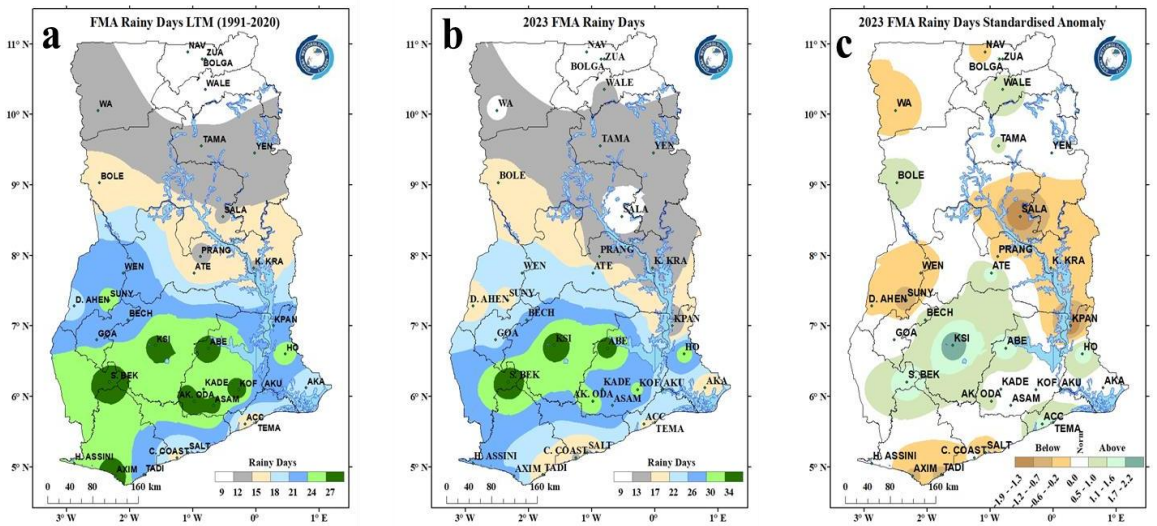


Figure 27 :(a) FMA LTM Rainy Days, (b) FMA Total Rainy Days, 2023 and (c) FMA Rainy Days Standardized Anomaly

Rainy days analysis for FMA, 2023 season illustrates that, greater number of stations in the southern parts, recorded more than 20 rainy days. In contrast, areas in the transition zone towards the Northern zone experienced below 20 rainy days.

Rainy days anomaly analysis for the FMA season, revealed an outcome of above-normal rainy days for most of the stations across the country. It includes Abetifi (133%), Koforidua (103.8%). However, a fall in the number of rainfall occurrences was noticed in Kpando and Salaga.

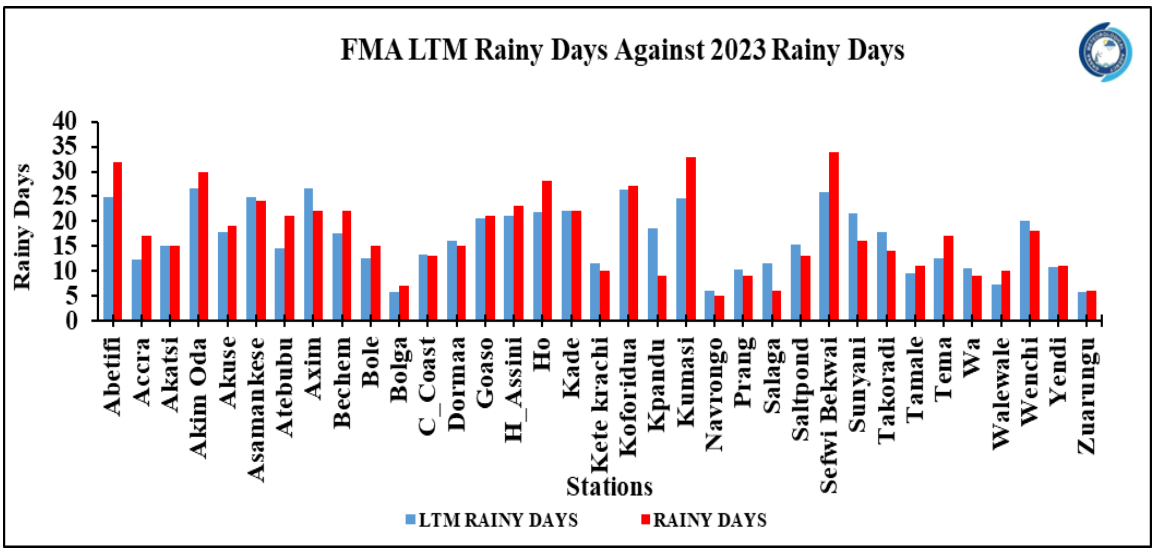


Figure 28 FMA LTM Rainy days Against Total Rainy days, 2023.

3.4.5 MAM Total Rainfall

The climatology map for MAM (1991-2020) rainfall for Ghana reveals the south-western portion of the country with the higher amount of rainfall. The amount of the rains reduced towards the north with the least seasonal average occurring over the north-east portion of the country. The south-western portions experience seasonal average rainfall of above 500.0 mm. The east coast, part of the transition and the northern portions received seasonal average values less than 400.0 mm (Figure 29 (a))

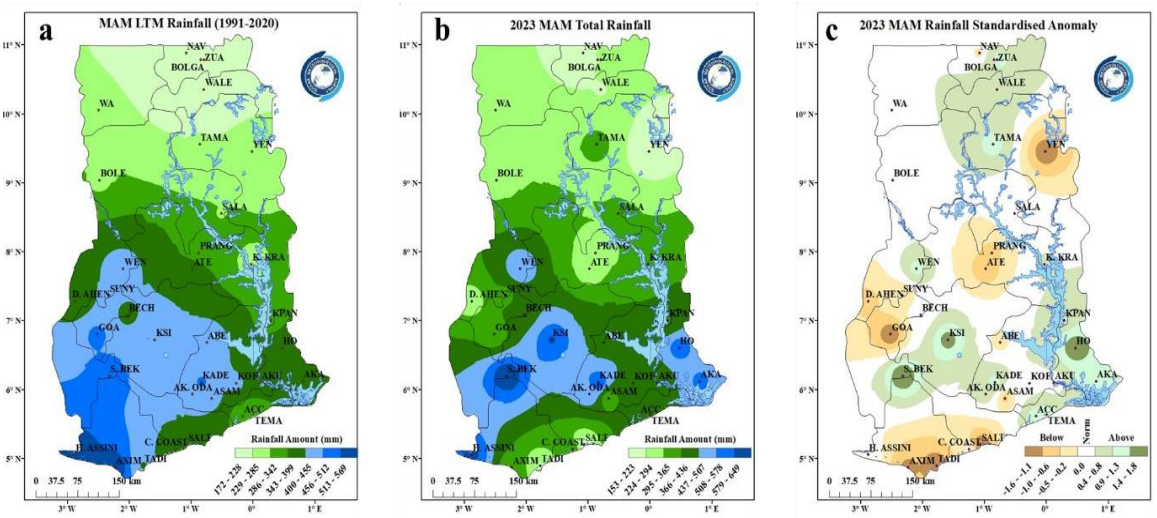


Figure 29 :(a) MAM LTM Rainfall, (b) MAM Total Rainfall, 2023 and (c) MAM Rainfall Standardized Anomaly

The total seasonal rainfall for MAM 2023 shows H. Assini, Sefwi Bekwai, Kumasi, Kade, Wenchi, Ho and Akatsi in the forest zone recorded rainfall values of about 500mm to slightly over 600mm. The rest of the coast and the forest zone experienced below 500mm with Dormaa Ahenkro, Prang, and Atebubu in the forest zone, Takoradi and Cape Coast along the coast recording the least values between 150mm to 300mm. The highest seasonal rainfall value of 649.1mm was recorded over Sefwi Bekwai. The north recorded below 350mm with the least seasonal value of 152.5mm and 153mm being recorded at Yendi and Navrongo respectively.

The rainfall anomaly analysis for the season revealed Tema, Akatsi, Ho, Sefwi Bekwai, Kumasi, Tamale, Walewale and Zuarungu recorded above normal rainfall during the period. Akatsi, Ho, Sefwi Bekwai, Kumasi, Tamale, Walewale and Zuarungu experienced an appreciable increase in rainfall of 46.5%, 38.3%, 35.9%, 30.8%, 38.3%, 26.4% and 45.3% respectively as compared to their LTM. Deficit rainfall anomaly was experienced over stations such as, Axim, Takoradi, Saltpond, Asamankese, Abetifi, Goaso, Dormaa Ahenkro, Sunyani in the coastal and forest zone, Prang and Atebubu in the transition zone and Yendi and

Navrongo in the north during the MAM season. The analysis indicates a significant decrease in rainfall amount of 41.4% over Axim, 44.4% over Takoradi, 52.5% over Saltpond, 27% over Asamankese, 35.9% over Goaso, 30.7% over Dormaa Ahenkro, 20.6% over Prang, 30.5% over Atebubu and 39% over Yendi during the MAM 2023 season as compared to their LTM. The rest of the country experienced normal rainfall.

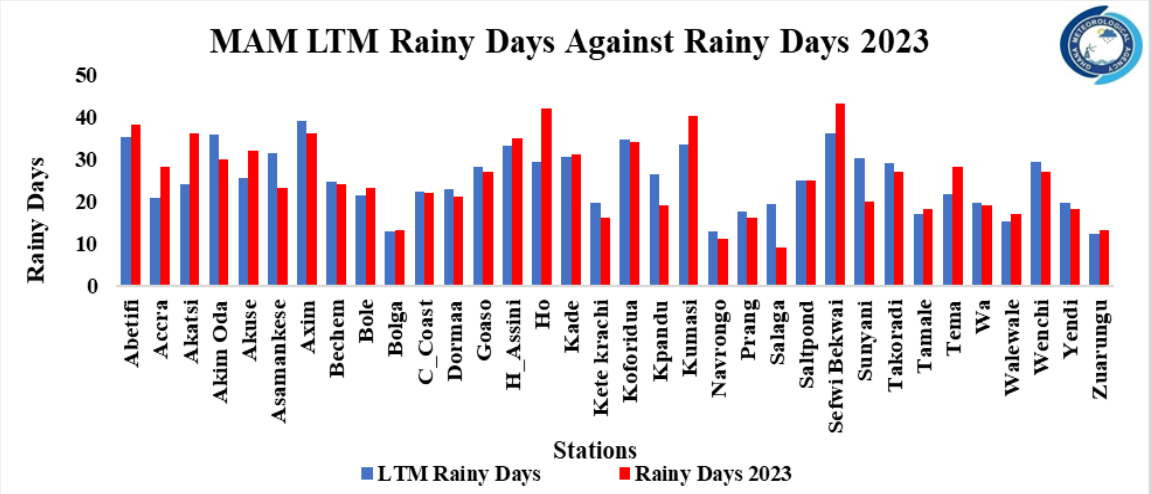


Figure 30 MAM LTM Rainfall Against Total Rainfall, 2023

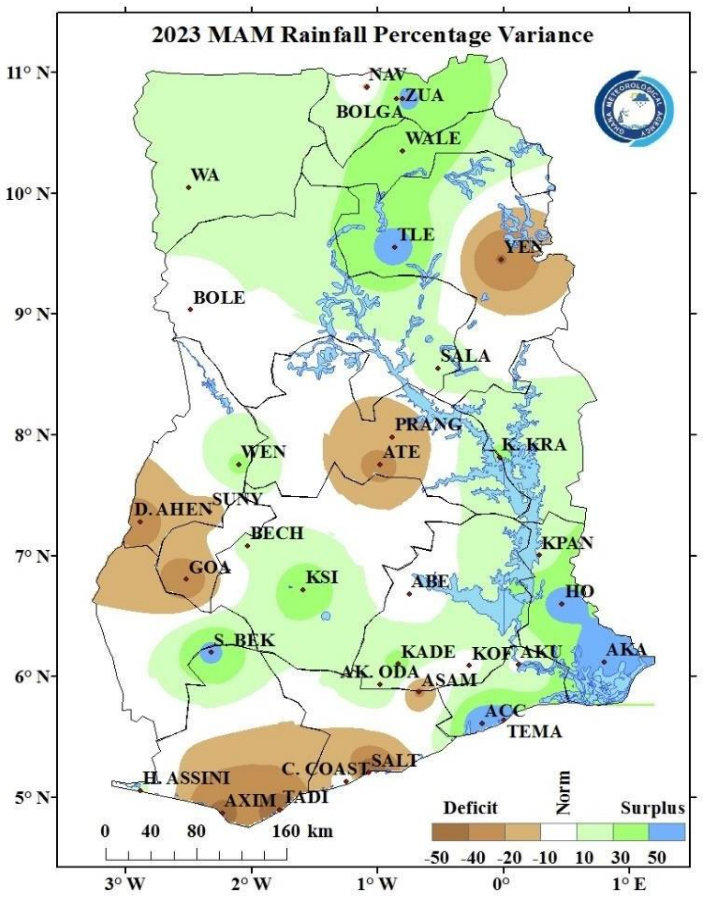


Figure 31 Percentage Variance for 2023 Annual Total Rainfall

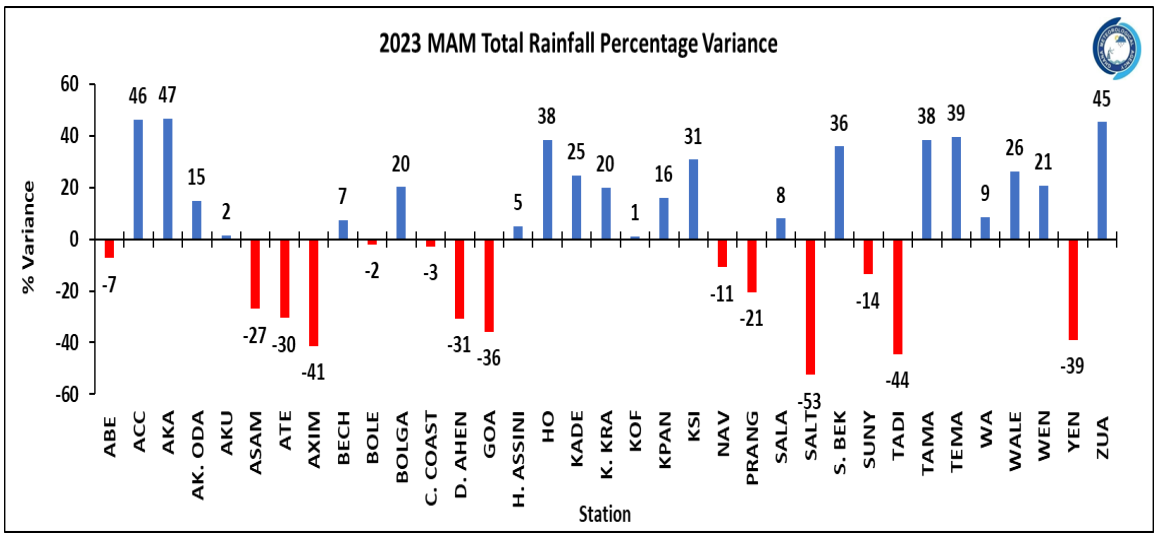


Figure 32 Percentage Variance for 2023 Annual Total Rainfall

In the northern Sector, Yendi recorded a deficit in rainfall variance of 39 percent. Tamale and Zuarungu recorded positive variances of 38 and 45 percent respectively. Wa, Bole and Navrongo also saw a normal variance within the range of -10 to 10 percent. Wenchi and Kete Krachi in the transition sector recorded 21 and 20 percent surplus in rainfall variance respectively which were the highest positive variance in the sector. On the contrary, Prang, Atebubu and surroundings areas recorded a deficit in rainfall variance ranging from 21 and 31 percent.

In the Forest zones of Ghana, Goaso, Dormaa Ahenkro, Sunyani and Asamankese saw a deficit in rainfall variance ranging from 14 to 36 percent, with Goaso recording the highest deficit variance of 36 percent and Sunyani recording the lowest deficit in rainfall variance of 14 percent. However, Sefwi Bekwai, Ho and Akatsi also in the forest zone recorded the highest positive variance (across Ghana) in rainfall of 36, 38 and 47 percent respectively.

Along the coastline of Ghana, the West coast generally saw a deficit in rainfall variance ranging from 44 to 53 percent. Saltpond saw the lowest deficit in rainfall variance of 53 percent across Ghana with Takoradi and Axim recording a deficit variance of 44 and 41 percent respectively. Accra and Tema in the East coast of Ghana recorded positive variance of 46 and 39 percent respectively.

3.4.6 MAM Rainy days

The number of climatological seasonal average rainy days for MAM season shows that, most portions of the forest and the coast experienced the highest number of rainfall occurrences (25 to 45), compared to the other parts of the country. The least average number of rainfall occurrences were over the north and portions of the transition with below 25 days.

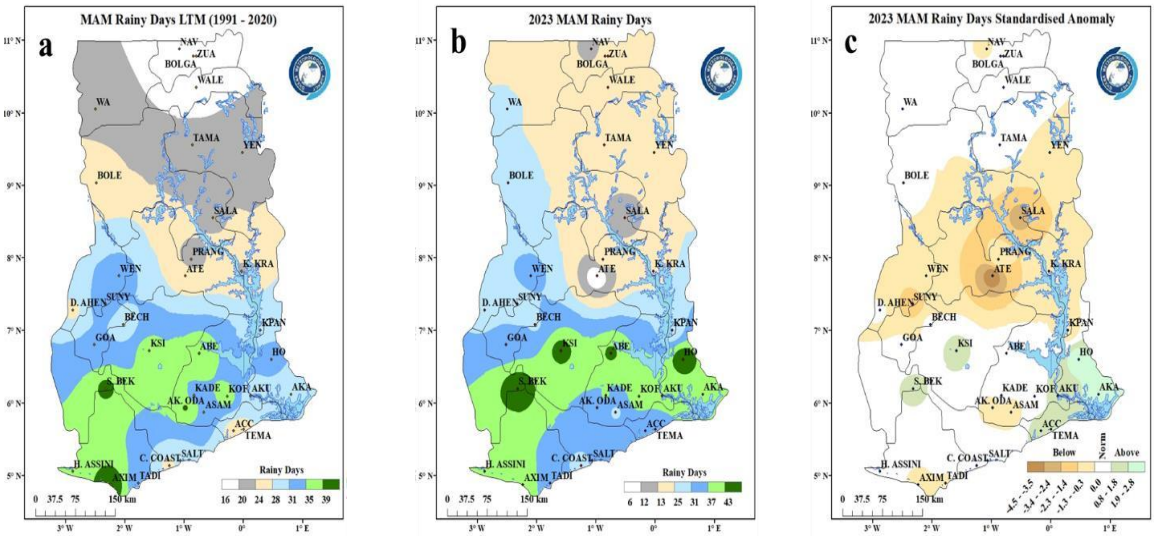


Figure 33 :(a) MAM LTM Rainy Days, (b) MAM Total Rainy Days, 2023 and (c) MAM Rainy Days Standardized Anomaly

The number of rainy days during the MAM season depicts the climatology, where most parts of the forest and the coast visibly dominate with the number of rainfall occurrence between 25 to 45 days. The other parts of the forest zone had rainy days between 21 to 25, whilst the transition and the north experienced 20 and below number of rainy days within the period. The average rainy days anomaly revealed below normal rainy days for almost the entire country. Stations such as Akim Oda, Kete Krachi, Asamankese, Kpando Sunyani and Salaga experienced an appreciable decrease in rainy days by 15.8%, 18.1%, 26.3%, 27.8%, 33.4% and 53.4% respectively as compared to their LTM. The extreme east coast and stations such as; Kade, Abetifi, Kumasi, Sefwi Bekwai, Half-Assini in the forest zone and Bole, Tamale, Walewale, Zuarungu and Bolga in the north recorded an increase in the number of rainy days. Stations that experienced a substantial increase in rainy days include Sefwi Bekwai (18.9%), Kumasi (22.2%), Akuse (25.7), Accra (35%), Tema (29.6%) and Ho (44%) as compared to their LTM

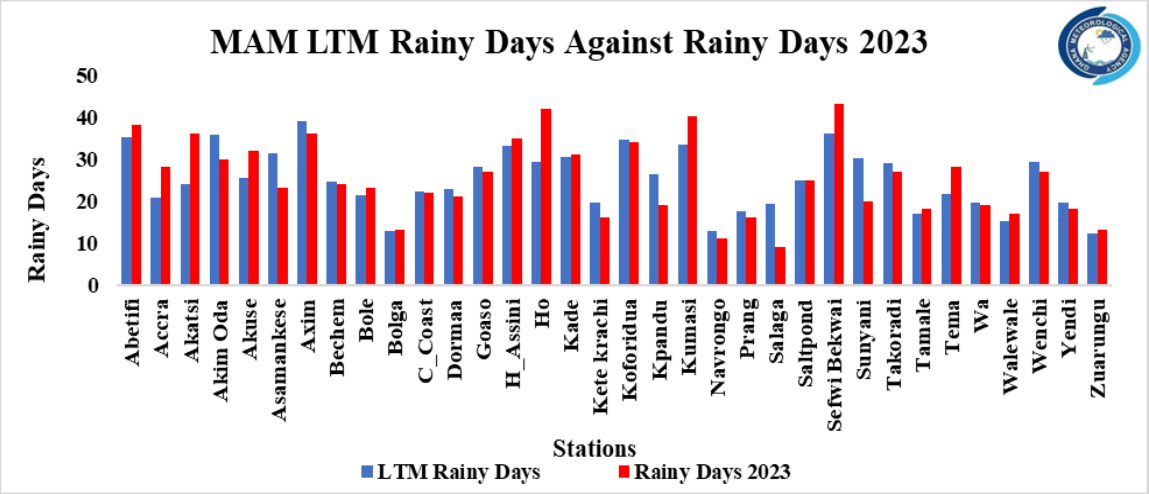


Figure 34 MAM LTM Rainy days Against Total Rainy days, 2023

3.4.7 AMJ Total Rainfall

The seasonal climatology analysis of AMJ season showed an average rainfall of about 280 – 400 mm over the extreme northern region where Navrongo, Bole, Walewale and Zuarungu recorded about 291, 302, 285, 288 mm of rainfall respectively. Stations such as Half- Assini(976mm) and Axim (949mm) had the highest rainfall amounts within the season. Areas within the forest zone, transition, and the east coast received average rainfall of about 500 – 700mm and areas within the northern sector except for Navrongo, Bole, Walewale and Zuarungu, had average rains ranging from 300 – 400 mm. Salaga in the northern sector recorded an average rainfall of about 408m. The 2023 rainfall for AMJ season had areas within the extreme north recording rains of about 200 – 300mm. Navrongo (21%) had a reduced rainfall to about 228mm, Bole recorded rainfall value of about 286mm with a reduction of 23% of its LTM rainfall, Yendi had 269mm and a reduction of 31% compared to its LTM and Navrongo recorded 228mm with a reduction of 21%. Areas within the south, with exception of Half-Assini (1,002mm), Axim(1324mm) and Saltpond (812mm) had rainfall amounts ranging from 400 – 700mm.

AMJ Rainfall anomaly shows a deficit rainfall over stations in the forest zone such as Goaso (35%), Dormaa Ahenkro (31%), Atebubu (25%), Abetifi (17%) as well as stations in the northern such as Yendi (31%), Navrongo (21%), and Bole (23%) together with Asamankese (27%) in the south. Areas such as Sefwi - Bekwai (38%), Axim (39%), Akim Oda (36%), Kpando (53%), Akuse (30%), Akatsi (28%), Ho (18%), Accra (13%) and Tema (34%) had surplus or increase in rainfall during AMJ season.

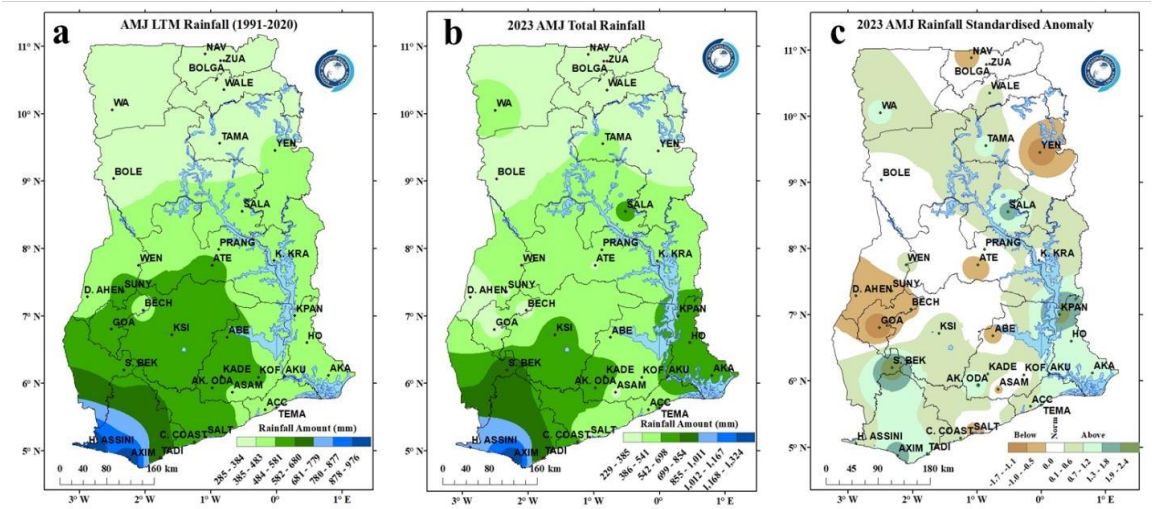


Figure 35 :(a) AMJ LTM Rainfall, (b) AMJ Total Rainfall, 2023 and (c) AMJ Rainfall Standardized Anomaly

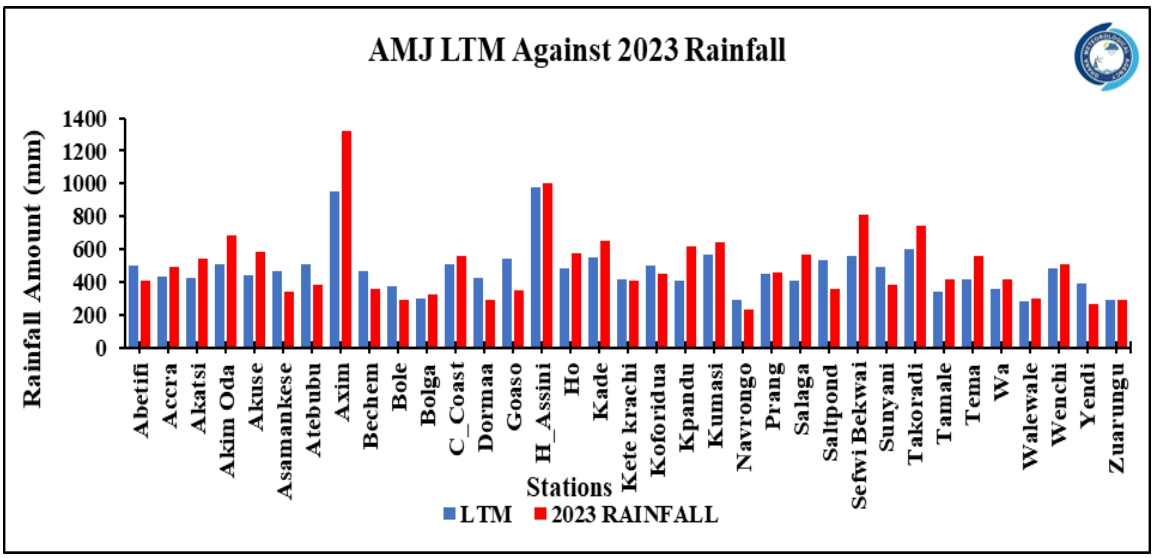


Figure 36 AMJ LTM Rainfall Against Total Rainfall, 2023

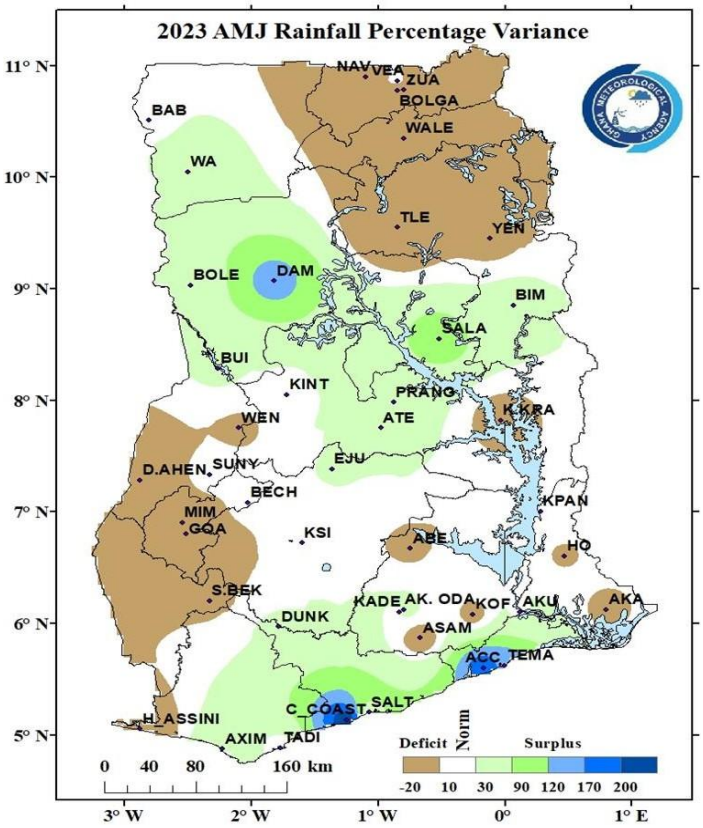


Figure 37 Percentage Variance for 2023 Annual Total Rainfall

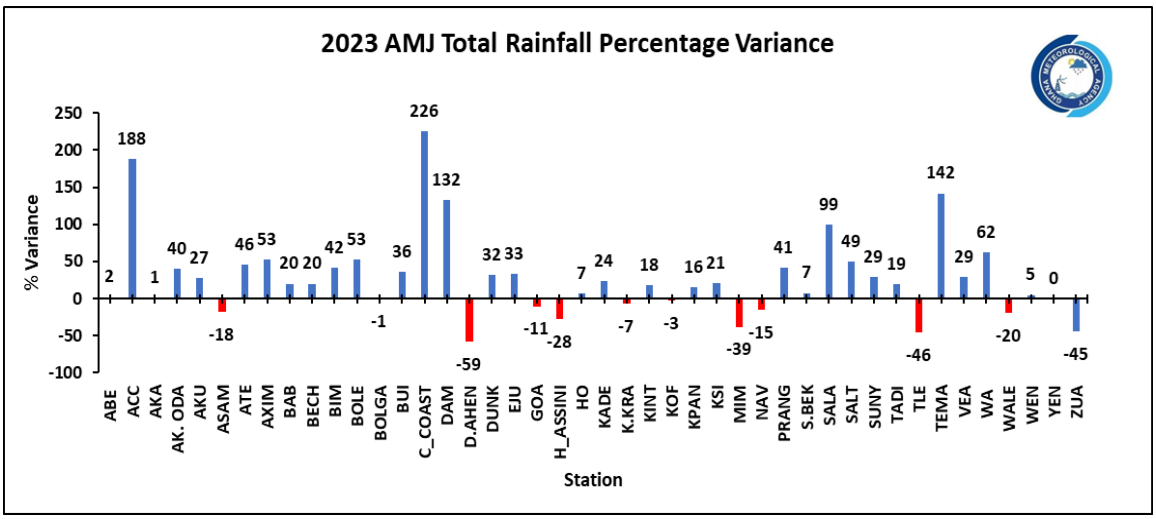


Figure 38 Percentage Variance for 2023 Annual Total Rainfall

The AMJ rainfall percentage variance map for Ghana from 1991-2020 illustrates, the western and north-eastern portion of the country had a deficit of (-20) with some patches at the eastern portions. A large portion of the middle zones experienced a normal percentage variance of (10). The transition to the Northern and some part of the southern sector experienced surplus rainfall percentage variance of (30-226), whiles other areas specifically Damango, (132), Cape Coast (226), and Accra (188) had extremes.

3.4.8 AMJ Rainy Days

The climatology for AMJ season illustrates areas within the north and some portions of the transition zone had average rainfall occurrences between 20 to 26 days, whereas areas in south and sections of the transition zone - excluding Dormaa Ahenkro, which recorded an average of 28 days - experienced average rainfall occurrences ranging from 32 to 56 days. Axim, a station in the coast, received average rains over a period of 56 days which is the highest number of days recorded during the season. Salaga in the north had rainfall within an average of 27 days.

AMJ rainy days in 2023 as shown in figure (b) illustrates areas within parts of the northern and transition zone such as Walewale, Navrongo, Zuarungu, Salaga, Prang, Atebubu, as well as Dormaa Ahenkro and Bechem had rainy days of about 20 -26, whereas most places in the southern part of Ghana, together with Wenchi, Tamale, Yendi, Bole in the north, and Kete – Krachi in the Transition zone experienced between 31 – 51 rainy days.

The standardized anomaly for AMJ rainy days shows deficit rainy days over areas within the north, transition, forest and some areas within the southwestern coast such as Abetifi (11%), Akim Oda (16%), Atebubu (30%), Bechem (20%), Bole (19%), Goaso (15%), Navrongo
(33%), Salaga (44%), Sunyani (33%) and Zuarungu (25%). Stations such as Wa (7%), Bolga (10%), and Tamale (20%) in the north as well as Sefwi- Bekwai (18%) in the southwestern part, and areas within the east coast such as Saltpond (11%), Akatsi (22%), Accra (13%) and Tema (23%), and Ho (32%), had an increment or surplus rainy days. Wenchi, Walewale, Kpando and Kade had normal rainy days as compared to their LTMs

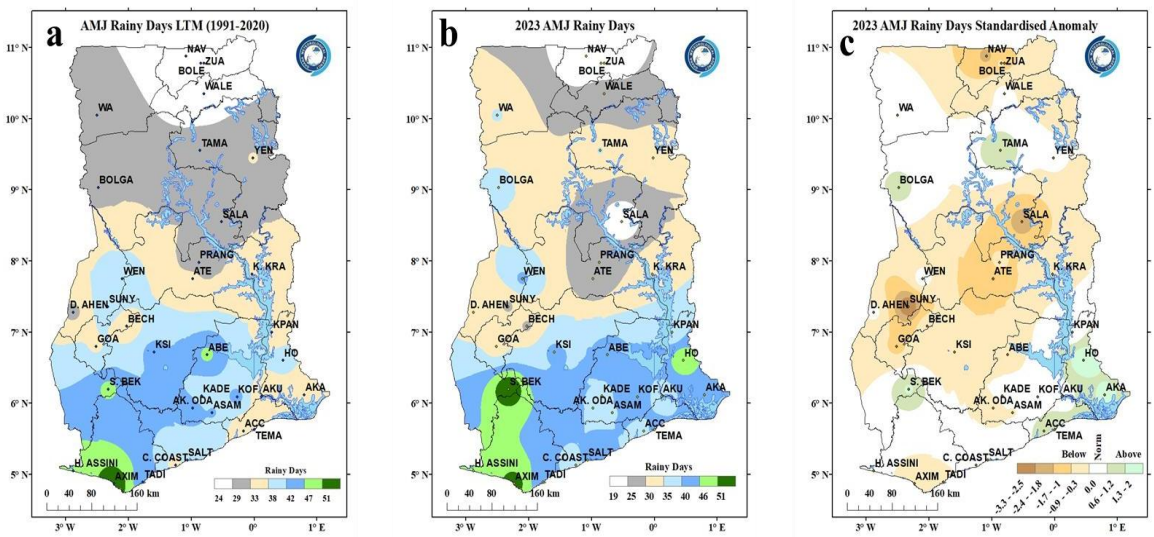


Figure 39 :(a) AMJ LTM , (b) AMJ Total Rainy Days, 2023 and (c) AMJ Standardized Anomaly

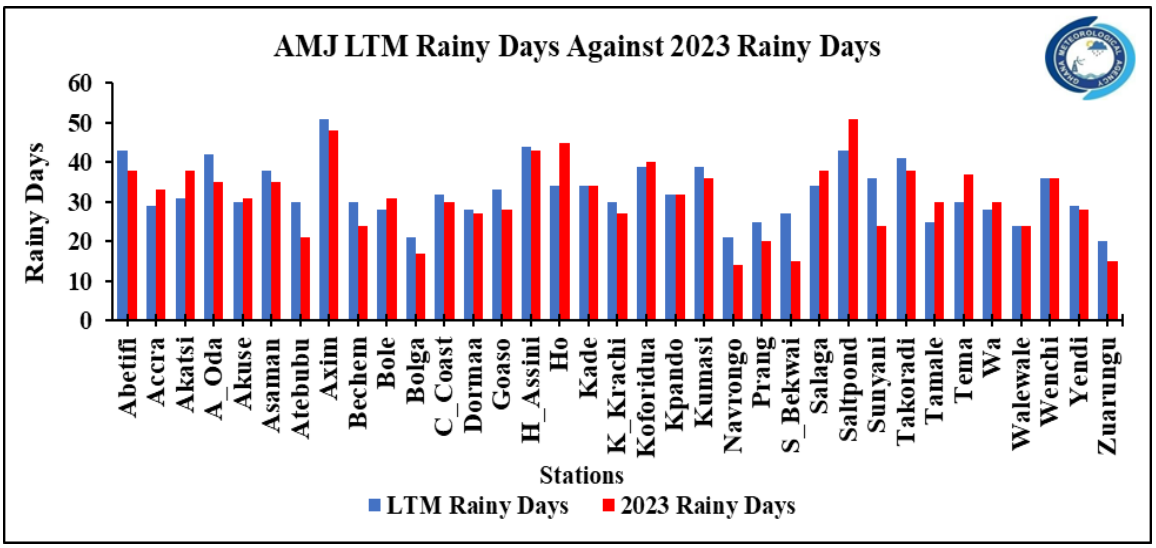


Figure 40 AMJ LTM Rainy days Against Total Rainfall, 2023

3.4.9 MJJ Total Rainfall

The seasonal Climatology analysis of MJJ season (1991-2020) shows over 500mm of rainfall occurring over the southwestern portion and some arears in the transition zone. The rest of the country experienced about 300mm to 500mm as shown in figure 41 (a).

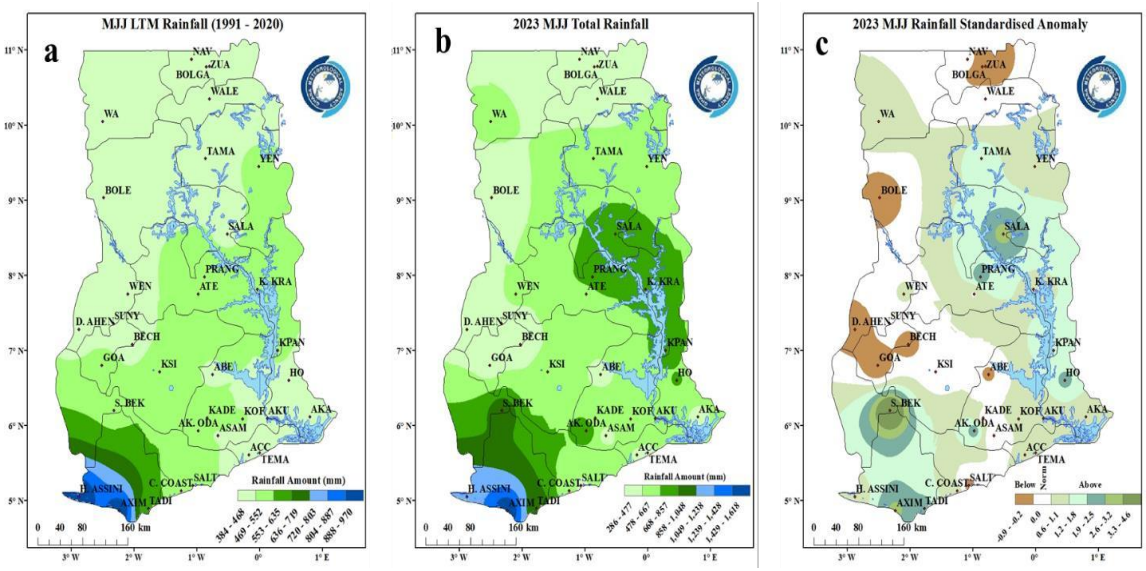


Figure 41 :(a) MJJ LTM, (b) MJJ Total Rainfall, 2023 and (c) MJJ Standardized Anomaly

The total seasonal values of rainfall for the year 2023 (figure 41 (b)) indicates high rainfall amount over most parts of the country. The south-western portions received rainfall values above their LTMs. Similarly, the east flanks of the country received rainfall values above their LTMs.

From figure 41 (c), the rainfall anomaly distribution for MJJ season, indicates normal rains to above normal rains over stations such as Axim, Akim Oda, Takoradi, Ho, Salaga, Tamale, Wa, Kpando, Sefwi Bekwai and Prang within the period, while below normal rains were also witnessed at Bole, Navrongo, Bolga, Zuarungu, Dorma Ahenkro, Bechem, Goaso, Abetifi, Cape Coast and Asamankese. There was a significant increase in rainfall amount over stations such as; Akim Oda (67%), Sefwi Bekwai (82%), Takoradi (64%), Axim (68%), Ho (47%), Kpando (57%), Prang (58%), Salaga (77%) and Tamale (36%) as compared to their LTM. Stations such as; Bole (20%), Bechem (20%), Dormaa Ahenkro (27%), Goaso (20%) and Zuarungu (20%) experienced an appreciable decrease in rainfall amount as compared to their LTM.

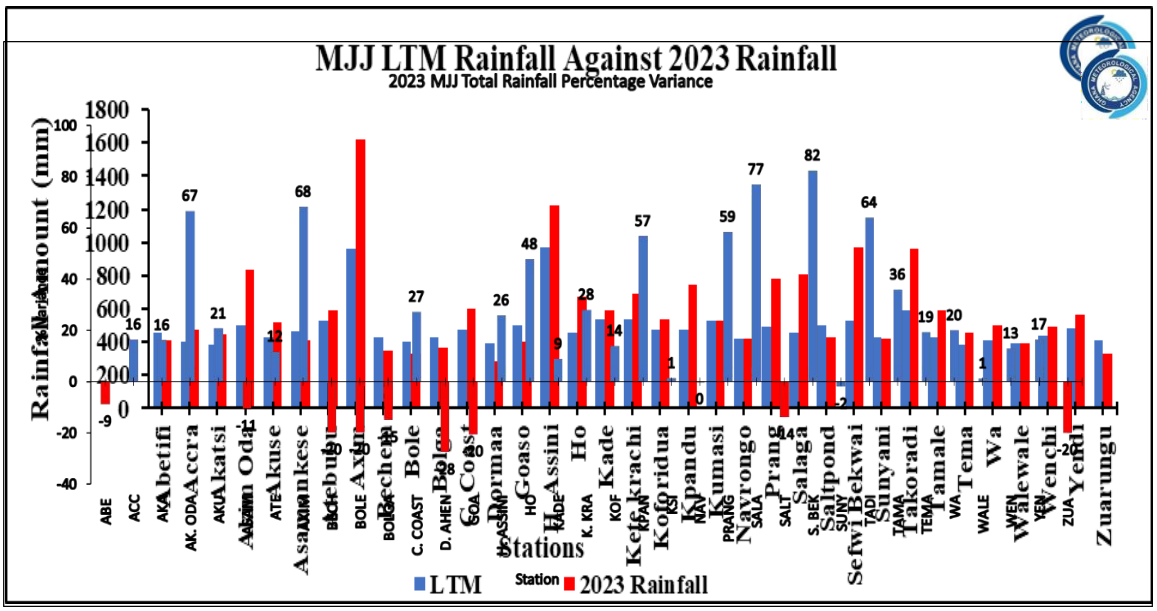


Figure 42 MJJ LTM Rainfall Against Total Rainfall, 2023

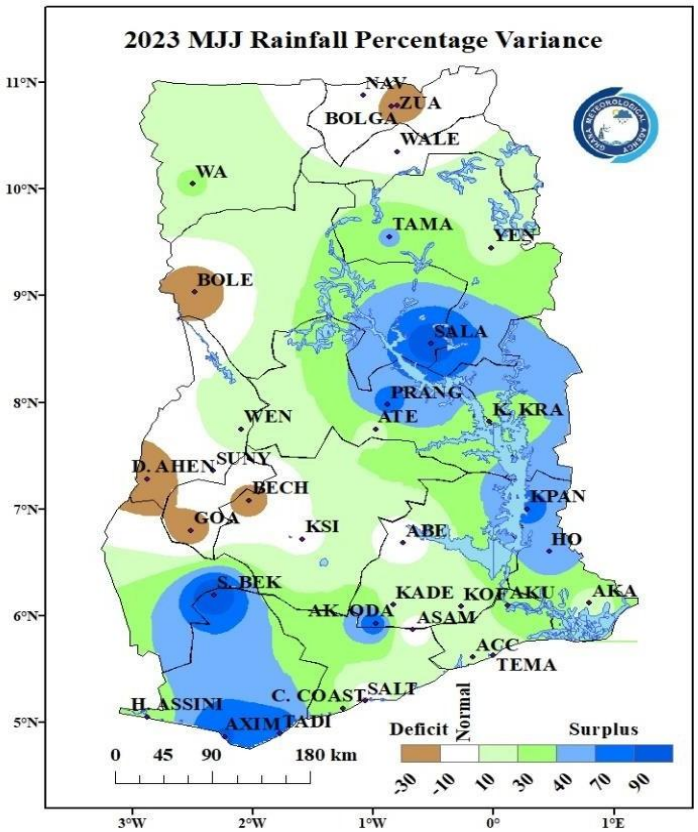


Figure 43 Percentage Variance for 2023 Annual Total Rainfall

Figure 44 Percentage Variance for 2023 Annual Total Rainfall

For the MJJ season, Salaga (77%) recorded surplus to its normal rainfall distribution,

whiles Bole (-20%), Bolga (-15%) and Zuarungu (-20%) recorded deficit. Navrongo, Walewale and areas around Bole recorded normal, the rest of the areas in the northern sector recorded surplus below 50% in 2023. Areas along the transition belt experienced rainfall above normal in 2023, Prang (59%) recorded above 50%, while the rest of the towns along the belt recorded below 50%. In the southern sectors Sefwi Bekwai (82%), Axim (68%), Akim Oda (67%), Kpando (57%) experienced above 50%, whiles Dormaa Ahenkro (-28%), Goaso (-20%) and Bechem (-20%) recorded a deficit. Large areas across the southern sector recorded surplus below 50% while few areas recorded normal in 2023.

3.4.10 MJJ Rainy days

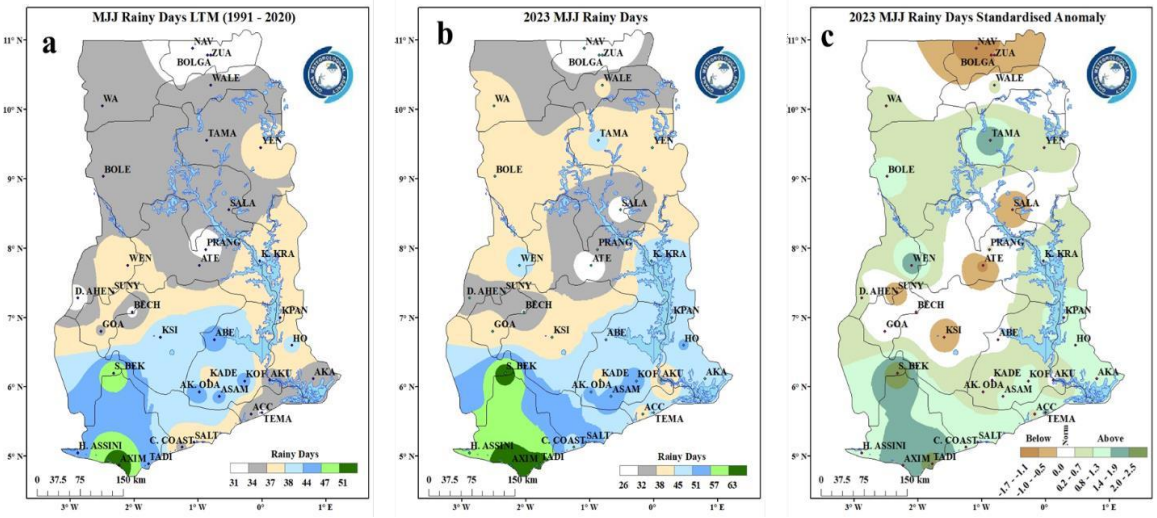


Figure 45 :(a) MJJ LTM, (b) MJJ Total Rainy Days, 2023 and (c) MJJ Standardized Anomaly

The average seasonal rainy days for MJJ (1991-2020) over Ghana depicts that, stations such as Axim, Half Assini, Sefwi Bekwai, Asamankese, Akim Oda, Koforidua and Abetifi and all within the forest zone experienced above 40 rainy days. Between 36 to 40 average rainy days occurred over stations such as Kumasi, Kade, Kpando, Kete Krachi, Wenchi, Sunyani and Ho within the forest zone. The rest of the forest zone experienced 35 and below number of rainy days. The coastal region experienced 35 and below number of rainy days. The northern part of the country in general received 40 and below number of rainy days with the least number of 27 rainy days recorded over Zuarungu.

The number of rainy days during the MJJ season for 2023, shows that most of the forest zone experienced 40 to about 63 rainy days with Axim and Sefwi Bekwai experiencing the highest of 63 and 55 respectively. The rest of the stations across the forest zone such as

Wenchi, Prang, Atebubu, Sunyani, Dormaa Ahenkro, Bechem, Goaso, Kumasi and Kade and the north of the country experienced between 20 to 40 rainfall occurrences. Accra and Tema in the coastal region experience less than 40 raining days the rest of the region experience more than 40 rainy days with Takoradi experiencing the highest of 59 rainy days.

The anomaly on rainy days for the period, reveals stations such as Navrongo, Bolga, Salaga and Zuarungu in the north, Atebubu, Bechem and Kumasi in the forest zone had fewer rainy days. These stations experienced 26%, 17%, 25%, 27%, 35%, 13% and 15% decreased in number of rainy days as com pare to their LTM respectively. The rest of the north, forest and coastal zone had increased rainy days during the MJJ season. Stations such as Akatsi (25%), Tema (34%), Saltpond (28%), Cape Coast (27%), Takoradi (35%), Axim (24%), Half Assini (26%), Sefwi Bekwai (29%) Wenchi (21%) and Tamale (26%) experienced an appreciable increase in number of rainy days as compared to their LTM.

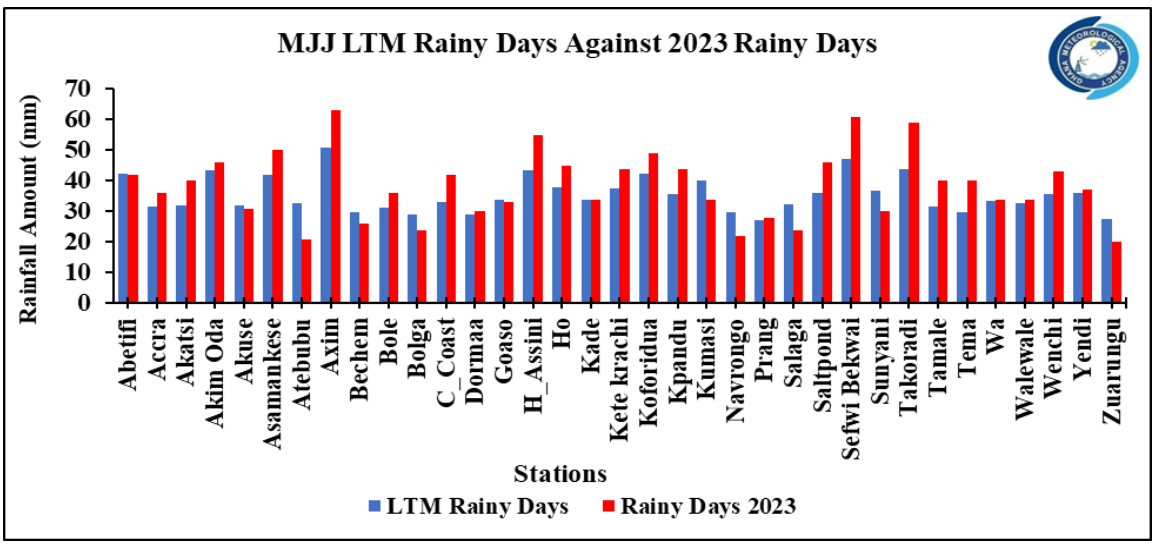


Figure 46 MJJ LTM Rainy days Against Total Rainy days, 2023

3.4.11 JJA Total Rainfall

The climatology map for JJA (1991-2020) rainfall Figure 47 (a) below shows that the south-western and most areas around the north recorded the highest amount of rainfall. The southwestern, northern and some areas in the transition experienced seasonal average rainfall ranging from 500 to 700mm. Generally, the middle and the eastern portions of the transition zone received seasonal average values of about 300mm and 500mm respectively.

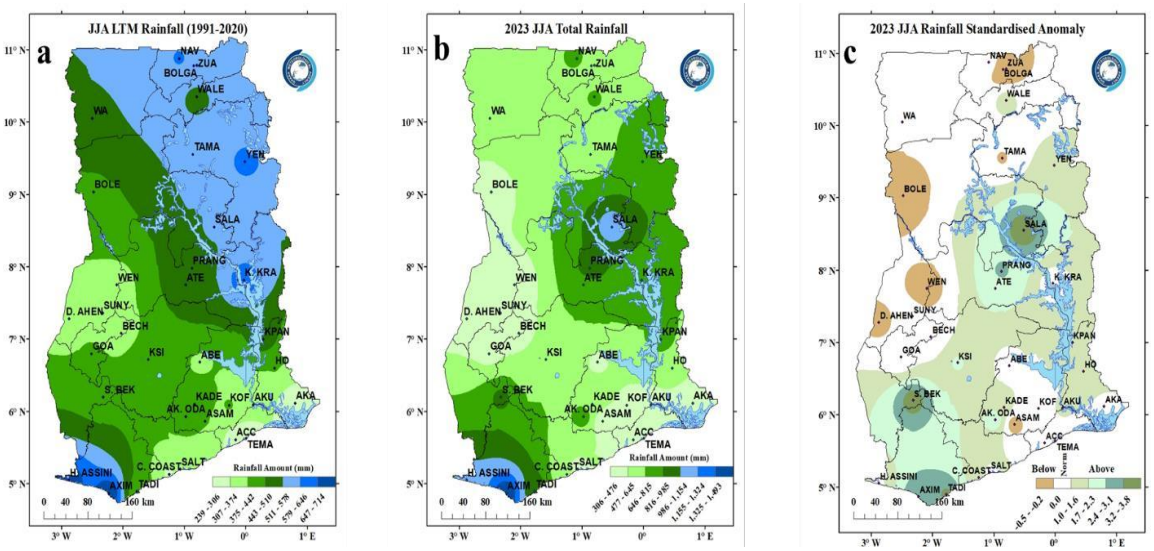


Figure 47 :(a) JJA LTM , (b) JJA Total Rainfall, 2023 and (c) JJA Standardized Anomaly

The total seasonal rainfall for JJA 2023 is shown in Figure 47 (b) above. The western portions of the coast and the eastern flanks of the country recorded the highest rainfall amounts of over 900mm. Few stations slightly north of the coast and some parts of the forest zone also experienced values above 300mm, whilst over the northern sector, seasonal values were mostly above 500mm.

The rainfall anomaly, Figure 47 (c) below, within the JJA season revealed above normal rains over most parts of the country. However, Bole, Wenchi, Bolga and Zuarungu revealed below normal rains. Generally, the eastern flanks and the western north portions recorded well above normal especially over Axim, Half Assini, Sefwi Bekwai and Salaga.

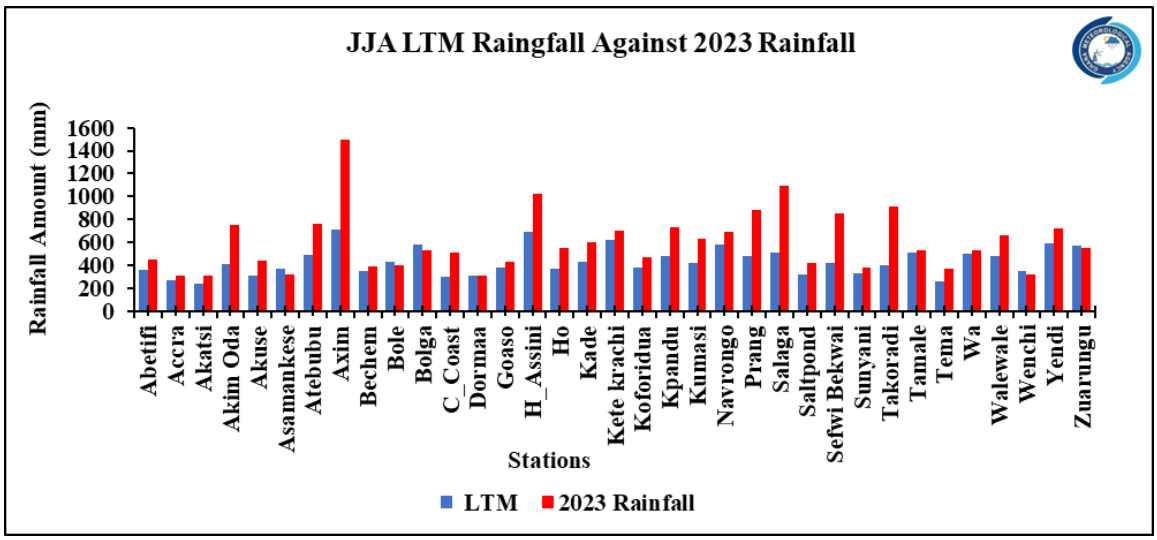


Figure 48 JJA LTM Rainfall Against Total Rainfall, 2023

Most stations in Figure 48 (b) above experienced an increment in the percentage of their 2023 rainfall compared to their long-term mean rainfall, with the exception of Wenchi, which showed a decrease of about 10% in rainfall over the long-term mean. Axim, Half Assini, Salaga, and Takoradi showed 109%, 48%, 112%, and 125% increments, respectively.

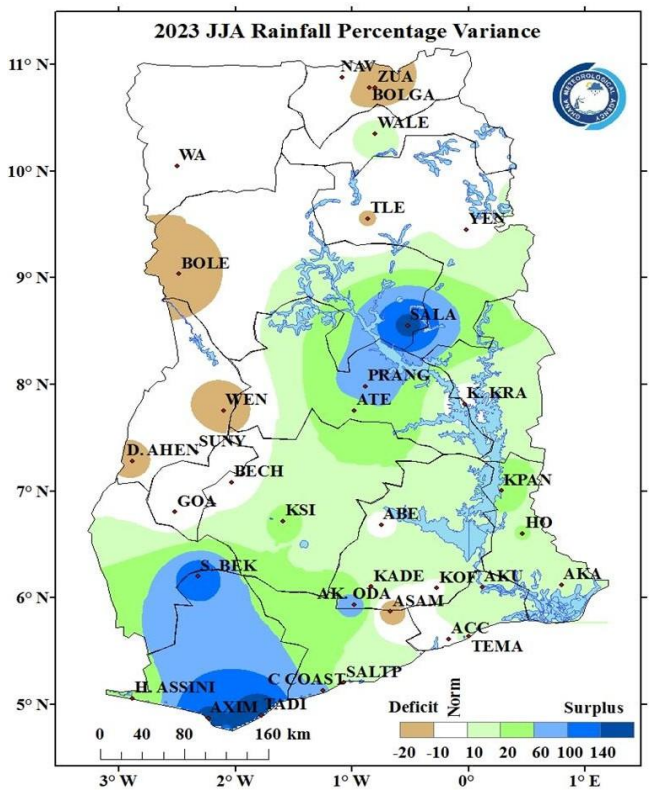


Figure 49 Percentage Variance for 2023 Annual Total Rainfall

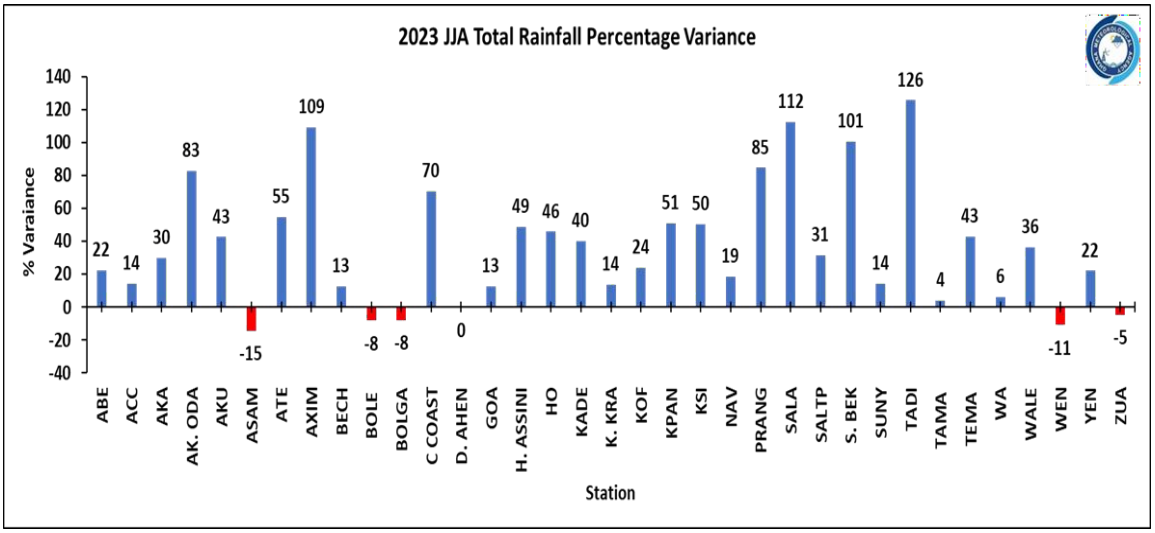


Figure 50 Percentage Variance for 2023 Annual Total Rainfall

The Northern part of Ghana saw a normal variance in rainfall, with Walewale recording the highest positive normal variance of 36 percent. Bolgatanga and Bole saw a deficit in rainfall variance ranging from 15 to 20 percent. Moreover, Salaga recorded the highest positive surplus variance of 112 percent.

For the transition zone, Wenchi saw a deficit in the rainfall variance of -11, slightly below the normal variance. Atebubu and Prang recorded a surplus variance in rainfall of 55% and 85%, respectively.

In the Forest zones, Dormaa Ahenkro and Asamankese recorded a deficit in rainfall variance of 12% and 15 %, respectively. In addition, Akim Oda and Sefwi Bekwai saw a surplus variance of 83% and 101 % respectively, with Abetifi, Goaso, Bechem, and Sunyani recording a normal variance.

Generally, along the coastline of Ghana, there was a surplus in rainfall variance ranging from 20% to 140%. Axim and Takoradi recorded the highest surplus variance of 109% and 126% respectively, with Accra recording a normal variance along the East coast of Ghana.

3.4.12 JJA Rainy Days

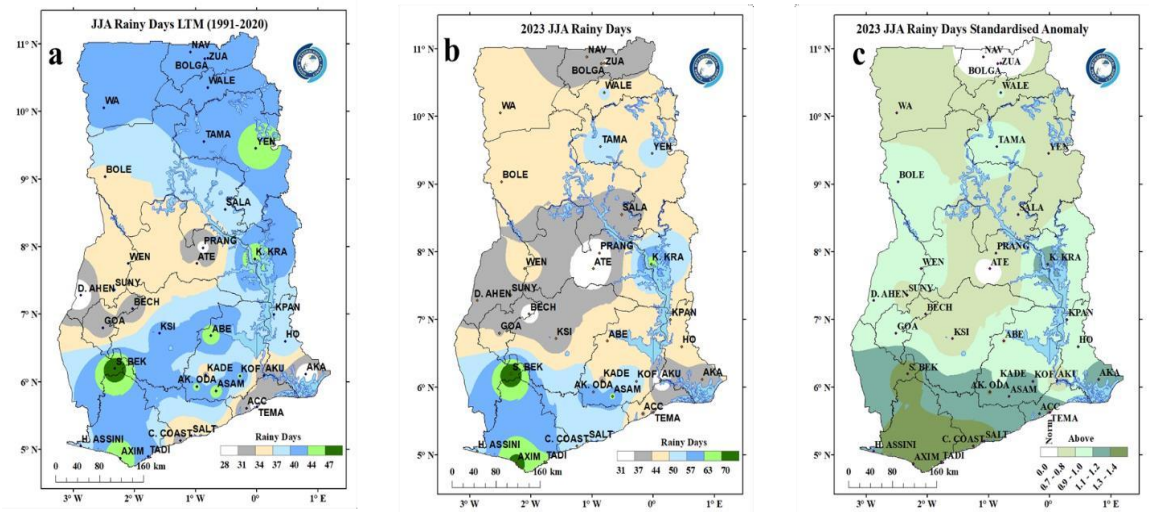


Figure 51 :(a) JJA LTM , (b) JJA Total Rainy Days, 2023 and (c) JJA Standardized Anomaly

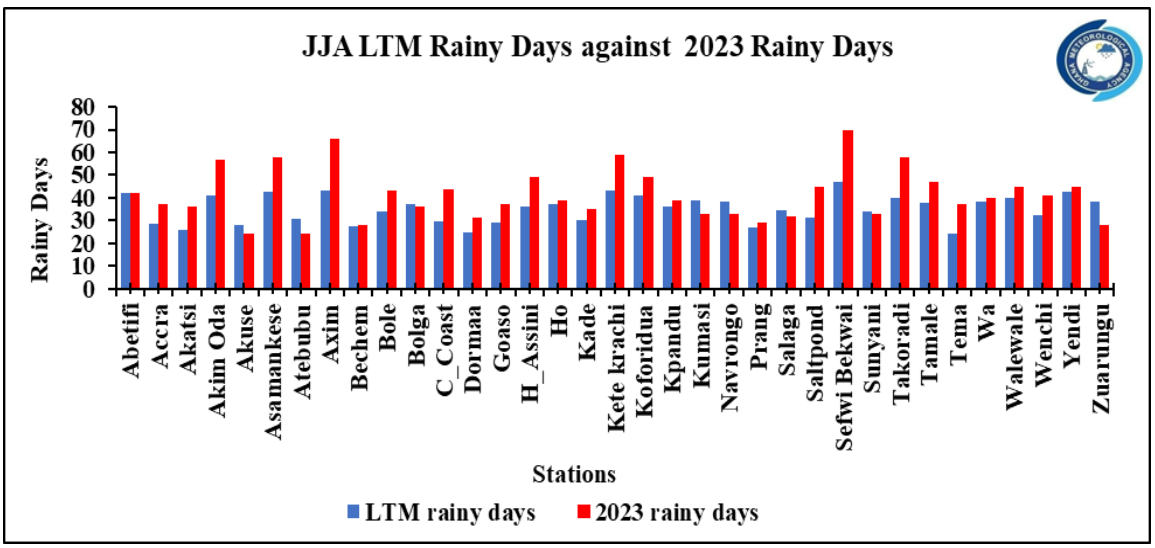


Figure 52 JJA LTM Rainy days Against Total Rainfall, 2023

An analysis of rainfall occurrences during the JJA 2023 season revealed that the majority of the stations in the northern and forest zones, as well as Kete Krachi and Wenchi in the transition zone, recorded more than 40 rainy days in Figure 52 (b) above. In contrast, most areas in the transition zone and the south-eastern portions of the country experienced below 40 rainy days. The analysis of rainy days anomalies across all sectors of the country indicates mostly well-above-normal rainy days. However, Navrongo, Bolga, and Zuarungu experienced normal rainfall occurrences as shown in Figure 10.4 (c) above. The rainy days for JJA 2023 saw a 49% and 53% increment of rainy days in Sefwi Bekwai and Axim, respectively, compared to their long-term mean. Stations such as Zuarungu, Salaga, Bechem, and Akuse had a decrease in their rainy days as against their long-term mean of about 26%, 9%, 22%, and 13%, respectively.

3.4.13 JAS Total Rainfall

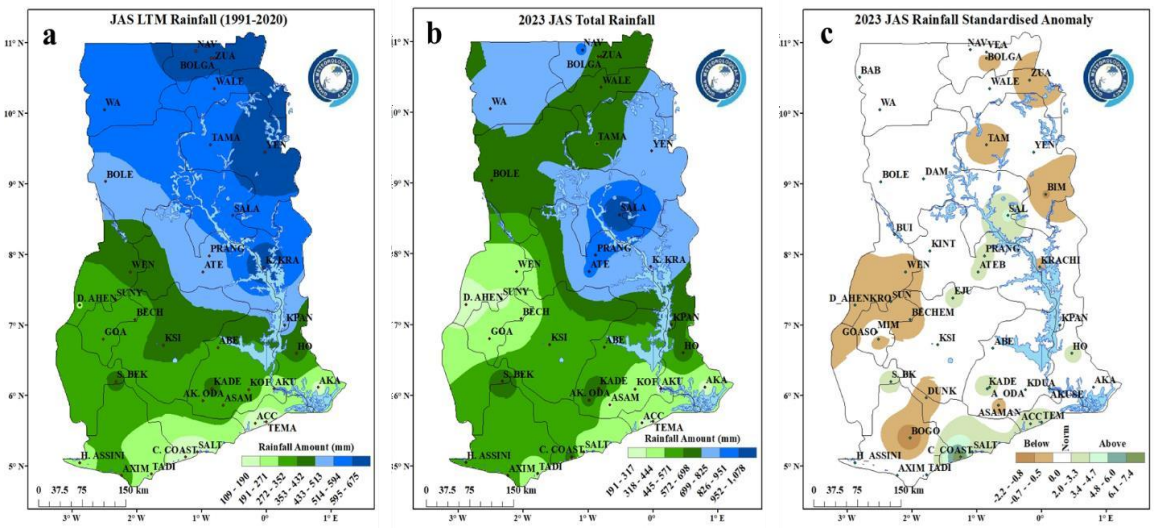


Figure 53 :(a) JAS LTM Rainfall, (b) JAS Total Rainfall, 2023, and (c) JAS Rainfall Standardized Anomaly

The analysis of the climatology for the JAS season (1991-2020), as shown by Fig. 1 below, indicates that the rainfall is concentrated more extensively in the northern portions of the country. In this part of the country, the average rainfall recorded during the season exceeded 500mm. On the other hand, the forest and coastal areas of the country experienced significantly lower average rainfall, with values below 500mm (Figure 53 (a)).

The analysis of the 2023 seasonal rainfall for the JAS season, as indicated in Figure 53 (b) below, shows that the northern portions and the transition zone of the country mainly experienced rainfall totals above 500mm, with Salaga recording the highest rainfall value of 1078.3mm. Except for Kumasi, Kpando, Ho, Kade, Akim Oda, Sefwi Bekwai, Half Assini, and Cape Coast, rainfall values less than 500mm were recorded over the rest of the forest and coastal portions of the country.

Figure 53 (c) represents the analysis of rainfall anomalies during the JAS season, which indicates that most parts of the country recorded above-normal rainfall, including Salaga, Cape Coast, Saltpond, Sefwi Bekwai, Accra, and Tema. These stations recorded a percentage increase of 83.3%, 361.4%, 133.9%, 76.1%, 147.1%, and 166.6% respectively, in their 2023 rainfall. Stations that recorded rainfall within the normal range are Wenchi and Tamale. On the other hand, Dormaa, Sunyani, and Bolga recorded rainfall amounts below their long-term means (LTMs) during this period. Dormaa experienced a reduction in its 2023 rainfall by 29.1%, Sunyani witnessed a reduction of 7.5%, whilst Bolga experienced a reduction of 12.6%.

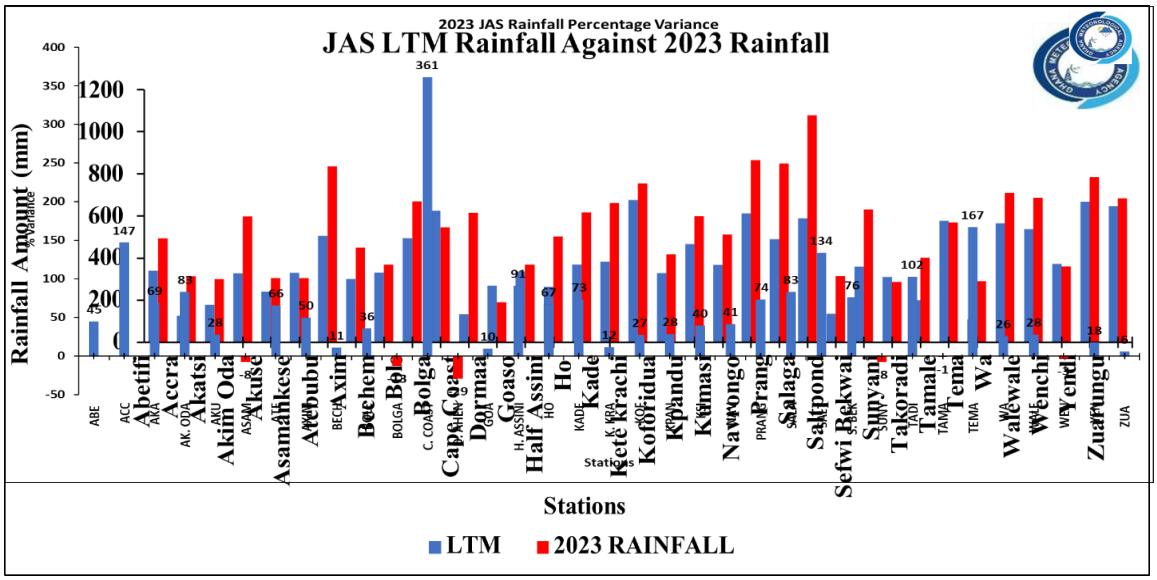


Figure 54 JAS LTM Rainfall Against Total Rainfall, 2023.

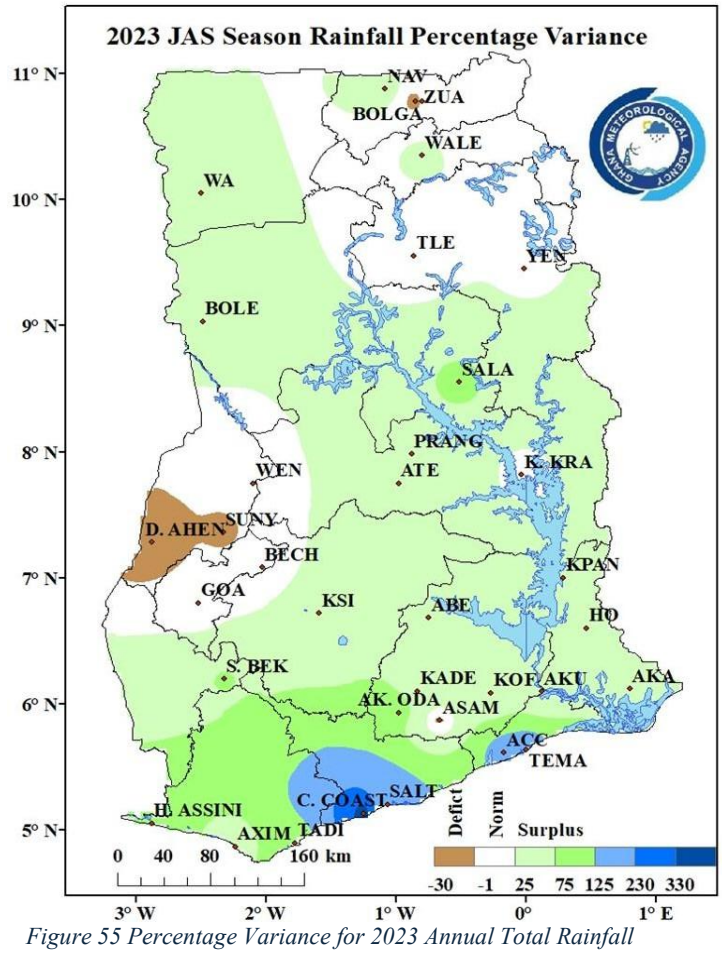


Figure 55 Percentage Variance for 2023 Annual Total Rainfall

Figure 56 Percentage Variance for 2023 Annual Total Rainfall

For the 2023 JAS rainfall season, the north experienced a deficit rainfall, with the percentage deficit ranging between 26% and 41%.

Most places in the transition zone recorded a normal rainfall percentage variance for the said season, except for the western part and Kete Krachi.

Normal percentage variance was recorded for most parts of the forest zone, except the western areas, which recorded deficits. Asamankese also recorded a deficit with a percentage variance of 8%.

Most areas along the coast recorded a surplus. Cape Coast recorded the highest surplus with a percentage variance of 361%, followed by Tema, Accra, and Saltpond with percentage variances of 167%, 147%, and 134%, respectively.

3.4.14 JAS Rainy Days

According to Figure 11.3 (a), the average rainy days (LTM) recorded during the JAS season is relatively higher in the northern part of the country compared to the south. In the north and parts of the south, stations such as Sefwi Bekwai, Akim Oda, Asamankese and Koforidua experienced average rainfall occurrences of over 40 days during the JAS season. The average number of rainy days of less than 20 occurred around the coast

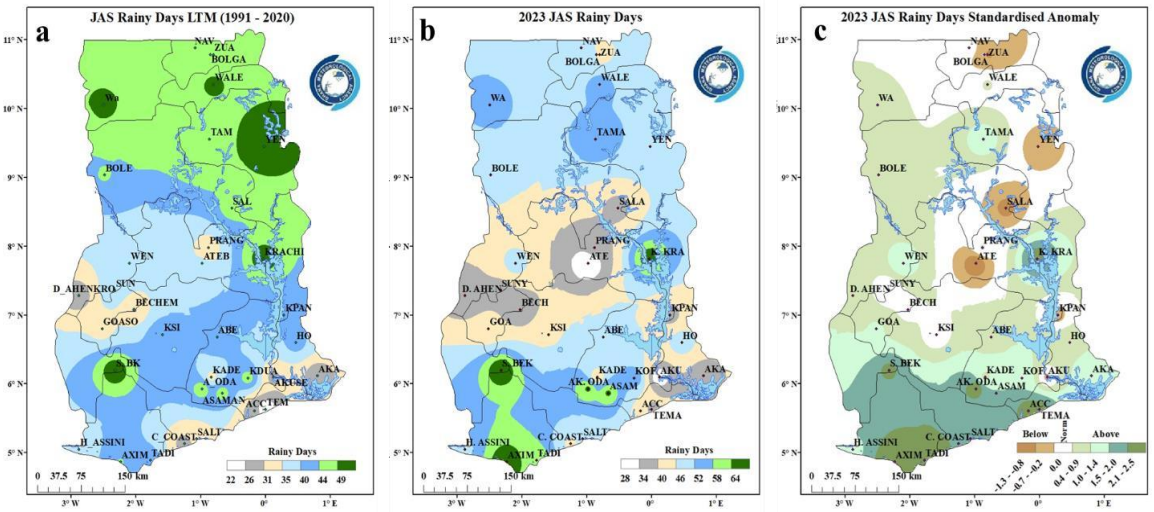


Figure 57 :(a) JAS LTM , (b) JAS Total Rainy Days, 2023 and (c) JAS Standardized Anomaly

The analysis of rainy days during the JAS 2023 season, as indicated in figure 57 (b), revealed that the majority of stations in the northern and forest zones, as well as Kete Krachi and Wenchi in the transition zone, recorded more than 40 rainy days. However, most areas in the transition zone and the south-eastern portions of the country experienced below 40 rainy days.

The analysis of rainy days anomaly across all sectors of the country (Figure 57 (c)) indicates a general occurrence of above-normal rainfall. Stations that recorded above normal rainy days include Sefwi Bekwai, Akim Oda, Axim, Takoradi, Accra, and Tema. These stations observed an increment in the number of rainy days in 2023 by 33.3%, 37.2%, 60.0%, 51.3%, 69.5%, and 88.5% respectively. However, Navrongo experienced a normal number of rainy days. Below normal rainfall occurrences were observed in Bolga, Zuarungu, Yendi, Salaga, Atebubu, Sunyani, Kpando and Akuse with percentage decreases of 2.3%, 16.2%, 6.1%, 21.9%, 29.0%, 5.8%, 13.5% and 8% respectively.

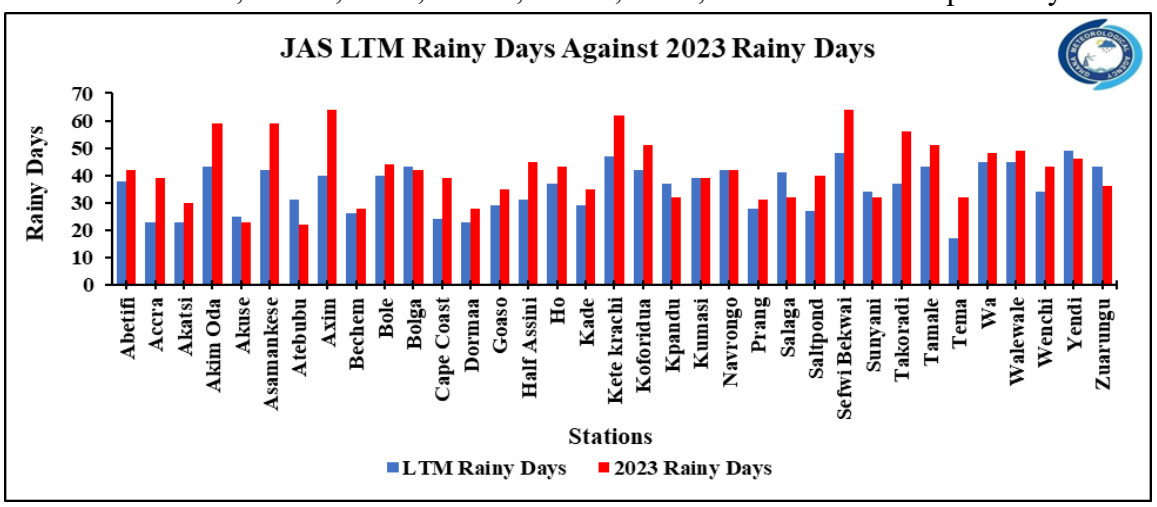


Figure 58 JAS LTM Rainy days against Total Rainfall, 20233.4.15

3.4.15 ASO Total Rainfall

A comprehensive analysis of the climatological patterns for seasonal rainfall (Figure 59(a)) in the country during the ASO season (1991-2020) indicates that a significant portion of the north, transition zone, and forest areas received high levels of rainfall (averaging between 200mm to 600mm). Conversely, some coastal areas experienced a lower amount of rainfall, measuring below 200mm. The distribution of rainfall during the ASO season in 2023, as indicated on Figure 59) was predominantly characterized by wet conditions, as most stations recorded rainfall values surpassing their long-term averages. Places such as Cape Coast, Atebubu, Prang, Kete Krachi, Salaga, Bole, Wa, and Navrongo reported seasonal rainfall totals exceeding 600mm, with Salaga recording the highest rainfall amount of 1250.2mm compared to its LTM of 584.9mm, which is an increase of 213.7%. This trend was observed across various stations, including those along the coast, where seasonal rainfall totals were higher than their long-term averages. Analysing the rainfall anomaly distribution for the ASO season across all regions of the country, as shown in Figure 59(c), it was observed that above normal rainfall was recorded over stations such as Salaga, Accra, Tema, Cape Coast, Bole, Navrongo, and Atebubu. These stations had an increase in their 2023 rainfall by the following percentages: 113.7%, 182.1%, 180.6%, 385.5%, 40.1%, 40.5%, and 51.9%, respectively. On the other hand, below-normal rainfall was observed over Bolga, Tamale, Wenchi, Dormaa, Goaso, Ho, Koforidua, and Asamankese. These stations witnessed a decrease in their rainfall by 9.3%, 21.4%, 7.2%, 29.2%, 4.8%, 28.0%, 8.6%, and 19.9%, respectively. Normal rainfall was witnessed at Sefwi Bekwai and Yendi during the period

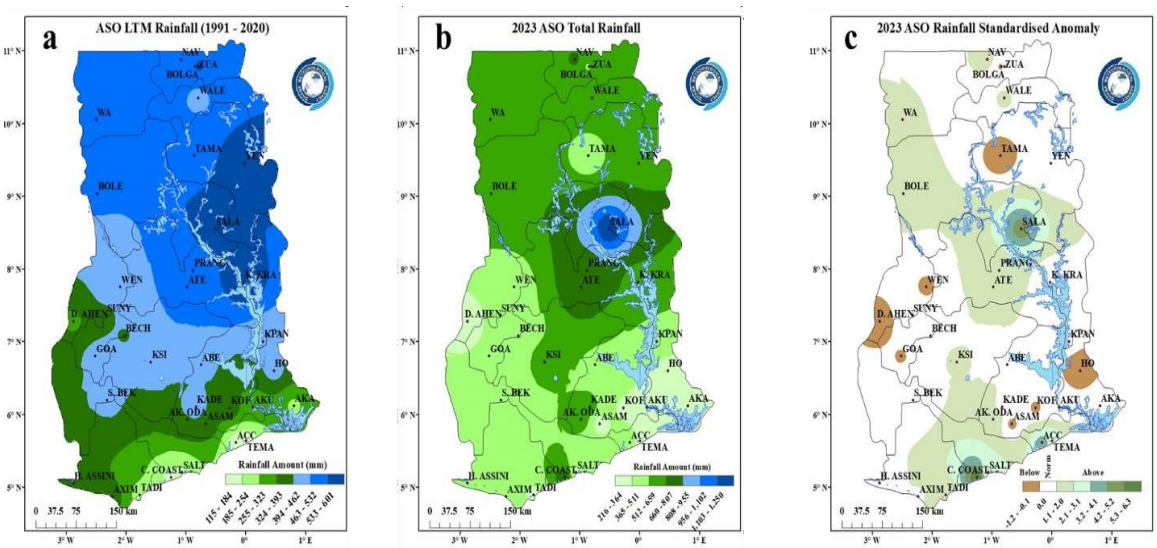


Figure 59 :(a) ASO LTM (b) ASO Total Rainfall, 2023 and (c) ASO Standardized Anomaly

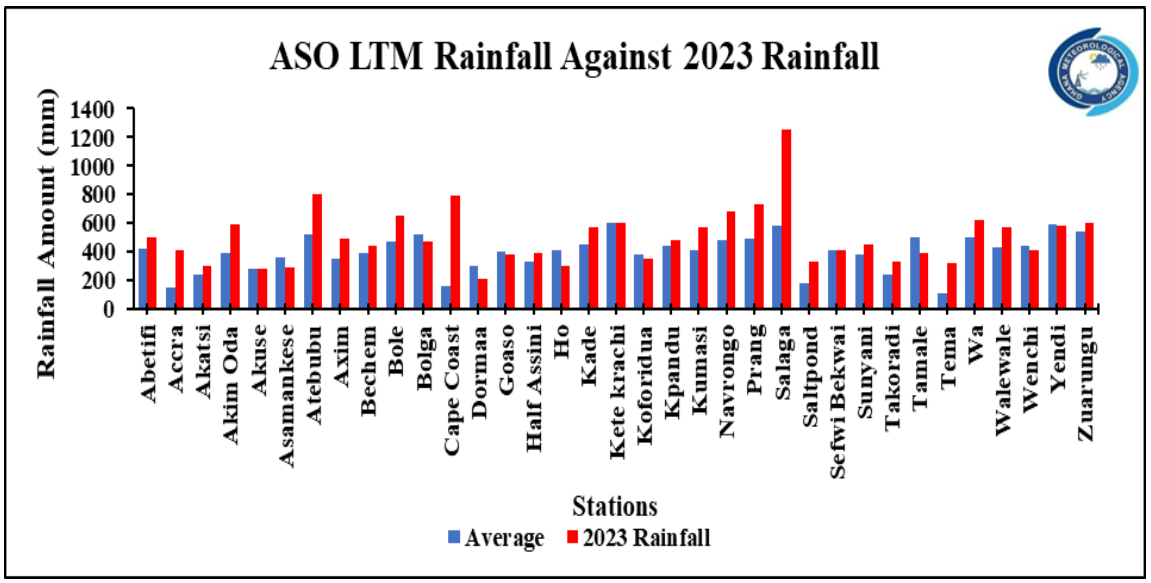


Figure 60 ASO LTM Rainfall against Total Rainfall, 2023.

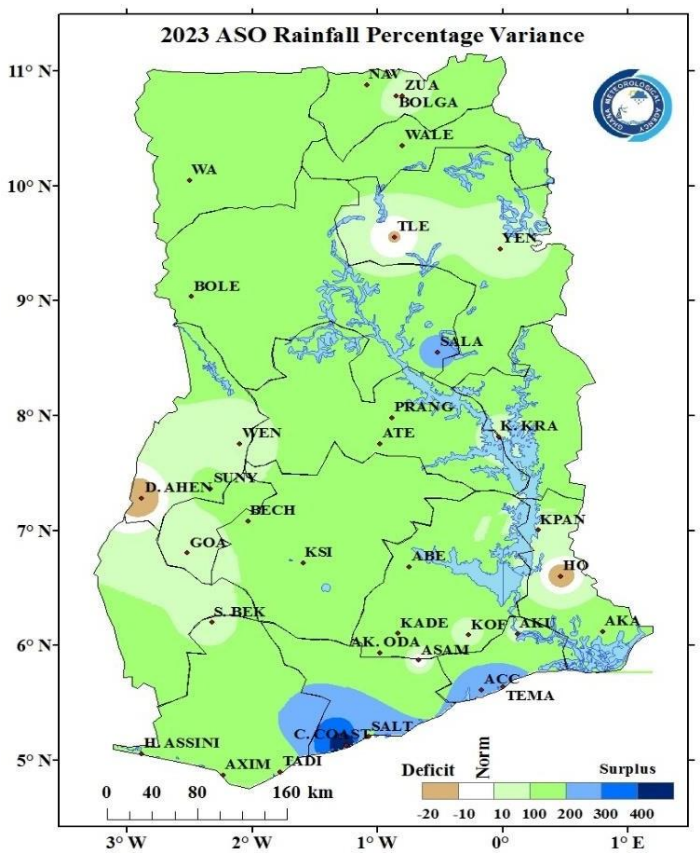


Figure 61 Percentage Variance for 2023 Annual Total Rainfall

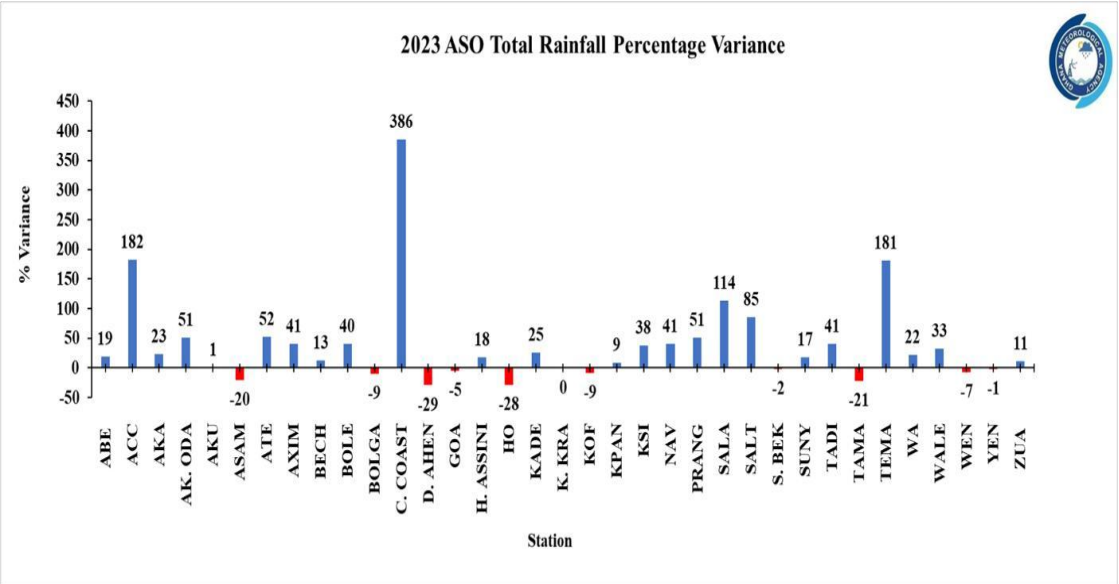
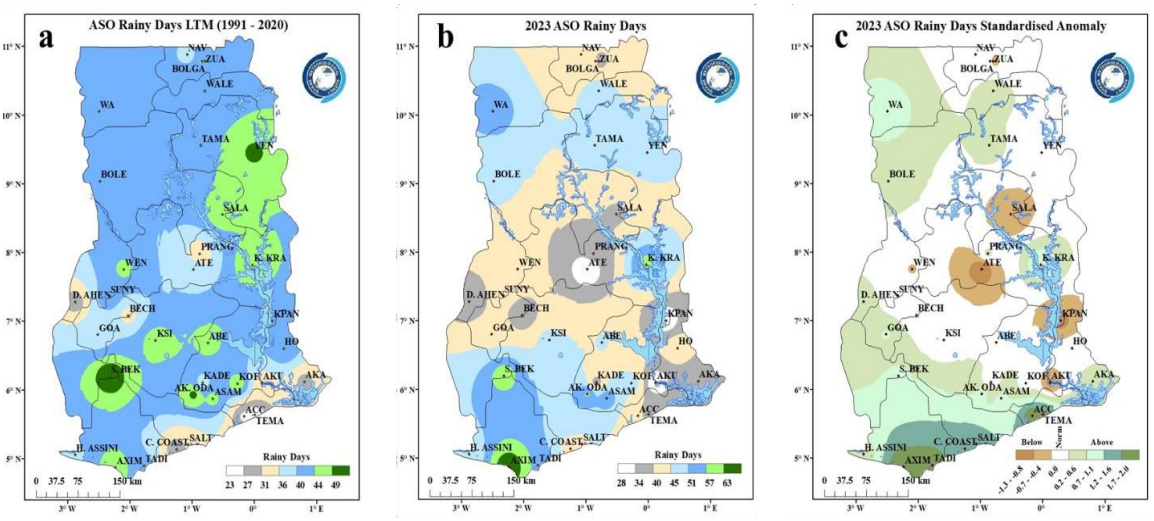


Figure 62 Percentage Variance for 2023 Annual Total Rainfall

The 2023 ASO rainfall percentage variance shows a surplus in most of the country ranging from 10% to 386% with specific areas of Cape Coast (386%), Accra (182%), Saltpond (85%) Tema (181%), and Salaga (114%) experiencing patches of extreme percentage variance. Portions of Tamale, Dormaa Ahenkro, and Ho experience deficits of 21%, 29%, and 21%, respectively. Normal percentage variances are experienced in some parts of the northern, western, and eastern portions of the country.

3.4.16 ASO Rainy days

Figure 63 :(a) ASO LTM, (b) ASO Total Rainy Days, 2023, and (c) ASO Rain Standardized Anomaly



The analysis of the climatological rainy days during the ASO season revealed that most parts of the country experienced an average of over 25 rainy days. The northern zone, parts of the transition, forest, and the western coast had an average of over 30 rainy days. However, stations such as Akatsi, Akuse, Accra, Tema, Cape Coast, Saltpond, Dormaa, and Prang recorded less than 30 average rainy days during the season.

The rainy days varied across all sectors of the country in the 2023 ASO season as shown in Figure 63 (b), ranging from 22 over Akuse to 63 rainy days over Axim. Stations such as Wa, Bole, Tamale, Wenchi, Sunyani, Sefwi Bekwai, Akim Oda, and Ho experienced over 35 rainy days, the northern portions mostly received a higher number of rainy days than the southern portions.

Analyzing the anomaly of rainy days in 2023 (compared to the period of 1991-2020) as indicated in Figure 63 (c), it was observed that stations such as Tema, Cape Coast, Saltpond, Axim, Takoradi, Kete Krachi, Wa, and Tamale recorded above normal rainy days. Tema had a percentage increase of 62.4%, Cape Coast had an increase of 53.7%, Saltpond had an increase of 42.6%, Axim had an increase of 45.0%, Takoradi had an increase of 38.4%, Kete Krachi had an increase of 23.6%, Wa had an increase of 23.6% and Tamale had an increase of 6.32%. On the other hand, Zuarungu, Yendi, Salaga, Wenchi, Atebubu, Kade, and Kpando, among other stations, experienced below normal rainy days anomaly. These stations witnessed a decrease in their number of rainy days by 15.4%, 4.5%, 22.5%, 7.4%, 32.6%, 7.5%, and 36.0%, respectively. Navrongo and Koforidua, however, recorded rainy days within the normal range.

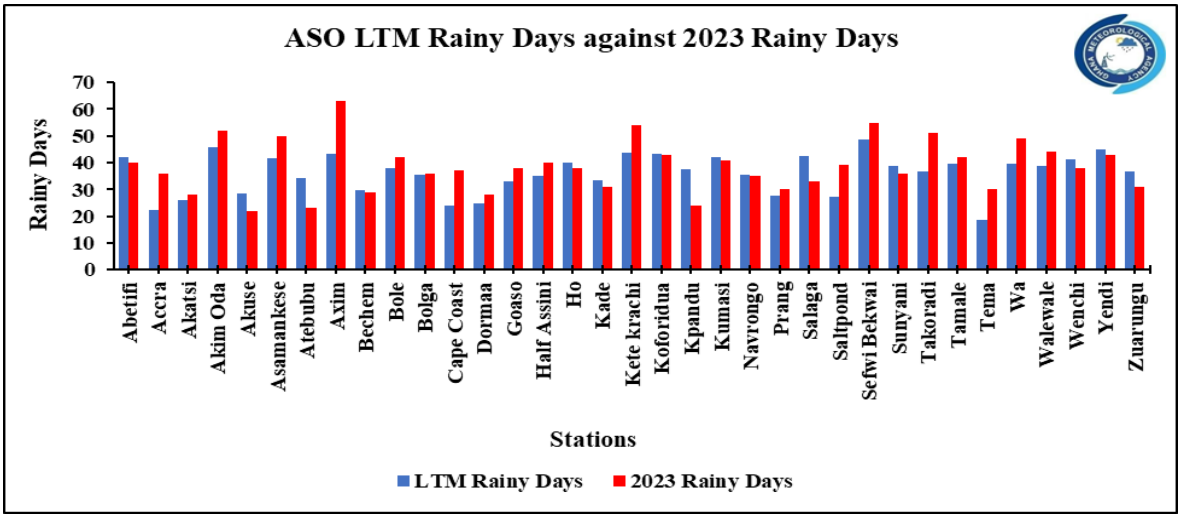


Figure 64 ASO LTM Rainy days Against Total Rainfall, 2023

3.4.17 SON Total Rainfall

September-October-November (SON) is a minor rainy season that usually occurs in southern Ghana. Over the 30 years (1991-2020), the average rainfall amounts for this season were analysed as shown in figure (Figure 65 (a). Areas such as Babile, Wa, Damango, Walewale, Vea, and Bimbila in the northern part of Ghana showed relatively less rainfall amounts of about 220 – 300mm, and areas within the coast, such as Accra, Akatsi, Cape Coast, Saltpond, and Tema also had relatively less rainfall amounts of about 135 – 283mm. Stations such as Kintampo, Atebubu, Kete-Krachi, Sefwi-Bekwai, Kade, Wenchi, Salaga, Goaso and Zuarungu experienced rainfall amounts ranging from 400 – 500mm. The highest and lowest rainfall average of 507.2mm and 135mm were recorded over Tamale and Tema respectively.

SON 2023 in (Figure 65 (b)) shows an increment of rainfall amount over most places especially in the middle and transition zone in areas such as Atebubu, Salaga, Kintampo, Prang, Damango, Bole, Kade, Cape Coast, Axim and Dunkwa with rainfall amount ranging from 600-800mm. Salaga in the northern Ghana received rainfall of about 830.0 mm which is the highest rainfall amount during the season as compared to its LTM. Tema recorded 325.0 mm of rain and Tamale also recorded 274mm. However, stations such as Zuarungu, Walewale, Bolga, Dormaa Ahenkro, and Akatsi received rainfall ranging from 200 – 300 mm during the SON season.

The anomaly rainfall for the SON season (Figure 65 (c)) depicts mostly normal to above normal rainfall across most areas in the country. Accra had an increase of 188% of its LTM, which resulted in flood cases in some areas in Accra. Cape Coast also recorded 225% increase of its LTM. On the other hand, Wa, Bole, Damango, Salaga, and Saltpond

recorded 62%, 53%, 132%, 99%, and 49% respectively in relation to their LTMs. On the contrary, deficit rainfall amounts were recorded in areas such as Dormaa Ahenkro (58%), Walewale (20%), Zuarungu (44%), Half- Assini (28%), Mim (39%) and notably Tamale (45%) in SON season.

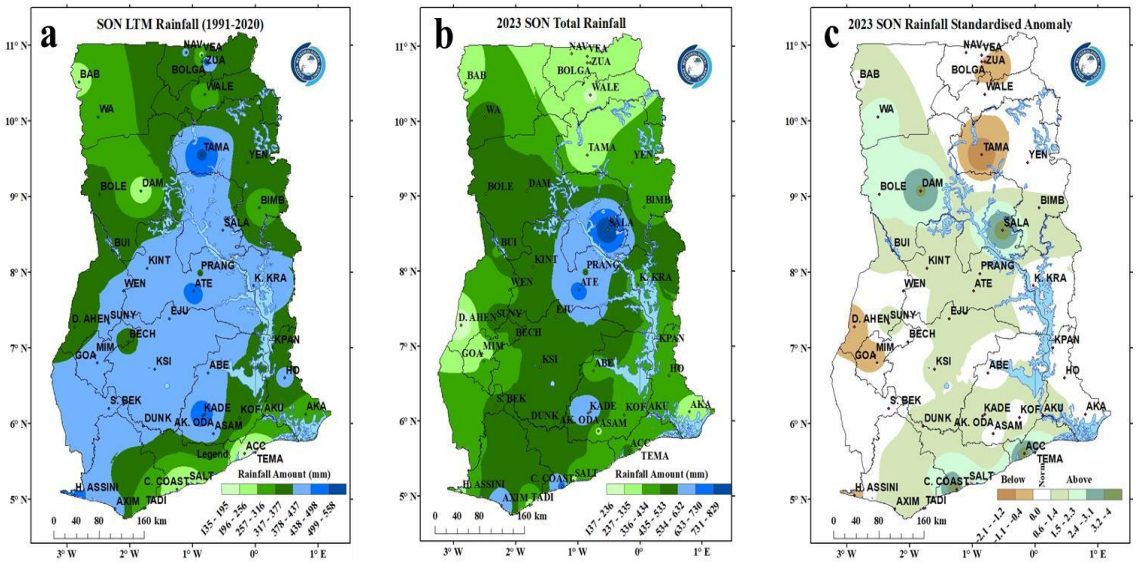


Figure 65 :(a) SON LTM Rainfall, (b) SON Total Rainfall, 2023 and (c) SON Rainfall Anomaly

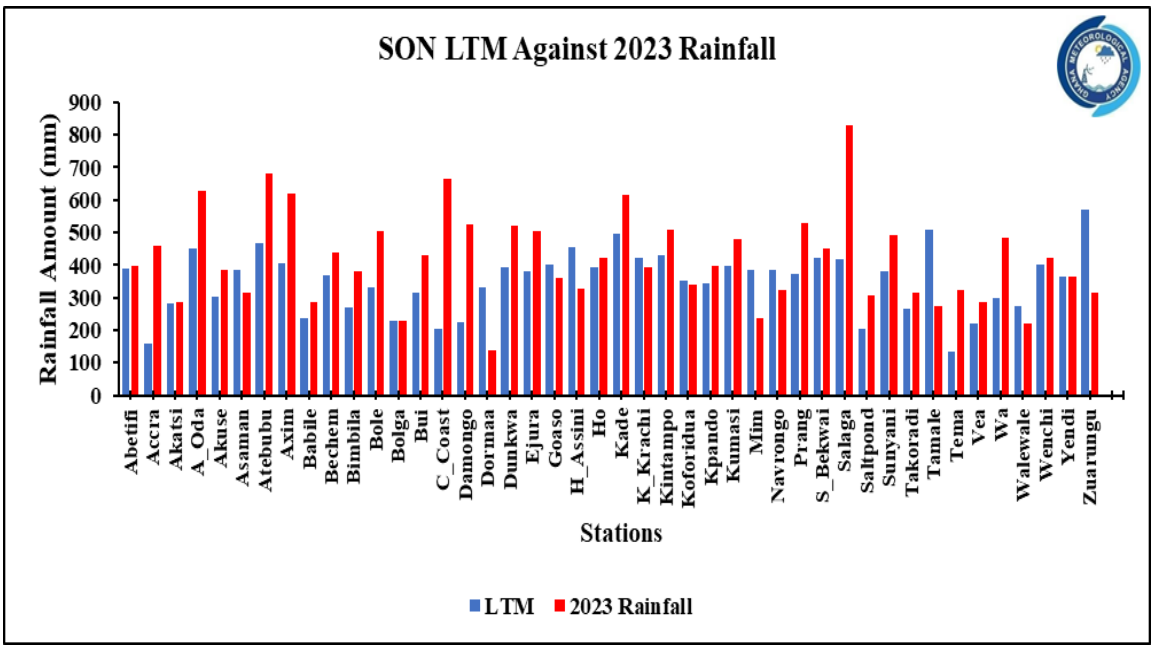


Figure 66 SON LTM Rainfall Against Total Rainfall, 2023

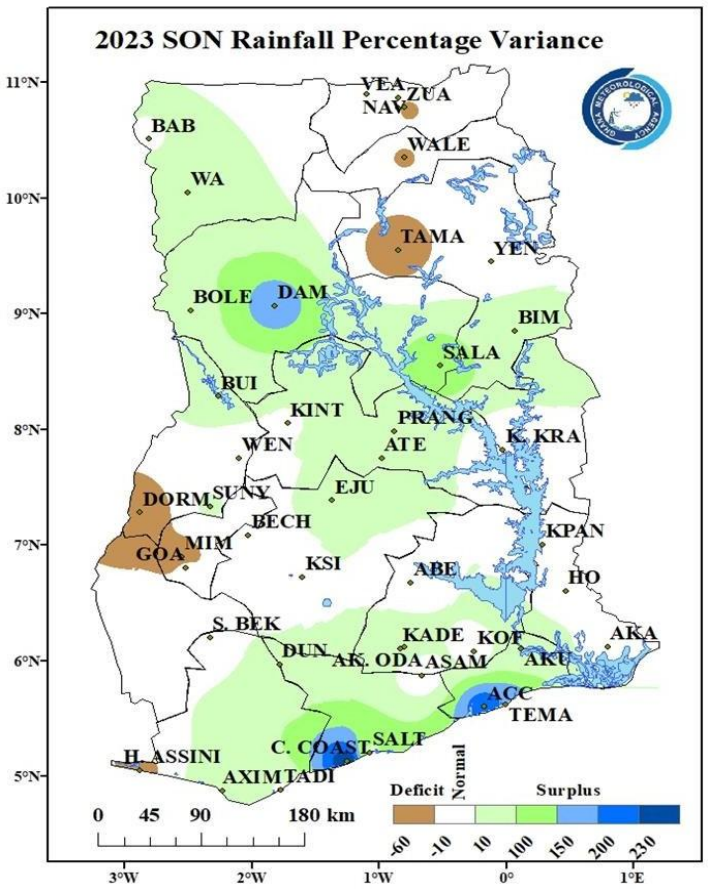


Figure 67 Percentage Variance for 2023 Annual Total Rainfall

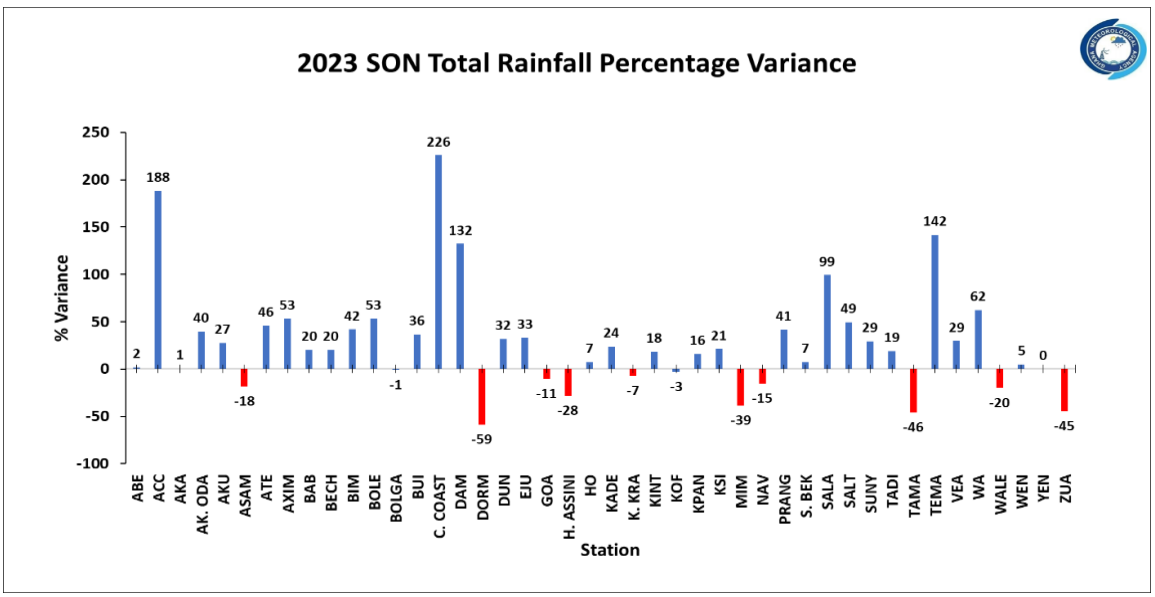


Figure 68 Percentage Variance for 2023 Annual Total Rainfall

From the Northern Sector, Tamale (-46%), Zuarungu (-45%), Walewale (-20%), and Navrongo (-15%), recorded a deficit in the 2023 SON season. Damongo (132%) recorded above 100% surplus while Salaga (99%), Wa (62%), Bole (53%), and Bimbila (42%) had

surplus below 100% in that season. For the Transition Zone, Bui, Kintampo, Prang, and Atebubu experienced surplus. Dormaa (-59%), Goaso (-11%), Mim (-39%), and Half Assini (-28%) recorded a deficit. Along the coastal sector, Cape Coast (226%), Accra (188%), and Tema (142%) had an extreme percentage variance in the SON season. Areas close to the coastal sector aside the Volta region and some parts of Ashanti, recorded below 50% surplus in 2023.

3.4.18 SON Rainy Days

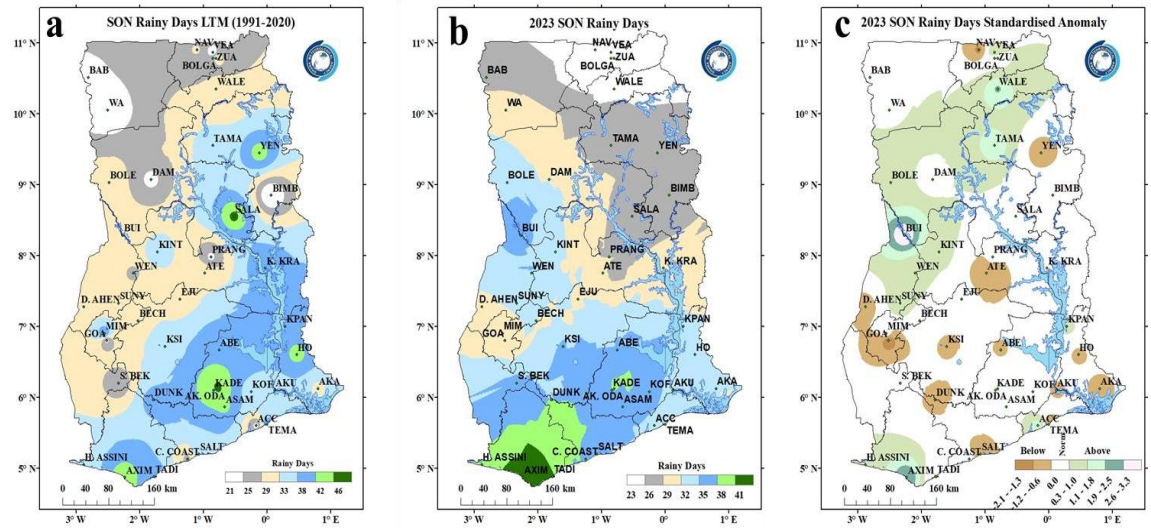


Figure 69 :(a) SON LTM , (b) SON Total Rainy Days, 2023 and (c) SON Standardized Anomaly

Figure 69 (a) below shows the average rainy days for SON season (1991-2020). Areas such as Axim, Accra, Kade, Salaga, Yendi, Kpando Ho, Abetifi, Akim Oda and Kete-Krachi had more rainy days ranging from 35 to 45 days. Most areas within the northern Ghana however had less rainy days of about 20 to 30 days. Wa had the least number of 17 rainy days.

Figure 69 (b) shows the total rainy days for SON 2023. Areas such as Kumasi, Kade, Sefwi- Bekwai, Asamankese, Half-Assini, Takoradi and Ho in the southern Ghana as well as areas such as Wenchi and Wa, in the transition zone and north experienced rainy days of about 30 to 41 days. However, Bui and Axim recorded the highest rainy days of 51 and 61 respectively. Stations which recorded the least rainy days are Babile, Dormaa Ahenkro, Navrongo, Zuarungu and notably Mim

Figure 69 (c) shows the rainy days anomaly for SON season. Stations which recorded above normal rainy days and had increment of their LTM are Accra (54%), Axim (49%), Bui (128%), Goaso (74%), Sefwi- Bekwai (90%), Sunyani (27%), Koforidua (30%), Wa

(116%) and Wenchi (40%). On the other hand, some stations which recorded below normal, or deficit rainy days as compared to their Long-Term Mean are Atebubu (30%), Dormaa Ahenkro (29%), Dunkwa (28%), Kpando (33%), Mim (76%), Navrongo (20%), Salaga (50%), Tema (33%) and Zuarungu (46%). Stations which recorded normal rainy days of their LTM are Abetifi, Akatsi, Akim Oda, Akuse, Babile, Bimbila, Bole, Bolga, Cape Coast, Ho, Kade, Kete-Krachi, Kumasi, Prang, Saltpond, Takoradi, Tamale, Walewale, and Yendi.

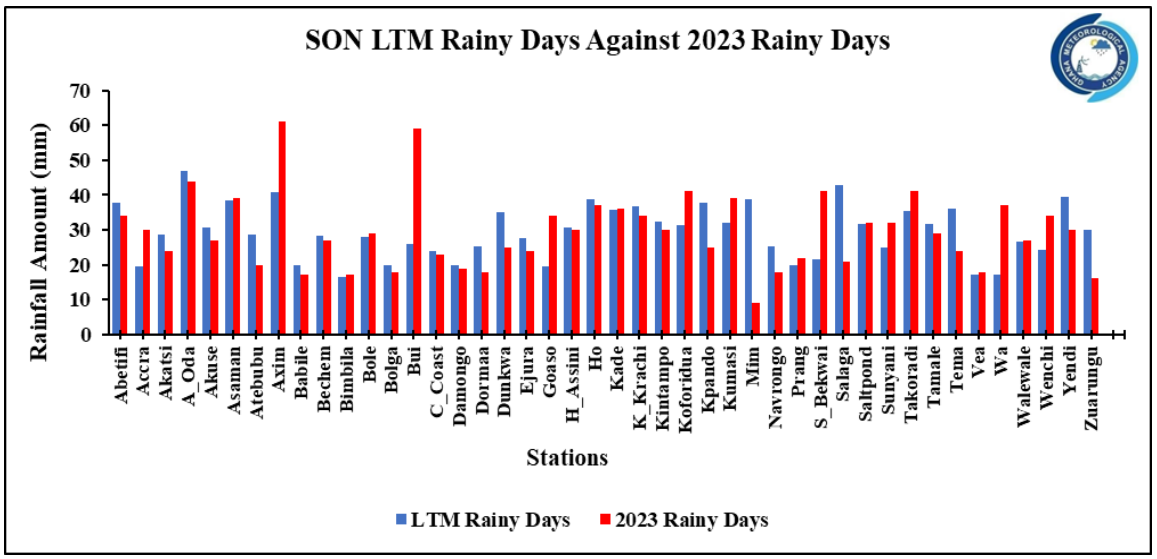


Figure 70 SON LTM Rainfall Against Total Rainfall, 2023.

Chapter 4:
RAINFALL CHARACTERISTICS

4.1 Onset Dates

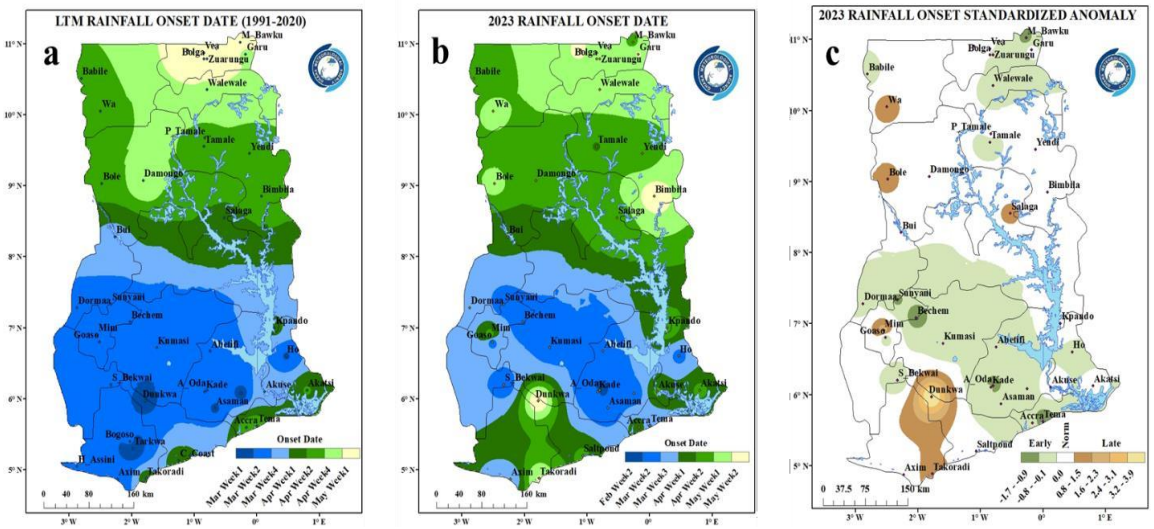


Figure 71 (a) Climatology (1991 - 2020), (b) 2023 Rainfall Onset and (c) Standardized Anomaly

Based on the long-term mean (1991-2020) analysis, the rainfall onset long term mean forecast indicates that the west coast (Axim, Half Assini, etc.,) and forest areas (such as Dunkwa, Tarkwa, and Asamankese) experience their onset of rains during the first and second weeks of March. This progressive movement of rainfall extends towards the middle portions of the Country including places like Kumasi, Koforidua, Ho etc. all before the 4th week of March. The long-term mean onset date for the southern part of Ghana is 18th March. The earliest onset date on record is the 1st of February and this has occurred multiple times across different stations in Ghana. The latest date for onset in the south is 22nd of June 2021 which occurred in Accra. On the other hand, the east coast and transitional areas have a normal to late onset of rainfall, occurring around the first week of April. For the 2023 rainfall Season, delayed onset (between the 3rd week of April and the 2nd week of May) was observed in and around Dunkwa, Bogoso, Axim and its surroundings.

The northern parts of Ghana recorded normal onset dates for the 2023 rainfall season. However, areas like Bole, Wa and their environs experienced late onset whereas Babile and few places in the upper east region of the country recorded an early onset to near-normal rainfall.

The standardized anomaly analysis provides more detailed information about specific

areas that may experience late or normal to early rainfall onset, highlighting variations from the average patterns.

4.2 Dry Spells

4.2 Early Dry Spells

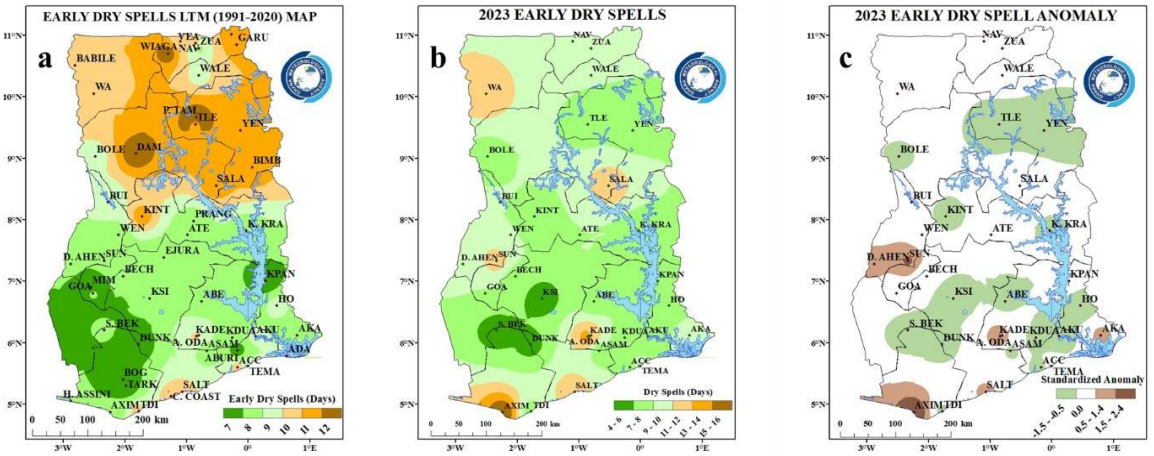


Figure 72 (a) Climatology (1991 - 2020), (b) 2023 Rainfall Early Dry Spell and (c) Standardized Anomaly

The term Early Dry Spell refers to the longest consecutive number of dry days from the onset date to the 50th day of the season.

Annual average climatological data (1991-2020) shows that most places around the forest area and western part of the middle portion of the country have the shortest Early Dry Spells of seven (7) days. Areas in this region include Tarkwa, Bogoso, Mim and Dunkwa. Asamankese and Kpando also have a climatological average of seven (7) days. Areas in the Northern part of the country (above 8°N) is characterized by relatively longer dry spells with most places recoding an average greater than ten (10) days. Damongo, Pong Tamale and Wiaga all have the highest climatological average of twelve (12) days.

In 2023 Kumasi, Sefwi Bekwai and Dunkwa recorded significantly shorter spells compared to their climatological averages with 4, 4 and 5 days respectively. Kade and Axim recorded the longest spells across the country with 16 days each.

Most places in Northern Ghana (above 8°N), showed a trend of slightly shorter spells than their climatological averages except for Wa and Salaga which recorded slightly longer dry spells (12 days each) in 2023.

4.3 Late Dry Spells

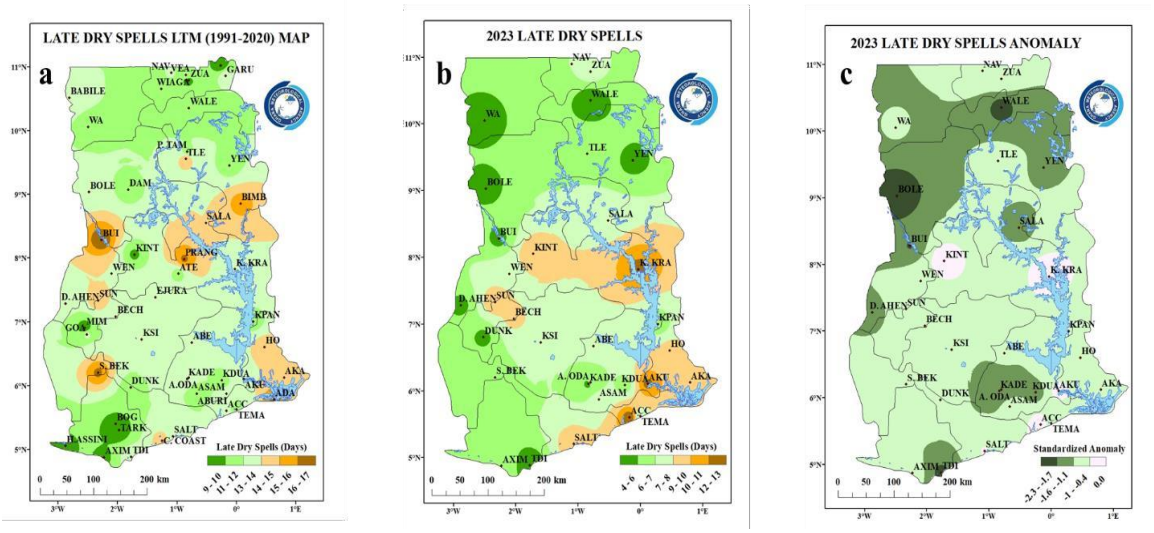


Figure 73 (a) Climatology (1991 - 2020), (b) 2023 Late Dry Spell and (c) Standardized Anomaly

From the 51st day of the season to the cessation date, the longest consecutive number of dry days is termed as Late Dry Spell.

Climatological data from 1991-2020 shows that most parts of the country record an average late dry spell length of 9 to 14 days. Ada, Bimbila, Bui, Prang and Sefwi Bekwai however, are exceptions and have a climatological average of 15 to 17 days with Bui having the highest average late dry spell length of 17 days. In 2023, Takoradi and Walewale recorded the shortest dry spells thus 4 days each compared to their climatological average of 13 and 11 days respectively. Kete-Krachi and Accra, areas found in the southern part of Ghana (below 8°N) recorded 12 days for Kete-Krachi and 13 days for Accra.

In Northern part of Ghana (above 8°N), Manga Bawku recorded the shortest late dry spells of 9 days and Bui recorded the longest late dry spell length of 17 days.

Generally, in 2023 the late dry spells recorded over the country was shorter compared to the Long-Term Mean (1991-2020).

4.4 Cessation

From the analysis of the long-term mean (1991 – 2020), rainfall cessation in Ghana starts from the north and then moves south gradually. This climatological assertion was observed during the 2023 rainfall cessation in Ghana.

The cessation map of Ghana for 2023 shows that there was early cessation for most places in the Upper East and West, whereas places like Tamale, Yendi, and their surrounding areas experienced late cessation for 2023. The cessation dates for 2023 were between the 1st and 4th weeks of October, compared to its climatological dates, which occurred between the 2nd and 3rd weeks of October.

The areas stretching from the inland areas of the central region to the Volta regions, such as Dunkwa, Kade, Abetifi, Kpando, Ho, and Akatsi, experienced Early cessations for the year 2023. Accra, on the other hand, recorded an extremely late cessation, i.e., the 3rd week of November, compared to that of its climatology, which is the 3rd week of October. Other places like Tema, Takoradi, and a few places along the coast also recorded late cessation for 2023.

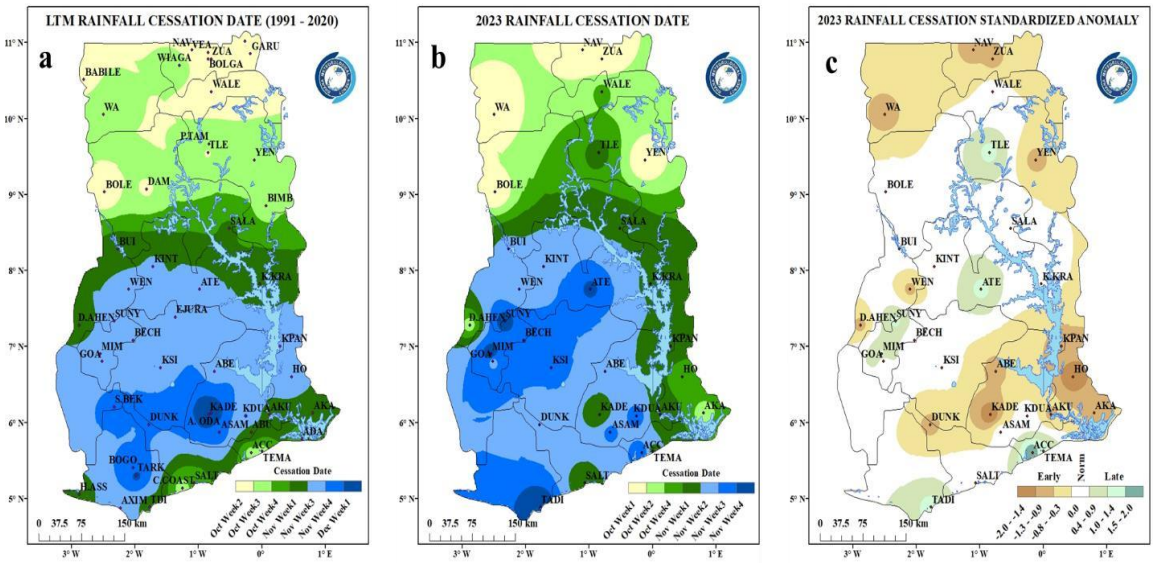


Figure 74 (a) Climatology (1991 - 2020), (b) 2023 Rainfall Cessation and (c) Standardized Anomaly

CHAPTER 5:
CONCLUSION

The impact of the late onset and early cessation for some places in the northern parts of the country was not that severe since there was shorter than normal dry spells in most of these places. However, those did early planting when the first few rains came had to re-plant since there was not enough moisture to support the growth of their crops during the period. The months of August and September recorded high rainfall amounts and increase in the rainy days. In fact, most places in the south of Ghana did not experience the "little dry season" which normally occurs between late July and August. These as a result and among other factors culminated in the Akosombo dam filling up to record levels. As a result of the high levels of the dam, there were couple of spillages from the dam to prevent it from collapsing. This spillage, unfortunately led to the flooding of towns along the volta river, the main source of the Akosombo dam.

The warm night temperatures for the year 2023 coupled with high humidities has been uncomfortable for the people and has led to high energy consumption. This situation led to load shedding by the Electricity company of Ghana at peak times of the day forcing people to depend on fossil fuel to the detriment of the environment.

Assessing and understanding weather and climate forecast information would contribute immensely to various aspects of our lives and society.

Accurate weather and climate forecasts enable us to better prepare for and respond to natural disasters such as hurricanes, tornadoes, floods, and droughts

2023 REPORTS FROM AICCRA PROJECTS ON ACCESS TO CLIMATE INFORMATION

390,000+ farmers are accessing and using climate information services (CIS) and climate smart agriculture (CSA)-one health technologies and practices. farmers are using seasonal forecasts from Ghana Meteorological Agency to select crop varieties and decide on the best time for planting, preparing land, and applying fertilizers and pesticides. These together with increased use of stress-tolerant crop varieties, enhanced biopesticides, crop rotation, and minimum tillage have helped farmers to manage risks from delayed rainfall onset, early cessation, dry spells, and pest attacks. GMET'S climate information services (CIS) were disseminated to enable 237305 men and 153321 women farmers to build climate resilience with timely CIS and accompanied CSAs. Extension officers of the department of agriculture trained 4093 farmers directly and leveraged farmer-to-farmer knowledge sharing to support 40930 farmers. [5]. a16-episode weekly radio extension program produced in conjunction with farm radio international and eight radio stations educated 245,603 farmers across 10 districts on CIS and CSA technologies and encouraged their use.[6]. esoko's voice and sms messages promoted climate-smart technologies to over 100,000 farmers to reinforce the information disseminated through local extension networks, esoko, and community radio stations.

CHALLENGES

- Most of them were aware of weather and climate information but, lack of phones being one of their challenges where most of farmers could not receive or access weather climate information services.
- False onset of rains was one of the main challenges during part of the season that caused unrepairable problems in their farming activities.
- The climate forecast information sometimes does not happen as expected and therefore lead to some avoidable losses.
- Too much rains affecting crop production during the season with which some of them attribute it to non-adherence to seasonal forecast information that spell out when planting of certain crops could be appropriate.

RECOMMENDATIONS

- Information centres should be installed in the AICCRA selected communities to enhance in the dissemination of the weather information since most of them do not have radio and phones to receive the forecast.
- Frequent engagement with the farmers would equally inform GMet as an organization responsible for the forecast information to properly assess its forecast performance within the season.
- Climate smart agricultural knowledge would improve farmer productivity if climate information services is well understood and applied throughout the season, hence efforts must be made to make these services readily and timely available to the farmers.
- Need for more explanation concerning the climate information service to enable them analyse and understand how their localities would be affected in terms of onset and cessation of rains, cumulative rainfall and dry spells expectations during the forecast period.

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APPENDIX

Station	Abbreviation	Station	Abbreviation
ABE	Abetifi	**KOF**	Koforidua
ACC	Accra	**KPAN**	Kpando
AKA	Akatsi	**KSI**	Kumasi
AK. ODA	Akim Oda	**NAV**	Navrongo
AKU	Akuse	**PRANG**	Prang
ASAM	Asamankese	**SALA**	Salaga
ATE	Atebubu	**ALT**	Saltpond
AXIM	Axim	**S. BEK**	Sefwi Bekwai
BECH	Bechem	**SUNY**	Sunyani
BOLE	Bole	**TADI**	Takoradi
BOLGA	Bolgatanga	**TAM**	Tamale
C. COAST	Cape Coast	**TEMA**	Tema
D. AHEN	Dormaa Ahenkro	**WA**	Wa
GOA	Goaso	**WALE**	Walewale
H. ASSINI	Half - Assini	**WEN**	Wenchi
HO	Ho	**YEN**	Yendi
KADE	Kade	**ZUA**	Zuarungu
K. KRA	Kete - Krachi		